ECONOMISING NITROGEN IN RICE PRODUCTION WITH *Sesbania rostrata*

By

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THESIS

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Dedicated to my beloved father

DECLARATION

I hereby declare that this thesis entitled "Economising Nitrogen in rice production with *Sesbania rostrata*" 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.

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LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

mm	-	millimetre
cm	-	centimetre
m	-	metre
g	-	gram
kg	-	kilogram
t	-	tonnes
ha	-	hectare
no.	-	number
kg ha^{-1}	-	kilogram per hectare
g/plant	-	gram per plant
no./plant	-	number per plant
°C	-	degree celsius
Fig.	-	figure
et al.	-	and others
%	-	percent
cv.	-	cultivar
DAT	-	days after transplanting
i.e.	-	that is
viz.	-	namely
N	-	Nitrogen
P_2O_5	-	Phosphorus
K_2O	-	Potassium
CD	-	Critical Difference
SEm	-	Standard Error of mean
BCR	-	Benefit-Cost Ratio
KAU	-	Kerala Agricultural University
TNAU	-	Tamil Nadu Agricultural University
IRRI	-	International Rice Research Institute

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INTRODUCTION

INTRODUCTION

Rice (Oryza sativa L.) is the most important food crop of the world and forms a primary and secondary staple food for about 3 billion people. Nitrogen is the fertilizer nutrient most commonly applied to rice (IRRI, 1986). In the year 2000, demographic forecast indicates an additional 1.7 percent increase in demand per annum for rice world over (IRRI, 1986) and accordingly the demand for nitrogen to fertilize rice will increase. Furthermore, with the introduction of high yielding varieties, there has been an increasing tendency to depend more on inorganic nitrogenous fertilizers for enhancing rice production. But the rapid escalation in the cost of chemical fertilizers resulting from withdrawal of government subsidies without corresponding proportionate increase in produce-prices frequently deter the resource poor farmers from using them in required quantities. It is therefore of both economical and ecological concern to look for alternative nitrogen sources.

Renewed interest has recently been given to green manures to sustain low land rice productivity, reduce farmer's dependence on mineral nitrogenous fertilizers and lower their high cash input. Biological nitrogen fixation by leguminous green manure crops has the potential to cover the substantial portion of the nitrogen required by rice.

Apart from supplying nitrogen to the succeeding crop, green manure crops help to increase the organic matter content of soils, maintain and improve soil structure, reduce loss of nutrients particularly nitrogen and reduce soil loss by erosion. However, narrow ecological adaptability and intolerance to waterlogging restrict the use of leguminous green manure in low land rice.

Sesbania spp. are ideal green manures as they can grow in a wide range of eco-geographical regions and on different types of soil. *Sesbania aculeata* (dhaincha), a leguminous green manure with root nodules is a very popular green manure for rice among farmers. *Sesbania rostrata* is a tropical, leguminous green manure, which produces nodules on both roots and stem and possess the capacity to grow in flooded as well as in dry condition. It is a native of Senegal, West Africa. Advantages of *Sesbania rostrata* as a green manure crop include its ability to pick up *Rhizobium* bacteria even from an aerial spray inoculant, adaptation to waterlogged conditions and production of more nodules than other green manure crops (Singh et al., 1988). Unlike other legumes, *Sesbania rostrata* can grow well in saline and alkaline soils.

In Kerala, the production and use of green manures is very much limited. Furthermore, use of farm yard manure is also limited because of its low availability and high cost. Growing green manure crops and *in situ* incorporation is an efficient method of adding organic manure to paddy fields. Leguminous green manure crops like *Sesbania rostrata* has the added advantage of enriching the soil nitrogen status. The average nitrogen yield of *Sesbania rostrata* is reported to be about 200 kg per hectare (Dommergues, 1983). Inoculation of *Sesbania rostrata* with *Rhizobium* has been found to have a positive influence on the green matter yield, dry matter production and nitrogen yield of *Sesbania rostrata*. The plant has been reported to have the capacity to pick up *Rhizobia* bacteria even from a spray inoculant. Considerable economy in nitrogen use can be effected by substituting at least a part of the chemical nitrogen recommended to the rice crop by the incorporation of *Sesbania rostrata*. Keeping the above facts in view the present investigation was carried out primarily to determine the extent upto which the nitrogen recommended for rice could be substituted by the nitrogen supplied through incorporation of *Sesbania rostrata*. The investigation was carried out with the following objectives:

(i) to study the influence of *Rhizobium* inoculation (seed, stem and seed and stem inoculation) on the growth and biomass productivity of *Sesbania rostrata* in rice fields.

(ii) to assess the influence of *in situ* raising and incorporation of *Sesbania rostrata* in conjunction with different rates of nitrogen on the growth and yield of succeeding rice crop.

(iii) to study the influence of incorporation of *Sesbania rostrata* in economising the use of chemical nitrogen for rice.

(iv) to work out the economics of the use of *Sesbania rostrata* in rice culture.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A brief review of literature pertaining to "Economising nitrogen in rice production with _Sesbania rostrata_" is presented in this chapter.

2.1 Growth performance and productivity of _Sesbania rostrata_

2.1.1 Effect of inoculation

Inoculating _Sesbania rostrata_ with _Rhizobium_ has been reported to have a favourable influence.

2.1.1.1 Green matter yield

Daroy et al. (1987) found that inoculating _Sesbania rostrata_ with _Rhizobium_ sp. ORS 571 had a significant effect on plant biomass. Further stem inoculation was inevitable for _Sesbania rostrata_ sown under dry conditions for higher biomass production.

Manguiat et al. (1987) found that inoculation of _Sesbania rostrata_ increased the biomass production by as much as 93 percent.

2.1.1.2 Nodulation characteristics

Dreyfus et al. (1985) found that _Sesbania rostrata_ plants were capable of picking up an aerial spray of specific _Rhizobium_ ORS 571. They observed an increase in stem nodulation when the shoots of Sesbania rostrata were sprayed with a liquid culture of specific Rhizobium ORS 571.

Daroy et al. (1987) obtained a greater number of nodules and nodule biomass in Sesbania due to inoculation. They found that under flooded conditions root inoculation alone was sufficient to induce both root and stem nodules whereas both root and stem inoculation was needed in unflooded condition.

Ladha et al. (1989) reported that inoculation with Azorhizobium caulinodans ORS 571 Str Spe (resistant to Streptomycin and Spectinomycin) on the stem alone or on both root and stem significantly increased nodulation and nitrogen fixation in plants. They also found that soil and seed inoculation yielded active nodules under flooded conditions.

2.1.1.3 Nitrogen yield of Sesbania rostrata

Bronson (1983) reported that Sesbania rostrata accumulated 18 kg nitrogen per hectare during 40 day growth period.

Rinaudo et al. (1983) estimated the nitrogen fixed by Sesbania rostrata to be at least 267 kg nitrogen per hectare, one-third being transferred to the crop and two-third to the soil.

Sesbania rostrata produced a nitrogen yield of 89 and 176 kg per hectare in 49 and 61 days respectively (Furoc et al., 1985; Morris et al., 1986).

Gines et al. (1987) obtained nitrogen yields ranging from 62 to 88 kg per hectare from 45 day old *Sesbania rostrata*.

Ventura et al. (1987) reported an yield of 79 kg nitrogen per hectare from a 47 day duration *Sesbania rostrata*.

Ndoye and Dreyfus (1988) found that about 83 to 109 kg nitrogen per hectare would be fixed in 60 days by *Sesbania rostrata*.

Halepyati and Sheelavantar (1990) found that *Sesbania rostrata* accumulated 156 kg nitrogen per hectare in 55 days.

Sahu and Sahu (1992) found that *Sesbania rostrata* contained about 4.65 per cent nitrogen and fixed about 44.2 kg nitrogen per hectare.

The above review reveals that the nitrogen accumulation by *Sesbania rostrata* varies widely from place to place. Even in Philippines, the nitrogen yield of *Sesbania rostrata* varied from 70 to 262 kg nitrogen per hectare in a crop of 45 to 50 day duration.

2.2 Growth and productivity of rice as influenced by *Sesbania rostrata*

Rinaudo et al. (1983) reported that the application chemical fertilizer nitrogen increased the grain yield above that of control by 1.69 tonnes per hectare, whereas incorporating Sesbania rostrata as green manure resulted in a grain yield increase of 3.72 tonnes per hectare.

Incorporation of Sesbania rostrata increased rice yields and nitrogen uptake 2-3 fold over the flood-fallow treatment (IRRI, 1987).

No significant differences in rice grain yield were observed between the green manure treatment with and without fertilizer application (IRRI, 1988).

Singh et al. (1988) observed that ploughing in of Sesbania rostrata before transplanting rice increased paddy yields by 3-7 tonnes per hectare, while 60 kg nitrogen per hectare increased yields by only 1.7 tonnes per hectare.

Furoc and Morris (1989) reported that the advantage of growing Sesbania spp. for more than 48 days to accumulate nitrogen in excess of 100 kg per hectare was limited.

Rabindra et al. (1989) reported that Sesbania rostrata could substitute fertilizer nitrogen upto 70 kg per hectare without significant yield reduction. Uptake of nitrogen was better with Sesbania rostrata.

Ladha et al. (1989) got increased grain yield and nitrogen uptake for succeeding rice crop after Sesbania rostrata

About 80 percent of nitrogen gained was transferred to succeeding rice crop and about 20 percent remained in soil.

Halepyati and Sheelavantar (1990) found that Sesbania rostrata along with 100 percent of recommended nitrogen increased the grain yield by 13.65 quintals per hectare over control.

Kalidurai and Kannaiyan (1990) found that Sesbania rostrata (with 3.7 percent nitrogen) and Sesbania aculeata (with 2.9 percent nitrogen) with 60 kg nitrogen per hectare significantly increased grain and straw yields.

Alagappan (1990) obtained a 12 percent increase in rice crop yield with the incorporation of Sesbania rostrata seedlings.

Raju and Anand Reddy (1991) observed that incorporation of dhaincha (Sesbania aculeata) @ 5 tonne per hectare increased grain yield by 42.8 percent compared with nitrogen. But Sesbania rostrata did not improve the yield of rice markedly.

Thakur (1991) obtained highest grain yields with recommended fertilizers, with Sesbania rostrata plus phosphorus and 40 kg nitrogen per hectare in two equal splits. Straw yields with these treatments also followed the same trend.

Sahu and Sahu (1992) observed that Sesbania rostrata gave 28 percent more yield of rice while Sesbania cannabina gave 29 percent more yield.

2.3 Growth and productivity of rice as influenced by nitrogen

2.3.1 Effect of nitrogen on growth characters

2.3.1.1 Plant height

Tomy (1963) recorded a significant increase in height of plants during the productive phase as the dose of nitrogen was increased.

Pillai (1971) reported an increase in plant height with graded doses of nitrogen supply upto 100 kg per hectare.

Sambali and Gupta (1972) observed that plant height increased with increasing levels of nitrogen upto 200 kg per hectare.

Eunus and Sadeque (1974) concluded that plant height was unaffected by different levels of nitrogen.

Balachandran Nair (1976) did not notice any significant increase in plant height due to different levels of nitrogen with direct seeded Triveni rice at Vellayani during the third crop season.

Lenka et al. (1976) obtained increase in plant height with increasing levels of nitrogen upto 180 kg per hectare.

Nagre and Mahajan (1981) obtained increase in plant height with increasing levels of nitrogen.

Increase in plant height due to nitrogen application were also reported by Nair and Koshy (1981) and Sushamakumari (1981).

Sreekumaran (1981) did not get any significant increase in plant height due to nitrogen application.

Sobhana (1983) obtained a marked increase in plant height as a result of application of nitrogen.

Ajithkumar (1984) found that nitrogen had no significant influence on the height of plants.

Reddy et al. (1987) reported that nitrogen significantly increased the height of plants.

2.3.1.2 Number of tillers per square metre

Lenka and Behera (1967) found that the number of tillers per square metre were progressively increased with increased application of nitrogen.

Sahu and Lenka (1967) reported that the number of tillers per plant was influenced by the different levels of nitrogen, though not significantly.

Nair (1968b) did not get significant increase in the number of tillers with increased rates of nitrogen application.

Ramanujam and Sakharam Rao (1971) have reported an enhancement in tiller production due to nitrogen application.

Alexander et al. (1972) and Meera Sahib (1974) reported that tiller production was found to be significantly influenced by nitrogen application.

Balachandran Nair (1976) did not obtain significant influence of nitrogen rates on tiller production.

Lenka et al. (1976) recorded an increase in the number of tillers with increasing levels of applied nitrogen upto 180 kg per hectare.

Nair and Koshy (1981) reported a significant influence of nitrogen on tiller production.

Nagre and Mahajan (1981) also noticed an increase in the number of tillers per plant with increase in the level of nitrogen.

Findings of Ajithkumar (1984) and Surendran (1985) were also an increase in tiller number with increase in nitrogen.

Reddy (1986) reported that increasing nitrogen application to rice cv. Jaya from 0 to 180 kg nitrogen per hectare increased the number of tillers per hill.

Thakur and Singh (1987) observed that the number of tillers per square metre increased with increasing levels of nitrogen upto 100 kg per hectare.

2.3.2 Effect of nitrogen on yield and yield attributes

2.3.2.1 Number of productive tillers per square metre

Sood and Singh (1972) observed an increase in the number of ear-bearing tillers in tall indica varieties with an increase in nitrogen levels from 0 to 90 kg per hectare.

Balachandran Nair (1976) observed that the effect of levels of nitrogen on the number of productive tillers per square metre was not significant.

Dixit and Singh (1978) reported that nitrogen application increased the number of productive tillers per square metre.

Singh et al. (1979) recorded an increase in productive tillers with increase in fertilizer levels.

Murthy and Murthy (1981) found that nitrogen application increases the productive tiller number.

Similar results were reported by Sreekumaran (1981), Balasubramaniyan (1984), Pillai et al. (1984), Reddy et al. (1987), Subbiah et al. (1988) and Ramasubba Reddy and Anand Reddy (1989).

2.3.2.2 Panicle weight

Pillai (1971) reported an increase in panicle weight with increase in levels of nitrogen application.

Sushamakumari (1981) reported significant increase in panicle weight at 60 and 90 kg levels of nitrogen in Jaya variety.

Ajithkumar (1984) did not observe any significant difference in panicle weight with levels of nitrogen.

Vaijayanthi (1986) observed no significant difference in weight of panicle due to different doses of nitrogen.

2.3.2.3 Percentage of filled grains

Alexander et al. (1972) found that with increase in the levels of nitrogen the number of filled grains per panicle increased.

Sreekumaran (1981) observed that levels of nitrogen had no significant influence on the number of filled grains per panicle.

Ajithkumar (1984) also did not observe any significant influence of nitrogen on the percent filled grains per panicle.

Pillai et al. (1984) found that the filled grain percentage was favourably influenced by nitrogen.

Surendran (1985) observed a significant increase in the percentage of filled grains when the level of nitrogen was increased from 20 to 40 kg per hectare.

Srinivasalu Reddy (1986) reported that increasing nitrogen levels from no nitrogen to 180 kg nitrogen per hectare increased the filled grain percentage.

Ramasubba Reddy and Anand Reddy (1989) also observed that the percentage of filled grains increased as the level of nitrogen was increased from 40 to 120 kg per hectare.

2.3.2.4 Percentage of unfilled grains

Balachandran Nair (1976) reported that application of nitrogen did not influence the percentage of unfilled grains in Triveni variety.

Bhaumik and Ghosh (1977) found that with increase in nitrogen rates applied, the number of unfilled grains per panicle increased.

Surendran (1985) observed a linear increase in the percentage of unfilled grains with increase in nitrogen dose from 20 to 60 kg per hectare.

Reddy et al. (1987) observed a greater percentage of chaffiness at higher nitrogen levels.

2.3.2.5 Thousand grain weight

Alexander et al. (1972) observed that thousand grain weight was increased by nitrogen levels in Triveni variety of rice.

Rajasekhara and Morachan (1974) found that increased doses of nitrogen decreased thousand grain weight.

Pillai et al. (1976) reported that thousand grain weight was not affected by nitrogen levels.

Nair and Koshy (1981) pointed out that the different levels of nitrogen had no significant influence on the thousand grain weight.

Balasubramaniyan (1982) noticed only a marginal increase in test weight due to application of nitrogen.

Sharma and Rajendra Prasad (1982) found that each successive increase in the dose of nitrogen from 0 to 120 kg per hectare significantly increased the thousand grain weight.

Sobhana (1983) obtained considerable increase in thousand grain weight due to increased fertilizer application.

Ajithkumar (1984) observed that the effect of nitrogen on thousand grain weight was not significant.

Surendran (1985) reported that thousand grain weight increased due to nitrogen application in Lekshmi variety of rice.

Srinivasalu Reddy (1986) found that increasing nitrogen levels from no nitrogen to 180 kg nitrogen per hectare increased the thousand grain weight.

Dalai and Dixit (1987) reported an increase in thousand grain weight with increasing levels of nitrogen.

2.3.2.6 Grain yield

Tanaka (1958) got no apparent increase in grain yield as a result of increased application of nitrogen.

Potty (1964) recorded significant increase in grain yield with the increase in dose of nitrogen.

Nair (1968a) found that there was a positive linear response upto 100 kg per hectare for IR-8 variety.

Le and Aleshin (1970) found that application of high rates of nitrogen to rice plants decreased paddy yields.

Rethinam (1974) observed steady increase in yield with enhanced doses of nitrogen and the highest yield was obtained with 160 kg nitrogen per hectare.

Fagundo et al. (1978) found that with four nitrogen levels from 0 to 240 kg per hectare showed increase in tillering but had very little effect on final yield.

Wells and Faw (1978) found that nitrogen rate was weakly correlated with yield.

Droupathi Devi et al. (1981) found that nitrogen had no significant influence on yield.

Sushamakumari (1981) found that fertilizer levels exert significant influence on grain yield.

Ayyaswamy et al. (1983) reported that application of different levels of nitrogen significantly increased yield and 120 kg nitrogen per hectare recorded the maximum yield.

Application of nitrogen at levels higher than 112.5 kg per hectare was found to induce more of vegetative growth and resulted in more chaffy grains and thereby lower grain yield (PL-480, 1985).

Perumal et al. (1985) found that grain yield of rice variety, Bhavani showed considerable increase upto 150 kg nitrogen per hectare.

Vaijayanthi (1986) obtained a significant increase in grain yield with increase in level of nitrogen in Cheradi variety of rice.

Reddy et al. (1987) found significant increase in grain yield with increasing levels of nitrogen from 0 to 120 kg nitrogen per hectare.

Babu Mathew (1987) observed that grain yield showed an increasing trend with increase in the level of nitrogen upto 112.5 kg per hectare in Jaya variety of rice.

Similar results were obtained by Thakur and Singh (1987), Wankhade and Pandrangi (1988) and Saikia and Dutta (1989).

2.3.2.7 Straw yield

Sahu and Lenka (1967) observed significant increase in straw yield with increased application of nitrogen.

Rao and Ramanujam (1971) reported that increase of nitrogen levels from 0 to 180 kg per hectare increased straw yield.

Raj et al. (1974) reported that straw yield was increased by the applied nitrogen from 0 to 250 kg per hectare.

Venkateswaralu (1978) found that straw yields increased with nitrogen levels upto 200 kg per hectare only and beyond this level it declined.

Sushamakumari (1981) observed that nitrogen at higher levels progressively increased straw yield and the highest straw yield was recorded at 90 kg nitrogen per hectare.

Sobhana (1983) obtained progressive increase in straw yield with increasing levels of nitrogen.

Ajithkumar (1984) reported that higher level of nitrogen positively influenced straw yield of Mashuri rice during rabi season.

Dalai and Dixit (1987) got increased straw yields with each successive level of nitrogen.

2.4 Chemical Analysis

2.4.1 Nitrogen uptake

Sadanandan et al. (1969) reported that nitrogen content in the plant decreased with advancement of growth. It remained at a comparatively higher level upto tillering phase, and thereafter declined steeply.

Gopalaswamy and Raj (1977) reported a linear increase in the uptake of nitrogen with an increase in the rate of applied nitrogen from 0 to 200 kg per hectare.

Agarwal (1978) found that application of nitrogen upto 120 kg per hectare increased the nitrogen uptake.

Sharma and Prasad (1980) reported that nitrogen uptake was increased with increase in rate of nitrogen applied.

Sushamakumari (1981) found that levels of nitrogen significantly influenced nitrogen uptake at all stages.

Sah and Mikkelsen (1983) found that nitrogen uptake of rice was increased with increasing nitrogen rates.

Perumal et al. (1985) reported that uptake of nitrogen by rice variety, Bhavani showed considerable increase upto 150 kg nitrogen per hectare.

Rama Subba Reddy and Anand Reddy (1986) found that nitrogen application increased nitrogen uptake at all growth stages.

Thakur and Singh (1987) found that nitrogen uptake increased with increasing levels of nitrogen upto 100 kg per hectare.

Wankhade and Pandrangi (1988) also got progressive increase in nitrogen uptake with increasing levels of nitrogen.

Saikia and Dutta (1989) also obtained similar results.

2.4.2 Phosphorus uptake

Loganathan and Raj (1972) reported that the uptake of phosphorus by paddy was not influenced by nitrogen application.

Pathak et al. (1972) observed higher concentration of phosphorus in plants at high fertility level.

Singh and Bhardwaj (1973) found that smaller amount of nitrogen application enhanced phosphorus absorption by rice plants.

Raju (1978) reported increased phosphorus uptake with increased nitrogen application from 0 to 180 kg per hectare.

Nair and Koshy (1981) found that nitrogen had no significant influence on the content and uptake of phosphorus by grain and straw.

Wankhade and Pandrangi (1988) observed a progressive increase in the uptake of phosphorus with the increasing levels of nitrogen.

2.4.3 Potassium uptake

Sadayappan and Kolandaiswamy (1974) noticed an increase in potassium uptake with increase in nitrogen level upto 100 kg per hectare.

Esakkimuthu et al. (1975) found that potassium uptake was increased with applied nitrogen.

Agarwal (1978) reported that potassium uptake was increased by application of nitrogen upto 120 kg per hectare.

Singh and Modgal (1978) observed that uptake of potassium was enhanced by the application of nitrogen upto 120 kg per hectare.

Nair and Koshy (1981) found that the potassium uptake was not influenced by nitrogen application.

Wankhade and Pandrangi (1988) observed a progressive increase in the uptake of potassium with the increasing levels of nitrogen.

2.4.4 Calcium uptake and Magnesium uptake

Gopalaswamy and Raj (1972) reported a highly significant correlation between uptake of nitrogen and uptake of calcium and magnesium.

Nair and Koshy (1981) found that the calcium uptake was influenced significantly by nitrogen, while magnesium uptake was not affected.

2.4.5 Protein content

Basak et al. (1961) observed that increased nitrogen level did not influence the protein content of rice markedly.

Govindaswami and Ghosh (1968) observed an increase in protein content from 6.55 percent to 7.98 percent as the nitrogen levels were increased from 0 kg per hectare to 80 kg per hectare.

Ramanujam and Rao (1970) observed an increase in protein content from 8.50 percent to 11.50 percent corresponding to nitrogen levels from 0 to 180 kg per hectare.

Kulkarni (1973) reported a 40 to 50 percent increase in grain protein content with increasing rates of nitrogen application from 0 to 150 kg per hectare.

Agarwal (1978) reported an increase in crude protein content from 9.09 to 10.65 percent due to nitrogen application.

Mahajan and Nagre (1981) observed an increase in protein content in rice grain with increase in level of nitrogen.

Jayakumar and Kandaswamy (1985) found that increasing nitrogen levels upto 120 kg per hectare increased the crude protein content considerably.

MATERIALS AND METHODS

MATERIALS AND METHODS

An investigation was carried out with the objective of assessing the influence of *in situ* growing and incorporation of *Sesbania rostrata* on the growth and productivity of rice and studying the economy of nitrogen use by rice.

The experiment was carried out during the period from July 1991 to December 1991. The details of the materials used and methods adopted for the study are presented in this chapter.

3.1 MATERIALS

3.1.1 Experimental site

The experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani. The farm is located at 8.5°N latitude and 76.9°E longitude, at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental site was sandy clay loam in texture. The physico-chemical properties of the soil of the experimental site are given below.

Table 1a. Mechanical Analysis of the soil of the experimental site

Constituent	Content in soil (%)	Method used
A. Mechanical Composition		International Pipette Method (Piper, 1950)
Coarse sand	50.75	
Fine sand	12.15	
Silt	5.00	
Clay	27.50	
Textural class	sandy clay loam	

Table 1b. Chemical properties of the soil of the experimental site

Constituent	Content in soil	Rating	Method used
B. Chemical Composition			
Available nitrogen (kg ha^{-1})	313.60	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	35.91	Medium	Bray colorimetric method (Jackson, 1973)
Available potassium (kg ha^{-1})	86.60	Low	Ammonium acetate method (Jackson, 1973)
Available calcium (kg ha^{-1})	201.20		Ammonium acetate method (Jackson, 1973)
Available magnesium (kg ha^{-1})	120.61		Ammonium acetate method (Jackson, 1973)
Organic carbon (%)	0.93	High	Walkley and Black rapid titration method (Jackson, 1973)
pH	4.9	Acidic	1:2.5 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 rice.

3.1.4 Season

The experiment was conducted during the period from July 1991 to December 1991.

3.1.5 Weather conditions

The experimental site enjoys a humid tropical climate. The data on various weather parameters (rainfall, mean maximum temperature, mean minimum temperature and relative humidity) during the cropping period are given in Appendix I and graphically represented in Fig. 1. The mean maximum and minimum temperatures during the cropping period ranged from 28.01°C to 31.07°C and 20.33°C to 24.61°C respectively. The mean relative humidity ranged from 70.43 to 87.36 percent. The total rainfall received during the crop period was 190.28 mm.

3.1.6 Seed materials

The seed material of _Sesbania_ _rostrata_ was obtained from Cropping Systems Research Centre, Karamana, Trivandrum.

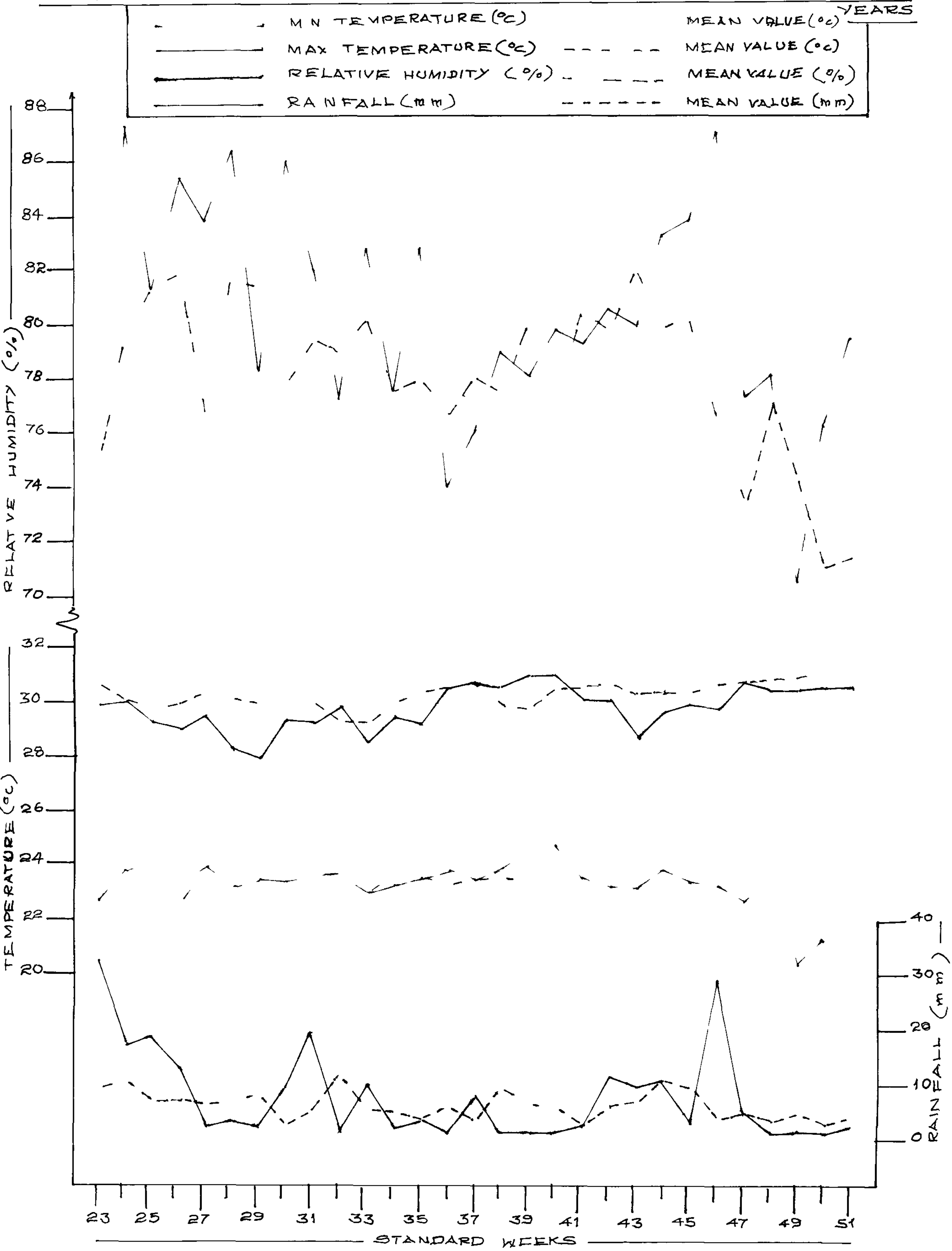


FIG 1 WEATHER DATA OF THE CROPPING PERIOD AND THE MEAN OF FIVE YEARS

The rice variety selected for the experiment was Jyothi, the progeny of a cross between Ptb.10 and IR.8 released from Rice Research Station, Pattambi, Kerala. Jyothi is a short duration variety (110-125 days) of high yielding nature recommended for cultivation in Kerala.

3.1.7 Fertilizer and soil amendment

For rice, urea containing 46 percent nitrogen, Mussoriephos containing 20 percent P_2O_5, muriate of potash containing 60 percent K_2O, farm yard manure containing 0.95 percent nitrogen, 0.54 percent P_2O_5 and 0.36 percent K_2O and quick lime were used. 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*. No fertilizer or soil amendment was used for *Sesbania rostrata*.

3.2 METHODS

3.2.1 Design and layout

The experiment was laid out in Randomised Block Design with three replications. The layout plan of the experiment is given in Figure 2. The details of the layout are given below.

Number of treatment combinations	:	15 + 1
Number of blocks	:	3
Number of replications	:	3
Gross plot size	:	5.1 x 4.0 m
Net plot size	:	4.5 x 3.6 m
Total number of plots	:	48

3.2.2 Treatments

Three levels of Rhizobium inoculation, five levels of nitrogen and one control were fixed as treatments.

Rhizobium inoculation

i_1 - seed inoculation

i_2 - stem inoculation

i_3 - seed and stem inoculation

Levels of nitrogen to succeeding

Crop of rice

n_0 - No nitrogen

n_1 - 25% of the recommended dose

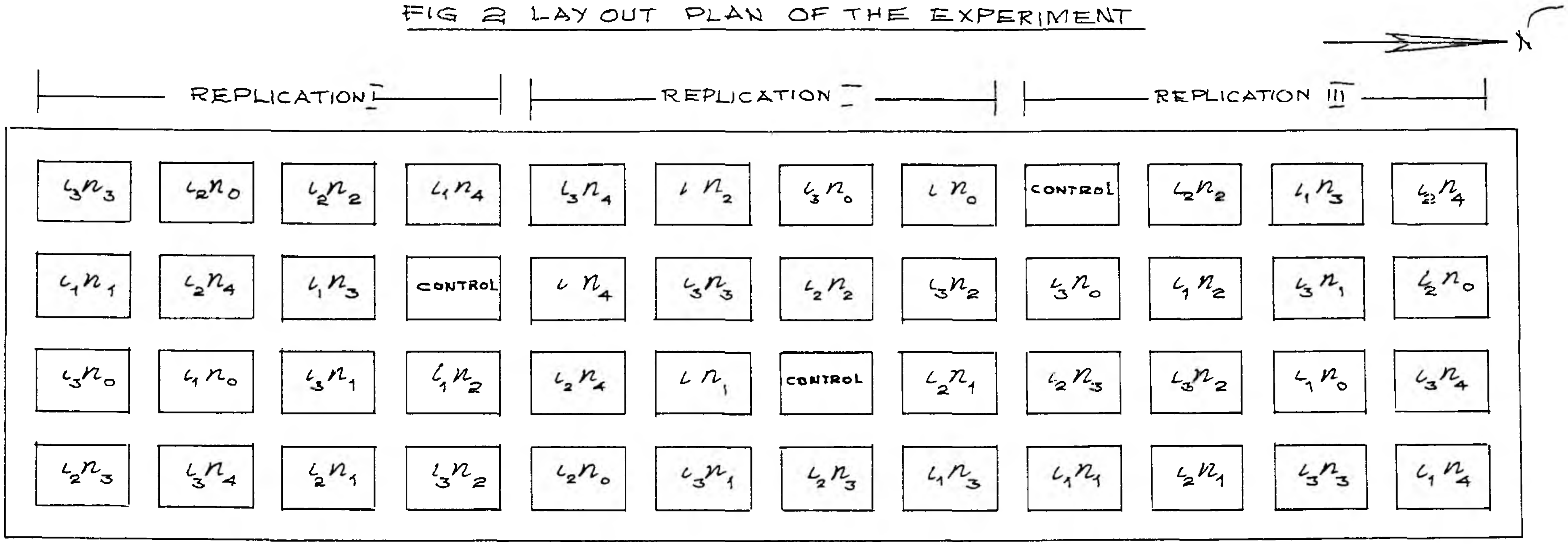
n_2 - 50% of the recommended dose

n_3 - 75% of the recommended dose

n_4 - 100% of the recommended dose

Control plot of rice : as per KAU package of practices recommendations (1989)

FIG 2 LAY OUT PLAN OF THE EXPERIMENT



Rhizobium INOCULATION

l_1 - SEED INOCULATION

l_2 - STEM INOCULATION

l_3 - SEED + STEM - INOCULATION

CONTROL PLOT OF RICE

KAU PACKAGE OF PRACTICES RECOMMENDATIONS

LEVELS OF NITROGEN TO SUCCEEDING CROP OF RICE

n_0 -- NO NITROGEN

n_1 -- 25 % OF THE RECOMMENDED DOSE

n_2 -- 50 % OF THE RECOMMENDED DOSE

n_3 -- 75 % OF THE RECOMMENDED DOSE

n_4 -- 100 % OF THE RECOMMENDED DOSE

GROSS PLOT SIZE -- 5.1 x 4.0 M

NET PLOT SIZE ---- 4.5 x 3.6 M

3.2.3 Treatment combinations

The treatment combinations are as follows:

T_1 - i_1n_0	T_6 - i_2n_0	T_{11} - i_3n_0
T_2 - i_1n_1	T_7 - i_2n_1	T_{12} - i_3n_1
T_3 - i_1n_2	T_8 - i_2n_2	T_{13} - i_3n_2
T_4 - i_1n_3	T_9 - i_2n_3	T_{14} - i_3n_3
T_5 - i_1n_4	T_{10} - i_2n_4	T_{15} - i_3n_4
		T_{16} - Control

3.2.4 Field culture

3.2.4.1 Land preparation

3.2.4.1.1 *Sesbania rostrata*

The experimental site was dug twice, weeds and stubbles removed, clods broken and the field was laid out with bunds of 30 cm width all around. Individual plots were again dug and perfectly levelled. Seeds of *Sesbania rostrata* were broadcast in all plots, except the control plots.

3.2.4.1.2 Rice

At about 50 percent flowering stage *Sesbania rostrata* was incorporated into the respective plots and rice seedlings were transplanted at the prescribed spacing. The cultivation practices recommended for short and high yielding varieties of rice in the package of practices recommendations of Kerala Agricultural University were followed.

3.2.4.2 Fertilizer application

3.2.4.2.1 *Sesbania rostrata*

No fertilizer or soil amendment was applied to *Sesbania rostrata*.

3.2.4.2.2 Rice

3.2.4.2.2.1 Control plots

Lime was applied to the control plots @ 600 kg ha^{-1} (in 2 splits, 350 kg ha^{-1} as basal 2 weeks before sowing and 250 kg ha^{-1} one month after transplanting). Nitrogen, phosphorus and potassium application to the control plots were as per the KAU package of practices recommendations (N : P_2O_5 : K_2O - 70 : 35 : 35 kg ha^{-1}). Farmyard manure was applied @ 5 t ha^{-1} to the control plots. Entire dose of phosphorus and potash were applied basally to provide 35 kg ha^{-1} each of P_2O_5 and K_2O. Two-third dose of the total recommended quantity of nitrogen was applied basally and the remaining 1/3 was applied at one week prior to panicle initiation.

3.2.4.2.2.2 Treatment plots

Lime and farmyard manure were not applied to the

3.2.4.4.2 Rice

Transplanting was done with a thin film of water. Subsequently the water level was raised to about 5 cm. One week prior to harvest the plots were completely drained. Two handweedings were given 20 days and 40 days after transplanting.

3.2.4.5 Plant protection

3.2.4.5.1 *Sesbania rostrata*

No pests and diseases were observed in the crop. Hence no plant protection operations were carried out for *Sesbania rostrata*.

3.2.4.5.2 Rice

Ekalux was sprayed against rice case worm at about 15 days after transplanting. No other pests or diseases were found on the crop in magnitudes requiring chemical control.

3.2.4.6 Harvest

3.2.4.6.1 *Sesbania rostrata*

Harvesting was done at 50% flowering stage, which occurred at about 50 days after sowing. The plants were cut at the base, weighed and ploughed into the soil of the respective plots.

3.2.4.6.2 Rice

The crop was harvested and threshed. In the case of all the treatments, the crop in the border rows were harvested separately and thereafter the crop in the net area of the individual plots was harvested and threshed individually. Weight of grain and straw of individual plots were recorded.

Observations

3.2.5 Growth characters of Sesbania rostrata

3.2.5.1 Height of plants

The height of the plants were taken at the time of harvest. The observations were taken from ten plants selected at random from the centre of the plots. The height of the plants were measured from the base to the growing tip. From the data obtained, the mean height of the plants was calculated and expressed in centimetres.

3.2.5.2 Number of root nodules

At harvest, four 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.

3.2.5.3 Number of shoot nodules

At harvest, four plants were randomly selected and their stem nodules were counted and expressed as a mean value.

3.2.5.4 Root and shoot 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.

3.2.6 Yield of *Sesbania rostrata*

3.2.6.1 Fresh weight of green manure

The entire plants of each plot were harvested 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 kg ha^{-1}.

3.2.6.2 Dry weight of green manure

Four 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 weight of green manure was expressed as kg ha^{-1}.

3.2.7 Growth characters of rice

3.2.7.1 Height of plant

The height of plants (in centimetres) was recorded on 20th, 40th and 60th day after transplanting and at harvest. Four hills were randomly selected within one square metre area marked in the net plot. Height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest earhead, whichever was taller.

3.2.7.2 Total number of tillers per square metre

Total number of tillers per square metre was recorded on the 20th, 40th, and 60th day after transplanting and at harvest. Tiller number was taken from twelve randomly selected hills and expressed as number of tillers per square metre.

3.2.8 Yield and yield attributes of rice

3.2.8.1 Productive tillers per square metre

Productive tillers were recorded from the twelve randomly selected hills on the 60th day after transplanting and at harvest and expressed as productive tillers per square metre.

3.2.8.2 Panicle weight

All the panicles in the 12 sample hills were weighed and weight per panicle was worked out.

3.2.8.3 Percentage of filled grains

The total filled and unfilled grains from the panicles were separately counted and the percentage of filled grains was recorded.

3.2.8.4 Percentage of unfilled grains

The total filled and unfilled grains from the panicles were separately counted and the percentage of unfilled grains was recorded.

3.2.8.5 Thousand grain weight

One thousand grains were counted from the samples drawn from the cleaned produce from each plot and weights recorded in grams.

3.2.8.6 Grain yield of rice

The grains harvested from each net plot was dried, cleaned and weighed and expressed as kg ha^{-1}.

3.2.8.7 Straw yield of rice

The straw harvested from each net plot was dried under sun, weighed and the weight was expressed as kg ha^{-1}.

3.2.9 Chemical analysis

3.2.9.1 Plant analysis

The whole plants of both Sesbania rostrata and rice were analysed for nitrogen, phosphorus, potassium, calcium and magnesium contents. In the case of rice the grains were analysed separately. The plant samples collected from each plot at the time of harvest(s) of Sesbania rostrata and rice were dried to constant weights in an electric hot air oven at 70°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 were determined and expressed as percentage on dry weight basis.

3.2.9.1.1 Total nitrogen content

Total nitrogen content was estimated by modified microkjeldahl method as given by Jackson (1973).

3.2.9.1.2 Total phosphorus content

Total phosphorus content was estimated by using Vanado-molybdo-phosphoric yellow colour 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

Total magnesium content in plant 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, potassium, calcium and magnesium at harvest(s) in both Sesbania rostrata and rice were calculated as the product of the content of these nutrients in the plant samples and the respective dry weights and expressed as kg ha^{-1}.

3.2.9.3 Protein content of rice

The protein content of the grains was computed by multiplying the percentage of nitrogen content in grains by the factor 6.25 (Simpson et al., 1965).

3.2.9.4 Soil Analysis

Composite soil sample collected before the start of the experiment ie. before sowing Sesbania rostrata was analysed to determine the available nitrogen, available P_2O_5, available K_2O, available calcium and available magnesium. The physical composition and pH were determined for this composite soil sample. After the harvest of rice, soil samples were taken from each plot separately and analysed for available nitrogen, available P_2O_5, available K_2O, available calcium and available magnesium.

3.2.9.5 Analysis of farm yard manure

The farm yard manure samples were taken from the lot applied to the control plots. These samples were analysed to determine the total nitrogen, phosphorus, potassium, calcium and magnesium.

3.2.10 Economics of cultivation

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

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

Benefit-cost ratio : $\frac{\text{Gross income}}{\text{Cost of cultivation}}$

3.2.11 Statistical Analysis

The data generated from the experiment were subjected to Analysis of Variance (ANOVA) technique as applied to factorial experiment in randomised block design described by Cochran and Cox (1965).

RESULTS

RESULTS

The results regarding the effect of the different levels of inoculation on the biomass productivity and nutrient uptake by *Sesbania rostrata* and effect of *Sesbania rostrata* on the succeeding crop of rice are given below.

4.1 Growth performance and productivity of *Sesbania rostrata*

4.1.1 Effect of inoculation

4.1.1.1 Height of plants

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

The three levels of inoculation viz. seed inoculation, stem inoculation, and seed and stem inoculation had no significant influence on the height of plants. However, stem inoculation recorded the maximum value for plant height, followed by seed and stem inoculation. Seed inoculation recorded the least value.

4.1.1.2 Fresh weight of green manure

The mean data on the fresh weight of green manure are presented in Table 2 and Fig. 3.

Inoculation did not show any significant influence on the fresh weight of green manure. However, the treatment consisting of seed and stem inoculation recorded the maximum value for this parameter, followed by stem inoculation. Seed inoculation recorded the lowest value.

4.1.1.3 Dry weight of green manure

The mean data on the dry weight of green manure are presented in Table 2 and Fig. 3.

The dry weight of green manure was not significantly influenced by the different levels of inoculation. However, the treatment consisting seed and stem inoculation recorded the maximum value for this parameter.

4.1.1.4 Number of shoot nodules per plant

The mean data on the number of shoot nodules per plant are presented in Table 2.

Inoculation did not affect the number of shoot nodules per plant significantly. However, stem inoculation recorded the maximum number of shoot nodules per plant followed by seed inoculation.

4.1.1.5 Number of root nodules per plant

The mean data on the number of root nodules per plant are presented in Table 2.

The effects due to the different levels of inoculation on the production of root nodules per plant were not statistically significant. However, stem inoculation recorded the maximum number of root nodules per plant followed by seed inoculation.

4.1.1.6 Dry weight of shoot nodules per plant

The mean data on the dry weight of shoot nodules per plant are presented in Table 2.

Dry weight of shoot nodules per plant was not influenced significantly by the different levels of inoculation. All the three levels of inoculation recorded almost similar values for the dry weight of shoot nodules per plant.

4.1.1.7 Dry weight of root nodules per plant

The mean data on the dry weight of root nodules per plant are presented in Table 2.

The effects of the different levels of inoculation on the dry weight of root nodules per plant were not statistically significant. However, stem inoculation gave the maximum value for dry weight of root nodules per plant.

4.1.1.8 Nutrient uptake by plants

4.1.1.8.1 Nitrogen uptake by plants

The mean data on the nitrogen uptake by the plants are given in Table 3 and Fig. 4.

Table 2. Growth characteristics of <u>Sesbania rostrata</u>

	Height of plants (cm)	Fresh weight of green manure (kg ha^{-1})	Dry weight of green manure (kg ha^{-1})	Shoot nodules (no./plant)	Root nodules (no./plant)	Dry weight of shoot nodules (g/plant)	Dry weight of root nodules (g/plant)
i_1	58.23	3787.33	1145.40	42.97	22.23	0.080	0.134
i_2	62.62	3836.53	1140.27	47.37	25.37	0.077	0.158
i_3	61.64	4215.67	1258.07	41.43	21.20	0.080	0.121
$F(2,28)$	NS	NS	NS	NS	NS	NS	NS
SEm$\pm$	2.542	328.064	112.931	3.628	2.069	0.009	0.014
CD(0.05)	-	-	-	-	-	-	-

i_1 - seed inoculation

i_2 - stem inoculation

i_3 - seed + stem inoculation

NS - Not Significant

The different levels of inoculation had no significant influence on the uptake of nitrogen by plants. However, the seed and stem inoculation treatment recorded the highest value for this aspect, followed by stem inoculation. Seed inoculation gave the lowest value.

4.1.1.8.2 Phosphorus uptake by plants

The mean data on the phosphorus uptake by plants are presented in Table 3.

Uptake of phosphorus by plants was not significantly influenced by the different levels of inoculation. However, the treatment consisting of seed and stem inoculation recorded the highest value, followed by stem inoculation. Seed inoculation recorded the least value in this respect.

4.1.1.8.3 Potassium uptake by plants

The mean data on the potassium uptake by plants are presented in Table 3.

The effects of the different levels of inoculation on the potassium uptake by plants were not statistically significant. However, the seed and stem inoculation gave the highest value for potassium uptake, followed by stem inoculation. The lowest value was noticed in seed inoculation treatment.

Table 3. Nutrient uptake by *Sesbania rostrata*

	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})	Calcium uptake (kg ha^{-1})	Magnesium uptake (kg ha^{-1})
i_1	55.44	4.43	21.21	12.00	4.49
i_2	58.76	5.04	21.98	12.22	4.54
i_3	64.23	5.59	25.09	13.20	5.10
F(2,28)	NS	NS	NS	NS	NS
SEm$\pm$	5.428	0.418	2.338	1.147	0.441
CD(0.05)	-	-	-	-	-

i_1 - seed inoculation

i_2 - stem inoculation

i_3 - seed + stem inoculation

NS - Not Significant

4.1.1.8.4 Calcium uptake by plants

The mean data on the calcium uptake by plants are presented in Table 3.

Calcium uptake by plants was not influenced significantly by the different levels of inoculation. However, the treatment comprising of seed and stem inoculation recorded the highest value for calcium uptake, followed by stem inoculation. The least value was recorded by seed inoculation.

4.1.1.8.5 Magnesium uptake by plants

The mean data on magnesium uptake by plants are presented in Table 3.

Inoculation did not show any significant influence on the uptake of magnesium by plants. However, seed and stem inoculation recorded the highest value for magnesium uptake followed by stem inoculation. Seed inoculation gave the least value for magnesium uptake.

The second part of the study consisted of assessing the effect of _Sesbania_ incorporation on the growth and productivity of rice and also estimating the replacement value of chemical nitrogen added to rice by the nitrogen addition by _Sesbania_ incorporation. The results on the effect of incorporation of _S. rostrata_ in conjunction with chemical nitrogen at different rates on the growth and productivity of rice are given below.

4.2 Growth characters of rice

4.2.1 Height of plants

The mean data on the height of rice plants at different stages of growth are presented in Table 4.

The data reveal that there was no significant difference in plant height at 20 days after transplanting and 40 days after transplanting, due to the various levels of nitrogen. But the different levels of nitrogen significantly influenced the plant height at 60 days after transplanting and at harvest. The treatment n_4 recorded the maximum plant height in both the stages (84.92 cm and 86.25 cm respectively).

It was also seen that there was no significant difference between the various treatments and control (treatment as per package of practices recommendations) in this respect.

4.2.2 Tiller number

The mean data on tiller number per square metre are presented in Table 4.

The different levels of nitrogen significantly influenced the tiller number per square metre at 20 days after transplanting. The treatment n_4 recorded the maximum number of tillers per square metre (675.61), followed by n_1 whereas n_0 recorded the least number of tillers per square metre.

At 40 and 60 days after transplanting and at harvest the tiller number per square metre was not significantly influenced by the nitrogen levels.

When the treatment effects were compared with the control, it was found to be statistically not significant at all the growth stages.

4.3 Yield and yield attributes

4.3.1 Productive tillers

The mean data on the number of productive tillers per square metre are presented in Table 5.

The different levels of nitrogen did not show any significant influence on the number of productive tillers per square metre at 60 days after transplanting. However, the maximum number of productive tillers per square metre was observed in treatment n_1 at 60 days (441.06) after transplanting.

At the harvest stage, nitrogen levels showed a significant influence on the number of productive tillers per square metre. The treatment n_1 recorded the maximum

Table 4. Growth characters of rice as influenced by different levels of Nitrogen

Treatment	Plant height (cm)				Total number of tillers per square metre			
	20 DAT	40 DAT	60 DAT	At harvest	20 DAT	40 DAT	60 DAT	At harvest
n_0	39.75	60.81	80.17	81.53	482.06	606.74	549.05	500.67
n_1	40.14	62.25	83.03	84.39	562.09	724.61	651.42	588.12
n_2	39.22	61.72	80.50	81.79	496.92	614.19	590.00	547.19
n_3	42.78	60.61	82.58	84.64	545.33	712.78	614.18	545.31
n_4	42.50	61.22	84.92	86.25	675.61	764.93	642.08	560.21
$F(4,30)$	NS	NS	3.265*	3.766*	3.625*	NS	NS	NS
SEm±	1.032	1.207	1.079	1.038	40.128	43.592	33.551	28.118
CD(0.05)	-	-	3.118	2.997	115.882	-	-	-
Control	40.67	62.50	81.75	84.00	474.60	641.87	636.53	580.70
Trtd. Vs. control								
$F(1,30)$	NS	NS	NS	NS	NS	NS	NS	NS

n_0 - 0 level of nitrogen

n_1 - 25% of recommended dose of nitrogen

n_2 - 50% of recommended dose of nitrogen

n_3 - 75% of recommended dose of nitrogen

n_4 - 100% of recommended dose of nitrogen

* Significant at 5% level

NS - Not Significant

number of productive tillers per square metre and n_0 recorded the least value for this parameter.

There was no significant difference between treatments and control.

4.3.2 Grain yield

The mean data on grain yield are presented in Table 5 and Fig. 5.

The effect of the various levels of nitrogen on the grain yield was not statistically significant. However, the treatment n_2 gave the maximum grain yield (2011.1 kg ha^{-1}).

The treatments when compared with the control were not significant. However the control recorded a higher value for grain yield than all the treatments.

4.3.3 Straw yield

The mean data on straw yield are presented in Table 5 and Fig. 5.

The nitrogen levels did not influence the straw yield significantly. However the treatment n_4 recorded the maximum value for straw yield (4682.7 kg ha^{-1}).

The treatments did not show any significant difference when compared with the control treatment.

4.3.4 Panicle weight

The mean data on panicle weight are presented in Table 5.

The panicle weight was not influenced significantly by the different levels of nitrogen.

There was no significant difference between the treatments and control also.

4.3.5 Percentage of filled grains

The mean data on percentage of filled grains per panicle are presented in Table 5.

Percentage of filled grains per panicle was not significantly influenced by the levels of nitrogen. However, the treatment n_2 recorded the maximum percentage of filled grains per panicle (85.96 percent). The filled grain percentage was found to decrease as the nitrogen level increased.

The treatments and control did not differ significantly in the percentage of filled grains per panicle. However, the control treatment recorded a high percentage of filled grains per panicle.

4.3.6 Percentage of unfilled grains

The mean data on percentage of unfilled grains per panicle are presented in Table 5.

Table 5. Yield and yield attributes of rice as influenced by different levels of nitrogen

Treatment	Productive tillers per square metre		Grain yield (kg/ha)	Straw yield (kg/ha)	Panicle weight (g)	Percentage of filled grains (%)	Percentage of unfilled grains (%)	Thousand grain weight (g)
	60 DAT	At harvest						
n_0	342.45	264.29	1665.4	4554.1	1.861	81.02	18.98	26.71
n_1	441.06	333.18	1970.2	5298.2	2.005	84.79	15.21	26.77
n_2	372.26	320.26	2011.1	4347.2	2.030	85.96	14.04	26.84
n_3	368.52	297.80	1863.4	4654.2	1.867	78.83	21.17	26.49
n_4	398.29	279.21	1718.7	4682.7	1.813	79.10	21.57	26.72
F(4,30)	NS	3.017*	NS	NS	NS	NS	NS	NS
SEm±	26.463	16.329	142.216	572.448	0.075	2.816	2.809	0.279
C.D(0.05)	-	47.156	-	-	-	-	-	-
Control	374.10	312.70	2167.3	4111.3	1.872	83.60	16.40	26.80
Trtd. Vs. control								
F(1,30)	NS	NS	NS	NS	NS	NS	NS	NS

* - Significant at 5% level

NS - Not Significant

The different levels of nitrogen had no significant influence on the percentage of unfilled grains per panicle. However, the lowest value for this parameter was recorded by the treatment n_2. It was seen that the percentage of unfilled grains increased with increasing levels of nitrogen with the maximum value for n_4 (21.57 percent).

When the treatments were compared against control, there was no significant difference.

4.3.7 Thousand grain weight

The mean data on thousand grain weight are presented in Table 5.

Thousand grain weight was not significantly influenced by the different levels of nitrogen. All the levels of nitrogen recorded almost similar results.

There was no significant difference between the various treatments and control in this respect.

4.4 Uptake of nutrients

4.4.1 Uptake of nitrogen

The mean data on uptake of nitrogen are presented in Table 6 and Fig. 6.

Nitrogen uptake was not affected significantly by the different levels of nitrogen. However the treatment n_1

recorded the highest value for uptake of nitrogen (77.22 kg ha^{-1}).

The treatments and control did not differ significantly in uptake of nitrogen.

4.4.2 Uptake of phosphorus

The mean data on uptake of phosphorus are presented in Table 6.

The different levels of nitrogen had no significant influence on the uptake of phosphorus. However the treatment n_4 gave the maximum value for phosphorus uptake (40.70 kg ha^{-1}). Treatment n_0 recorded the least value for the uptake of phosphorus.

The comparison between the treatments and control showed that there was no significant difference in uptake of phosphorus between the two.

4.4.3 Uptake of potassium

The mean data on uptake of potassium are presented in Table 6.

Uptake of potassium was not influenced significantly by the different levels of nitrogen. However, the treatment n_1 recorded the maximum value for potassium uptake (119.34 kg ha^{-1}).

Table 6. Nutrient uptake of rice as influenced by the different levels of nitrogen

Treatment	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})	Calcium uptake (kg ha^{-1})	Magnesium uptake (kg ha^{-1})
n_0	69.84	31.02	88.53	11.40	9.15
n_1	77.22	40.03	119.34	11.85	10.61
n_2	63.91	40.53	93.16	11.24	9.71
n_3	75.62	37.49	93.31	13.82	9.25
n_4	66.15	40.70	87.63	10.55	11.14
$F(4,30)$	NS	NS	NS	NS	NS
SEm±	7.089	3.548	9.440	1.065	1.228
C.D(0.05)	-	-	-	-	-
Control	75.25	29.74	104.36	8.65	10.24
Trtd. Vs. control					
$F(1,30)$	NS	NS	NS	NS	NS

NS - Not Significant

The treatments did not show any significant difference over the control.

4.4.4 Uptake of calcium

The mean data on uptake of calcium are presented in Table 6.

The different levels of nitrogen did not show any significant influence on the uptake of calcium by rice plants. However, the treatment n_3 gave the highest value for uptake of calcium.

The treatments and control did not vary significantly in uptake of calcium.

4.4.5 Uptake of magnesium

The mean data on uptake of magnesium are presented in Table 6.

Uptake of magnesium was not influenced significantly by the application of the different levels of nitrogen. However, the treatment n_4 recorded the highest value for the uptake of magnesium.

The treatments and control did not show any significant difference in uptake of magnesium.

4.5 Protein content of rice

The mean data on protein content of rice are presented in Table 7 and Fig. 7.

The treatments consisting of the different levels of nitrogen were found to influence the protein content of rice significantly. The treatment n_3 recorded the maximum content of protein (9.33 percent).

The difference in protein content due to the treatments and control was found to be significant. The control recorded a protein content which was significantly higher than that of the treatments.

4.6 Soil nutrient status after the experiment

4.6.1 Available nitrogen

The data on the available nitrogen content of the soil after the experiment are presented in Table 8 and Fig. 8.

It was seen that the different levels of nitrogen significantly influenced the nitrogen content of the soil. Increasing levels of nitrogen application increased the available nitrogen content with n_4 recording the maximum value (437.97 kg ha^{-1}).

The treatments and control did not show any significant difference in the available nitrogen content of soil after the experiment.

4.6.2 Available phosphorus

The data on the available phosphorus content of the soil after the experiment are given in Table 8.

Table 7. Protein content of rice as influenced by levels of nitrogen

Treatment	Protein content (%)
n_0	8.52
n_1	9.04
n_2	7.53
n_3	9.33
n_4	8.23
F(4,30)	4.717**
SEm±	0.326
C.D(0.05)	0.943
Control	10.33
Trtd. Vs. control	
F(1,30)	9.474**

** Significant at 1% level

The different levels of nitrogen significantly influenced the phosphorus content of the soil. Maximum value for available phosphorus was recorded by the treatment n_0.

The control treatment recorded a significantly higher value for available phosphorus, than the other treatments.

4.6.3 Available potassium

The data on the available potassium content of the soil after the experiment are presented in Table 8.

The available potassium content in soil after the experiment was not influenced significantly by the different levels of nitrogen.

The difference between the treatments and control was also found to be not significant.

4.6.4 Available calcium

The data on the available calcium content of the soil after the experiment are presented in Table 8.

The different levels of nitrogen were found to influence the available calcium content of the soil after the experiment significantly. The highest value for the available calcium in soil after the experiment was recorded by the treatment n_0 (310.03 kg ha^{-1}).

Table 8. Available soil nutrient status after the experiment as influenced by the different levels of nitroge

Treatment	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Available calcium (kg ha^{-1})	Available magnesium (kg ha^{-1})
n_0	171.51	41.40	80.49	310.03	73.34
n_1	282.02	27.89	77.90	309.43	67.84
n_2	313.80	32.25	87.57	243.48	56.91
n_3	318.61	31.95	72.23	284.83	61.01
n_4	437.97	39.37	82.31	241.11	63.12
F(4,30)	143.793**	784.141**	NS	182.286**	8.179**
SEm$\pm$	7.943	0.201	5.989	2.515	2.242
C.D(0.05)	22.938	0.580	-	7.264	6.475
Control	343.77	40.67	79.80	330.80	70.33
Trtd. Vs. control					
F(1,30)	NS	NS	NS	NS	NS

** Significant at 1% level

NS Not Significant

The control treatment recorded a significantly higher value than the other treatments for the available calcium content of the soil after the experiment.

4.6.5 Available Magnesium

The data on the available magnesium content of the soil after the experiment are presented in Table 8.

The available magnesium content of the soil after the experiment was significantly influenced by the different levels of nitrogen, with n_0 recording the highest value.

The difference between the treatments and control was not significant.

4.7 Economics of cultivation

The data on net returns and benefit-cost ratio are presented in Table 9.

Among the different treatments, n_1 (25% recommended dose of nitrogen + Sesbania rostrata incorporation) recorded the maximum value for net returns and benefit-cost ratio. When the five rates of nitrogen were compared n_4 (100% recommended dose of nitrogen + Sesbania rostrata incorporation) recorded the lowest value for net returns and benefit-cost ratio.

Table 9. Economics of cultivation of rice

Treatment	Cost pf cultivation (Rs.) (y)	Gross Income (Rs.) (x)	Net Income (Rs.) (x-y)	BCR (x/y)
n_0	10083.17	13659.29	3576.12	1.355
n_1	10265.07	16025.12	5760.05	1.561
n_2	10446.97	14766.31	4319.34	1.413
n_3	10574.27	14621.24	4046.97	1.383
n_4	10701.37	14070.72	3369.35	1.314
Control	11620.40	15052.88	3432.48	1.295

Cost of Rhizobium = Rs.5.00 per packet

Cost of 1 t Farm yard manure = Rs.300.00

Cost of 1 kg lime = Rs. 2.00

Cost of 1 kg nitrogen = Rs. 7.28

Cost of 1 kg phosphorus (P_2O_5) = Rs. 10.00

Cost of 1 kg potassium (K_2O) = Rs. 3.33

Cost of 1 kg grain = Rs. 4.10

Cost of 1 kg straw = Rs. 1.50

Labour charge (Man) = Rs. 54.60

(Woman) = Rs. 54.60

DISCUSSION

DISCUSSION

The first part of the experiment was to study the effect of inoculation on the growth and productivity of *Sesbania rostrata*. The results of the study are discussed below.

5.1 Growth characters

5.1.1 Plant height

The results on the plant height are presented in Table 2.

An appraisal of the data in the table shows that the three levels of inoculation (seed inoculation, stem inoculation and seed inoculation + stem inoculation) did not significantly influence the plant height.

Inoculation when compared with no inoculation proved non-significant in its influence on plant height of *Sesbania rostrata* (Murali, 1989).

5.1.2 Fresh weight and dry weight of green manure

The data on the fresh weight and dry weight of green manure are presented in Table 2.

Both the fresh weight and dry weight of *Sesbania rostrata* were not influenced significantly by the three levels of inoculation. However, i_3 (seed inoculation + stem inoculation) recorded the maximum value for both fresh weight and dry weight of green manure.

In general, 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 have the capacity to photosynthesize (Du Houx, 1984). Similar results have been reported by Daroy et al. (1987).

5.1.3 Nodule characteristics

5.1.3.1 Number of root nodules and shoot nodules

The data on the number of root nodules and number of shoot nodules are presented in Table 2.

The number of root nodules and shoot nodules were not significantly influenced by the three levels of inoculation. However, i_2 (stem inoculation) recorded the maximum value for the number of root nodules and shoot nodules. Similar results were obtained by Ladha et al. (1989) who found that inoculation on the stem alone, increased the overall nodulation.

The general trend seen in the experiment was a lesser number of both root and stem nodules. The reduction in the root nodule number may be attributed to the adverse effect

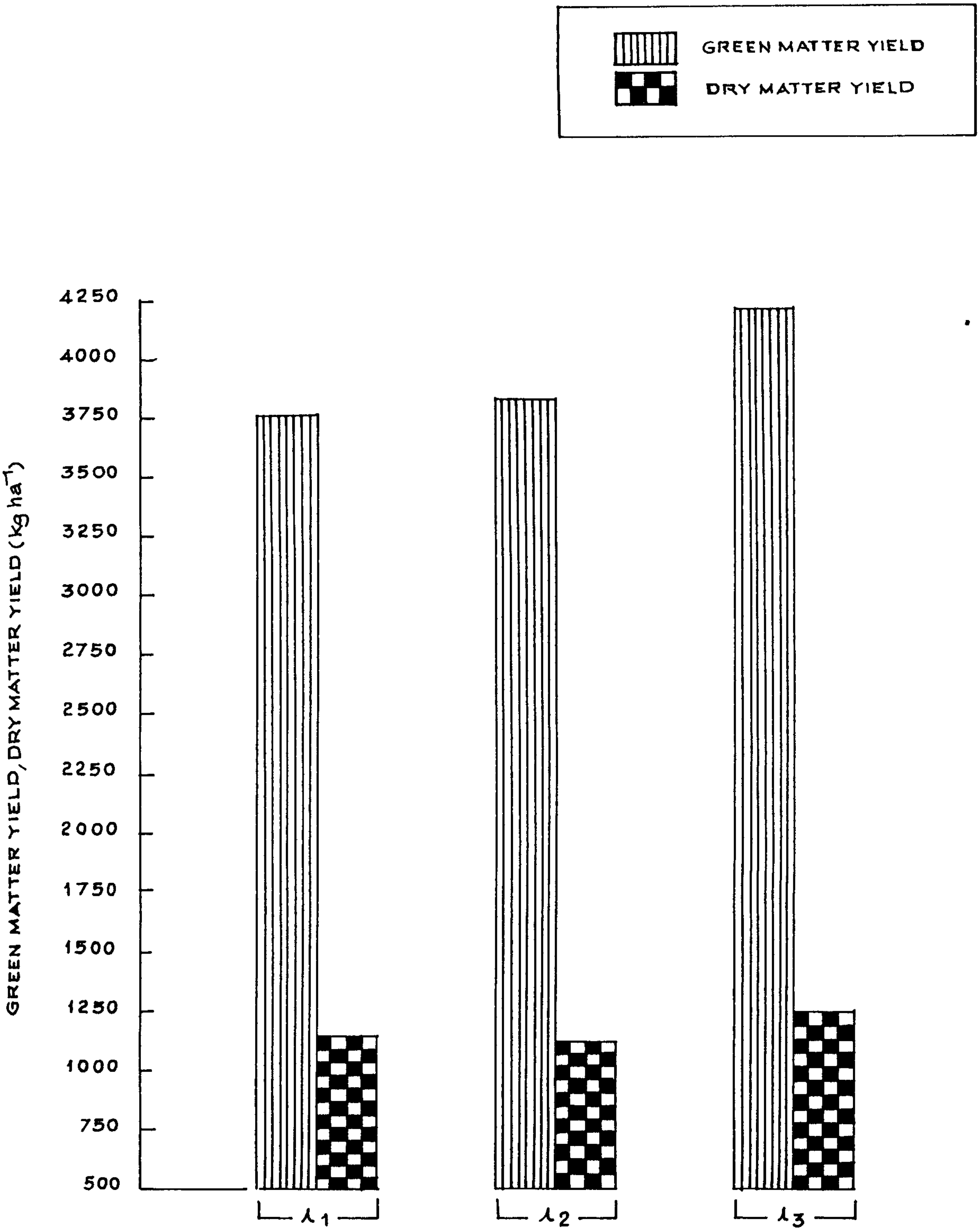


FIG 3 EFFECT OF INOCULATION LEVELS ON THE GREEN MATTER AND DRY MATTER YIELD OF *Sesbania rostrata*

of waterlogging which prevailed during the period when Sesbania rostrata was grown. Dreyfus et al. (1988) has shown that waterlogging condition considerably affected root nodulation and caused root decay.

The pH of the experimental area was acidic (pH - 4.9). Under acidic condition nodulation is restricted. Calcium is one of the major plant nutrients and it influences plant growth characters (Tisdale et al., 1985). Russell(1973) concluded that non-availability of calcium in acid soils appeared to restrict nodulation by many legumes grown in soils having low pH.

The medium status of available nitrogen may be another reason for the poor nodulation. Lie (1974) reported that nodulation was strongly reduced in the presence of moderate or high levels of nitrogen.

5.1.3.2 Dry weight of root nodules and shoot nodules

The data on the dry weight of root nodules and dry weight of shoot nodules are presented in Table 2.

The three levels of inoculation did not influence the dry weight of root nodules and dry weight of shoot nodules significantly.

The non-significant influence of inoculation levels on the dry weight of root nodules may be due to the adverse effect of waterlogging on root nodulation as reported by Dreyfus et al. (1988). Excessive water supply was found to reduce nodule formation (Sprent, 1969).

The available nitrogen status of the soil of the experimental site was medium. A higher concentration of nitrogen has been found to affect the stem nodule size and weight (Moudiongui and Rinaudo, 1987).

5.2 Nutrient uptake by Sesbania rostrata

Table 3 shows the effect of inoculation on the uptake of nitrogen, phosphorus, potassium, calcium, and magnesium by the plants.

The uptake of nitrogen, phosphorus, potassium, calcium and magnesium by the plants were not influenced significantly by the three levels of inoculation. However, the maximum value of uptake for all these nutrients was recorded by i_3 (seed inoculation + stem inoculation).

The treatment i_3 recorded the maximum green matter and dry matter. Possibly the higher nutrient uptake in i_3 might have resulted in higher green matter and dry matter production. In general, the uptake of plant nutrients at any stage of growth is mainly related to dry matter production. One of the factors which control nutrient uptake is the rate of increase in dry matter production (Tanaka et al., 1964).

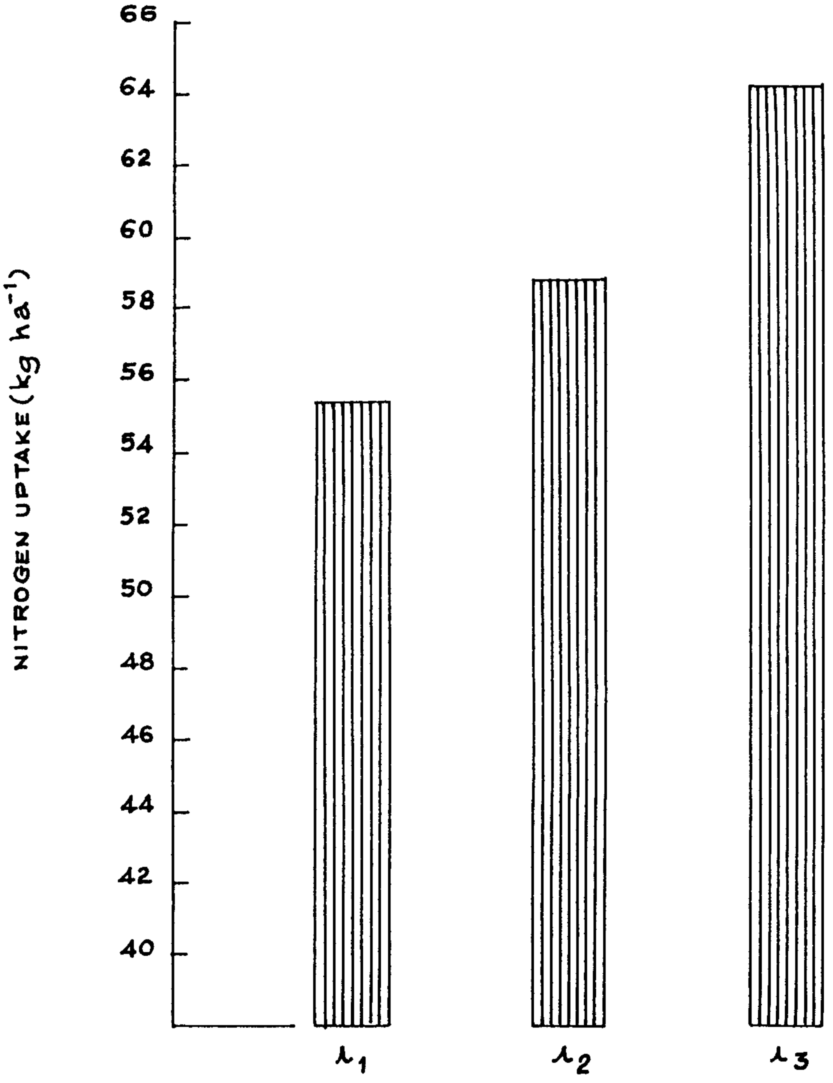


FIG 4 EFFECT OF INOCULATION LEVELS ON THE NITROGEN UPTAKE BY *Sesbania rostrata*

Moundiongui and Rinaudo (1987) observed that higher nitrogen concentration in soil affected both stem and root acetylene reduction and ultimately the nitrogen fixation. Similarly the medium available nitrogen status of the soil of the experimental site may be the reason for the lack of response of the plant to inoculation with regard to nitrogen uptake.

Phosphorus, potassium, calcium and magnesium were not applied to Sesbania rostrata and their uptake is not of much importance.

The second part of the experiment was to study the effect of incorporation of Sesbania rostrata in soil in combination with different levels of nitrogen on rice. The results on this part of the experiment are discussed below.

5.3 Growth characters of rice

5.3.1 Height of plants

The data on the height of plants at various stages of growth are presented in Table 4.

From the results it is evident that the different levels of nitrogen had no significant influence on plant height at 20 days and 40 days after transplanting. However the treatments receiving higher levels of nitrogen were seen recording more height than those receiving no nitrogen. There was significant increase in plant height at 60 days after transplanting and at harvest. In both the stages the highest dose of nitrogen (n_4 - 100% recommended dose of nitrogen + Sesbania rostrata) recorded the maximum height and no nitrogen (n_0 - Sesbania rostrata alone) recorded the minimum height.

The effect of nitrogen in increasing the vegetative growth, especially the plant height, is a well established fact. Nitrogen has a pronounced role in cell multiplication (Tisdale et al., 1985). This would naturally cause an increase in height of plant. Similar responses to nitrogen fertilization have been reported by many previous workers like Tomy (1963), Patel (1967), Lenka et al. (1976), Nair and Koshy (1981) and Reddy et al. (1987).

There was no significant difference in plant height between the different levels of nitrogen in combination with Sesbania rostrata incorporation and control (package of practices recommendations of KAU).

5.3.2 Number of tillers per square metre

The data on the number of tillers per square metre are presented in Table 4.

From the results it is seen that the effect of nitrogen on the number of tillers per square metre was significant only at 20 days after transplanting. At all other stages the effect of nitrogen on the number of tillers per square metre was not significant. However, irrespective of the stage of growth, an increasing trend was seen in the number of tillers with increase in the level of nitrogen. At all the stages of growth the tiller number was found to increase with nitrogen and the lowest tiller count per square metre was recorded by n_0 (no nitrogen).

Enhancement of tiller production as a result of nitrogen supply has been reported by several workers (Ramanujam and Sakharam, 1971; Nair and Koshy, 1981; Sushamakumari, 1981; Ajithkumar, 1984; Reddy, 1986; Babu Mathew, 1987).

The various levels of nitrogen and the control did not differ significantly in the number of tillers per square metre.

Another observation was that the number of tillers per square metre at 60 days after transplanting was greater than at the harvest stage. Similarly the number of tillers per square metre was greater at 40 days after transplanting than at 60 days after transplanting. This trend was seen at all levels of nitrogen. However, it was seen that as the level of nitrogen increased the magnitude of decrease in tiller count also increased. Thus the largest decrease in tiller count per square metre was at n_4. This decrease in tiller number might be due to mutual shading and death of lower positioned tillers. Similar results have been reported by Sreedharan (1975), Thampi (1979) and Sreekumaran (1981).

5.4 Yield and yield attributes of rice

5.4.1 Productive tillers per square metre

The data on the number of productive tillers per square metre are presented in Table 5.

The results showed that the influence of nitrogen on the number of productive tillers per square metre was more pronounced at the harvest stage. The treatment n_1 (25% recommended dose of nitrogen + *Sesbania rostrata*) recorded the largest number of productive tillers per square metre and n_0 (no nitrogen) recorded the least productive tiller count.

An increase in the production of productive tillers have been noticed at higher levels of nitrogen by several workers like Sood and Singh (1972), Dixit and Singh (1978), Murthy and Murthy (1981), Balasubramaniyan (1984) and Subbiah et al. (1988). At the same time, Thampi (1979) reported that the number of productive tillers per square metre decreased when the levels of nitrogen increased above 60 kg per hectare. Similarly Sreekumaran (1981) reported that increasing the dose of nitrogen from 90 to 120 kg resulted in a decrease in productive tiller count.

5.4.2 Panicle weight

The data on panicle weight are presented in Table 5.

Panicle weight was not significantly influenced by the different levels of nitrogen. There was no significant difference in panicle weight between the different levels of nitrogen and control. However, upto the treatment n_2 (50% recommended dose of nitrogen + Sesbania rostrata) there was a progressive increase in panicle weight.

The results showed that fertilization upto a certain level was beneficial for increasing the panicle weight. The influence of nitrogen in increasing the photosynthesis and thereby increasing the source is a very well established phenomenon (Sreedharan, 1975; Sushamakumari, 1981). This increase in source has helped in accumulation of more assimilates in sink (panicle).

This may be due to an unfavourable balance between potassium and nitrogen on account of increasing the level of nitrogen beyond certain limit and because of the low potassium status of the experimental area. Russell (1973) reported a marked influence of potassium in the translocation of carbohydrates to the panicles and thereby causing an increase in the panicle weight.

5.4.3 Percentage of filled grains

The data on the percentage of filled grains are presented in Table 5.

The different levels of nitrogen did not exert any significant influence on the percentage of filled grains. The control and treatments did not differ significantly in the percentage of filled grains. The percentage of filled grains, however, was found to increase with dose of nitrogen upto n_2 (50% recommended dose of nitrogen + Sesbania rostrata) and thereafter it decreased.

Increasing the level of nitrogen might have increased the unfilled grains, thereby resulting in a comparatively lesser percentage of filling in n_3 and n_4. Similar results of reduced percentage of filled grains with high levels of nitrogen has been reported by Nair (1968b), Muthuswamy et al. (1972), Surendran (1985) and Vaijayanthi (1986).

The fertility status of the experimental area with reference to available potassium was low. Mukherji et al. (1968) noticed a marked decrease in grain filling as the nitrogen supply was increased. Further, potassium has been found to maintain the ratio between reducing and non-reducing sugars at a moderate level and provide more sucrose for conversion to insoluble polysaccharides for storage (Kundu and Sircar, 1969).

5.4.4 Percentage of unfilled grains

The data on percentage unfilled grains are presented in Table 5.

The various levels of nitrogen in combination with Sesbania rostrata did not influence the percentage of unfilled grains significantly. There was no significant difference between the treatments and control. The treatment n_2 (50% recommended dose of nitrogen + Sesbania rostrata) recorded the least percentage of unfilled grains. Doses of nitrogen greater than n_2 were found to increase the percentage of unfilled grains.

Kalyanikutty et al. (1968) reported that the percentage of chaffiness increased with increased rates of application of nitrogen. Balachandran Nair (1976) also reported a non-significant influence of nitrogen in Triveni variety. This is also in agreement with the finding of several workers (Bhaumik and Ghosh, 1977; Surendran, 1985; Vaijayanthi, 1986; Reddy et al., 1987). The greater degree of chaffiness at higher levels of nitrogen may be due to accumulation of more soluble and non-productive nitrogen which would have affected the production of grains.

5.4.5 Thousand grain weight

The data on thousand grain weight are presented in Table 5.

Results showed that the thousand grain weight was not influenced significantly by the different levels of nitrogen. However, n_2 (50% recommended dose of nitrogen + Sesbania rostrata) recorded the maximum value for the parameter. There was no significant difference between the treatments and control, in thousand grain weight.

Pillai et al. (1976), Nair and Koshy (1981) and Ajithkumar (1984) also reported that nitrogen had no significant influence on thousand grain weight.

5.4.6 Grain yield

The data on grain yield are presented in Table 5.

From the data it is seen that grain yield was not significant on account of the different levels of nitrogen. There was no significant difference between the different treatments and control. However, control (KAU package of practices recommendations, 1989) recorded the maximum value for grain yield. Among the different levels of nitrogen in combination with *Sesbania rostrata*, n_2 (50% recommended dose of nitrogen + *Sesbania rostrata*) recorded the maximum grain yield. Beyond n_2 level grain yield decreased.

The increase in grain yield due to nitrogen application upto n_2 may be attributed to the role of nitrogen in photosynthesis which is directly related to the carbohydrate manufacture and grain yield (Moss and Musgrave, 1971). Similar increase in yield due to nitrogen application with or without incorporation of *Sesbania rostrata* have been reported by several workers (Rinaudo et al., 1983; Dalai and Dixit, 1987; Wankhade and Pandrangi, 1988; Husain and Sharma, 1991; Kalidurai and Kannaiyan, 1990; Thakur, 1991; Sahu and Sahu, 1992).

Another trend noticed from the grain yield data is that application of a higher level of nitrogen (above n_2) has resulted in a decrease in grain yield. The straw yield data given in Table 5 showed that in treatments where grain yield was lesser the straw yield was higher. This shows that the extra nitrogen has been utilised for straw production rather than for grain production. Similar results have been reported by Yoshida et al. (1973) and Sreekumaran (1981).

The actual trend exhibited by the treatments is a non-significant effect of nitrogen on grain yield. This may be because of the fact that the experimental area was medium in native fertility status with reference to available nitrogen and the crop might have utilised this nitrogen mostly for its growth and development which might have resulted in the lack of response to added nitrogen. The nitrogen recommendation adopted was 70 kg per hectare. But from the present investigation it is seen that a recommendation comprising of just 50% of recommended dose of nitrogen in combination with incorporation of Sesbania rostrata is more than sufficient to produce maximum grain yield. Similar results of non-significant effect of nitrogen on grain yield due to high nitrogen status of soil has been reported by Droupathi Devi et al. (1981).

Dommergues (1983) reported that use of Sesbania rostrata as green manure could dramatically increase rice yields only in nitrogen deficient soils.

In an experiment conducted at the International Rice Research Institute, Philippines, it was seen that rice grain yield was not significantly influenced by the incorporation of Sesbania rostrata with and without fertilizer nitrogen. This was because of the fact that a considerable amount of nitrogen released from the incorporated Sesbania rostrata went into straw production (IRRI, 1988).

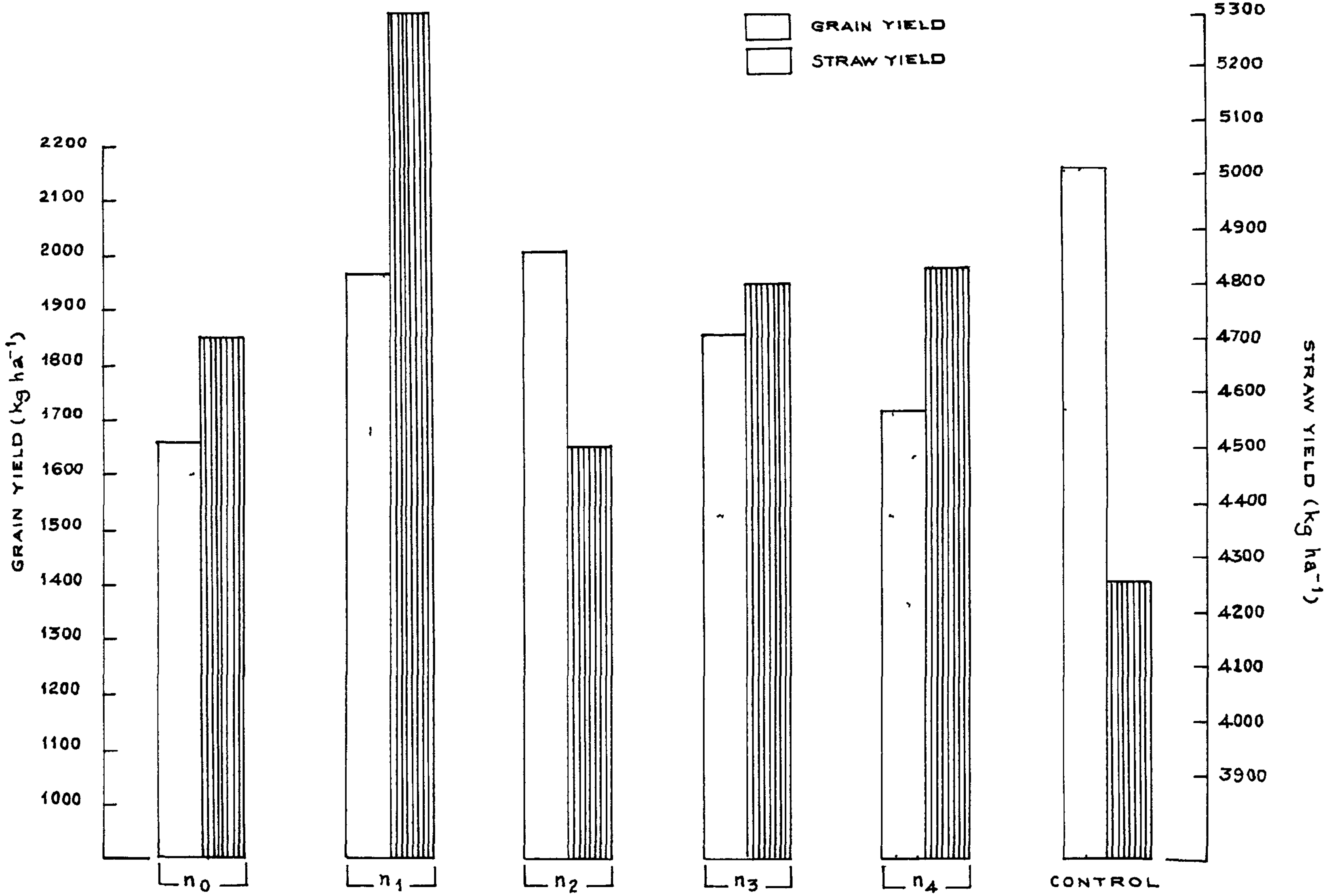


FIG 5 EFFECT OF NITROGEN ON THE GRAIN YIELD AND STRAW YIELD OF RICE

5.4.7 Straw Yield

The data on straw yield are presented in Table 5.

The results show that the different levels of nitrogen in combination with incorporation of *Sesbania rostrata* did not influence the straw yield of rice significantly. There was no significant difference in straw yield between the different treatments and control (KAU package of practices recommendations, 1989). The least value for straw yield was recorded by control. Among the different treatments n_2 recorded the least value for straw yield.

The general trend noticed was a progressive increase in straw yield as the levels of nitrogen increased. This may probably be due to the greater vegetative growth observed at higher levels of nitrogen as is evidenced from the data on plant height and tiller number. In treatments with excess nitrogen the extra nitrogen might have been utilized for straw production rather than for grain production. Similar results have been reported from IRRI (1988).

The native fertility of the experimental area was low with reference to available potassium. The reason for higher grain yield and a low straw yield recorded by the control may be attributed to an improper balance between nitrogen and potassium created by the application of higher doses of nitrogen. Potassium is highly essential for the proper translocation of carbohydrates from the source to the sink (Tanaka, 1972). The dose of potassium applied to all the treatments including control were uniform (35 kg potassium per hectare). Studies conducted by Mukherji et al. (1968) have shown that significant effect of potassium was noticeable only with moderate levels of nitrogen.

5.5 Uptake of nutrients by rice

5.5.1 Nitrogen uptake

The data on the nitrogen uptake by rice are presented in Table 6.

The different levels of nitrogen in combination with *Sesbania rostrata* incorporation did not influence, the nitrogen uptake by rice significantly. Control and the treatments did not differ significantly. Among the different levels of nitrogen in combination with *Sesbania rostrata* incorporation, n_1 (25% recommended dose of nitrogen + *Sesbania rostrata*) recorded the maximum value for nitrogen uptake.

The treatment n_1 recorded the maximum biological yield (grain yield + straw yield). This may be the reason for the higher value of nitrogen uptake recorded by n_1. Nutrient uptake is directly related to the dry matter production (Tanaka et al., 1964).

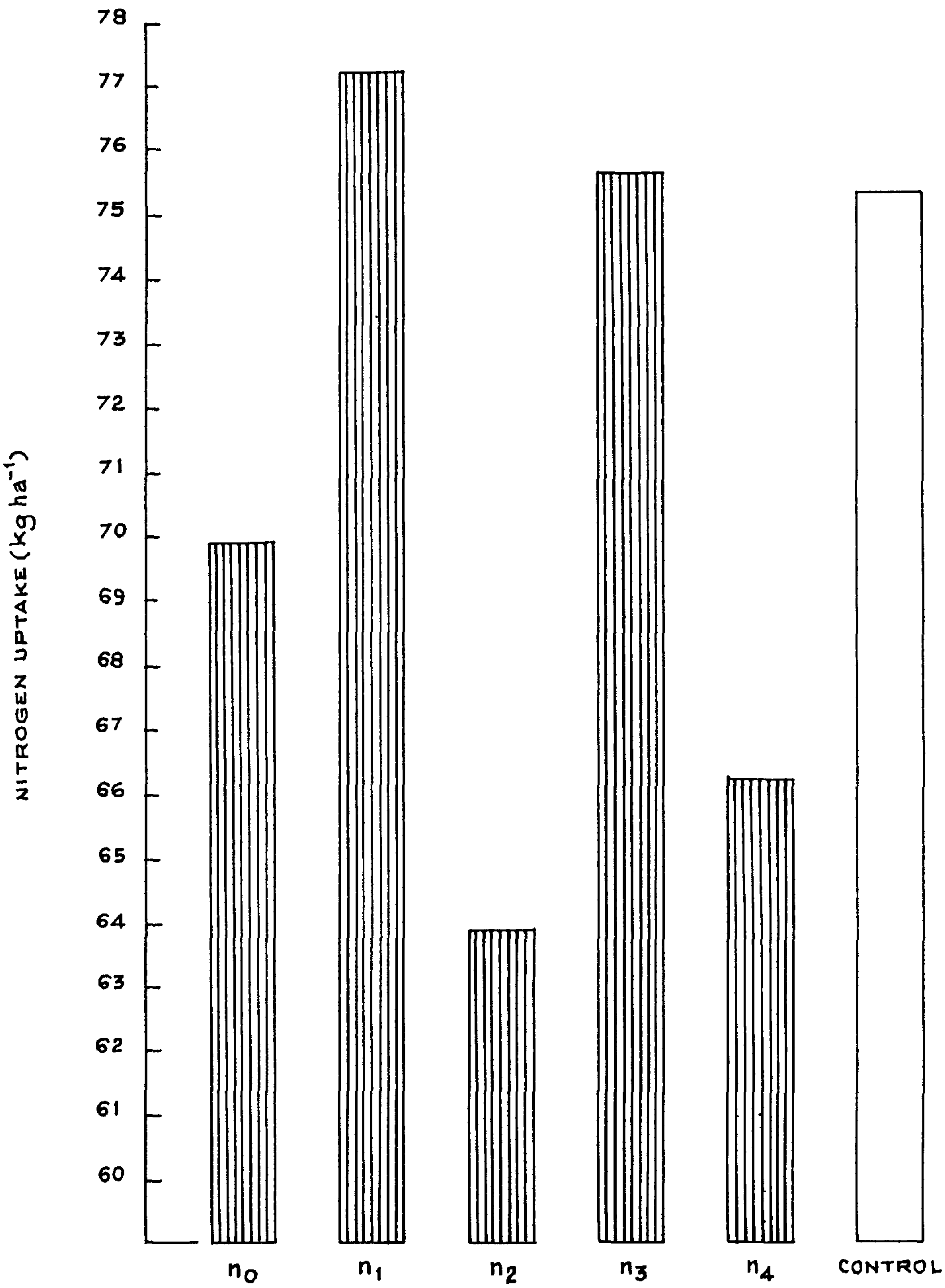


FIG 6 EFFECT OF NITROGEN ON THE NITROGEN UPTAKE OF RICE

5.5.2 Phosphorus uptake

The data on phosphorus uptake are presented in Table 6.

The phosphorus uptake by rice was not influenced significantly by the different levels of nitrogen in combination with incorporation of Sesbania rostrata. Further, the control and the treatments did not differ significantly in phosphorus uptake. However, the maximum value for phosphorus uptake was recorded by n_4 (100% recommended dose of nitrogen + Sesbania rostrata).

A progressive increase in the uptake of phosphorus due to application of nitrogen has been reported by Wankhade and Pandrangi (1988). Loganathan and Raj (1972) found a progressive increase in phosphorus uptake due to nitrogen application, but the increase was not significant.

Grunes (1959) has reported that the addition of nitrogen has marked effect on the absorption of phosphorus by plants. Nitrogen frequently increases root growth and foraging capacity for phosphorus.

5.5.3 Potassium uptake

The data on potassium uptake are presented in Table 6.

No significant difference was observed in potassium uptake between the various levels of nitrogen in combination with incorporation of Sesbania rostrata or between these treatments and control. However, among the different treatments n_1 (25% recommended dose of nitrogen + Sesbania rostrata) recorded the maximum value for potassium uptake. At high nitrogen levels potassium uptake was found to decrease.

The data show that at higher nitrogen levels the potassium uptake decreased. Similar results have been observed by Prema (1967) who found that the application of nitrogen in increasing levels decreased the potassium uptake.

5.5.4 Calcium and Magnesium uptake

The data on calcium and magnesium uptake are presented in Table 6.

Calcium uptake and magnesium uptake were not influenced significantly by the different levels of nitrogen application combined with the incorporation of Sesbania rostrata. The treatments did not differ significantly from the control with regard to uptake of calcium and magnesium.

The pH of the experimental site was acidic. Thus the low availability of calcium and magnesium may be the reason for the non-significant influence of treatments on the uptake of calcium and magnesium.

5.5.5 Protein content of rice

The data on the protein content of rice are presented in Table 7.

The different levels of nitrogen in combination with *Sesbania rostrata* incorporation were found to influence the protein content of rice significantly. The difference in protein content between the various treatments and control was significant. Among the different levels of nitrogen in combination with *Sesbania rostrata*, n_3 (75% recommended dose of nitrogen + *Sesbania rostrata*) recorded the maximum value for protein content. Control recorded the highest protein content when compared with the treatments.

5.6 Available nutrient status of the soil after the experiment

5.6.1 Available nitrogen

The data on the available nitrogen status of the soil after the experiment are presented in Table 8.

The results show that the available nitrogen increased significantly as the dose of applied nitrogen increased. The treatment n_4 (100% recommended dose of nitrogen + *Sesbania rostrata*) recorded the maximum value for available nitrogen followed by control (KAU package of practices recommendations).

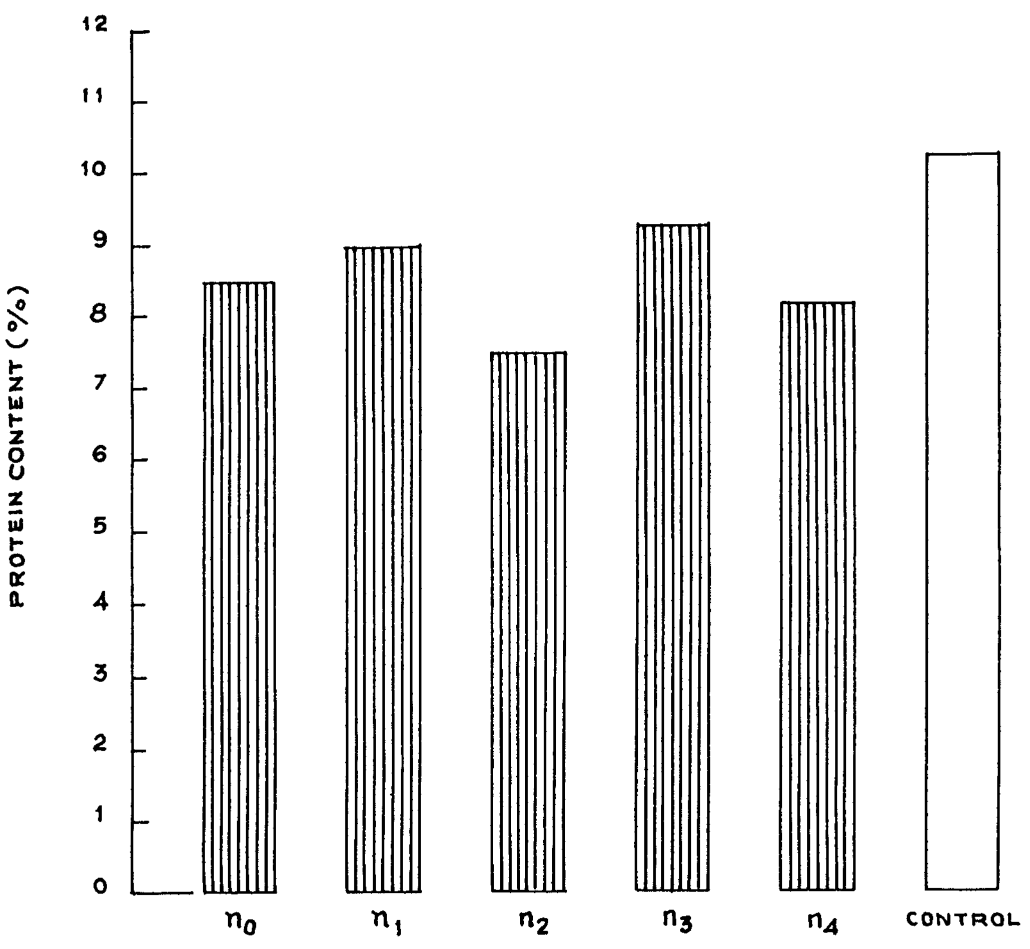


FIG 7 EFFECT OF NITROGEN ON THE PROTEIN CONTENT OF RICE

The available nitrogen status of the soil before the experiment was medium. Hence the applied nitrogen might have had only very little contribution in the nitrogen uptake by the crop. Thus most of the applied nitrogen might have contributed to enrich the available nitrogen status of the soil.

5.6.2 Available phosphorus

The data on the available phosphorus status of the soil after the experiment are presented in Table 8.

The available phosphorus of soil was found to be influenced significantly by the different levels of nitrogen combined with the incorporation of Sesbania rostrata. The control and treatments also differed significantly. The maximum value for available phosphorus was recorded by n_0 (no nitrogen + Sesbania rostrata) followed by control (KAU package of practices recommendations, 1989).

As in the case of available nitrogen, the native fertility of the soil before the experiment, with respect to the available phosphorus status was medium.

The uptake of phosphorus by rice in the treatment n_0 was the least (Table 6) which in turn might have led to a higher available phosphorus status of the soil.

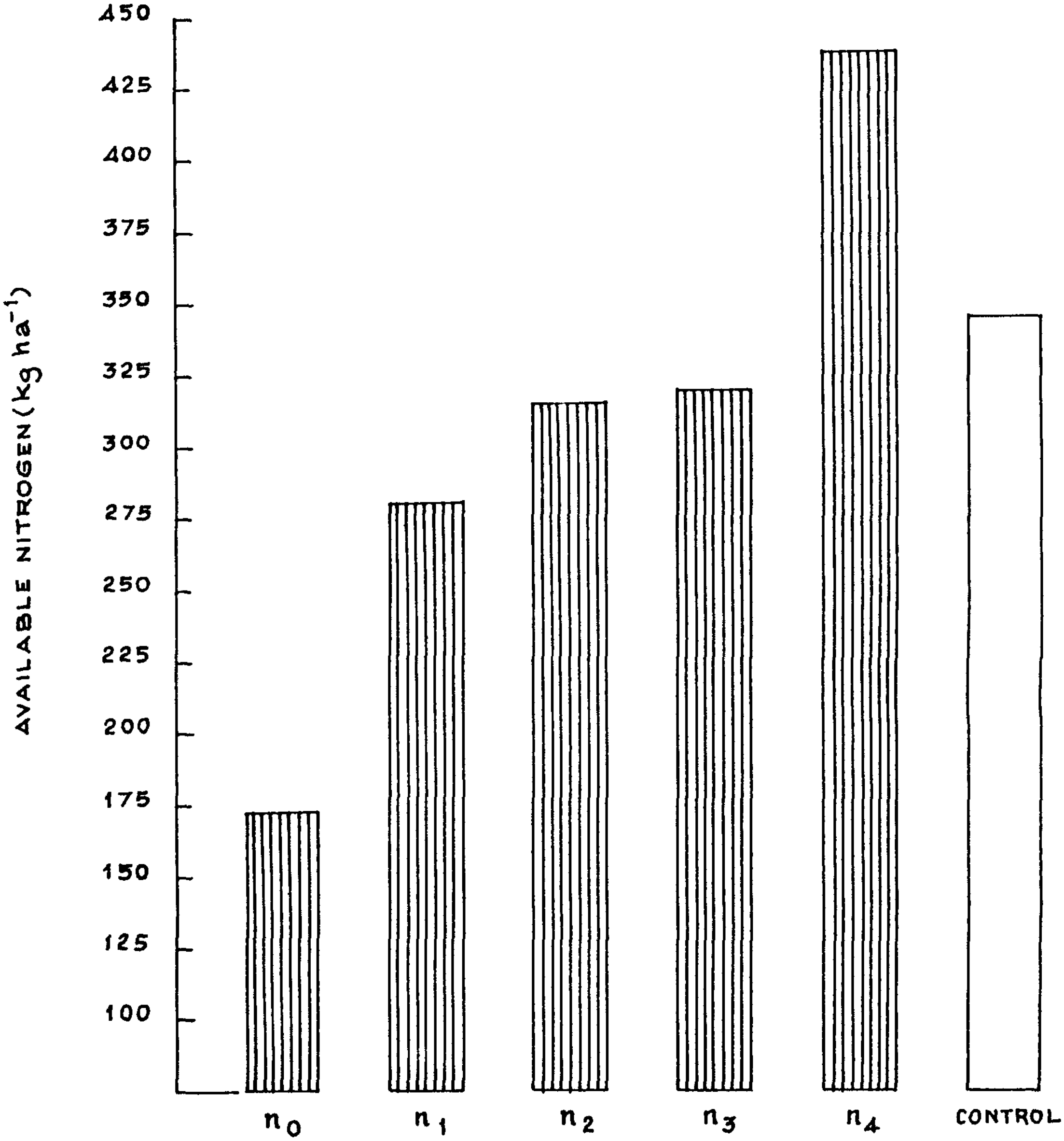


FIG 8 EFFECT OF NITROGEN ON THE AVAILABLE NITROGEN CONTENT OF SOIL AFTER THE EXPERIMENT

5.6.3 Available potassium

The data on the available potassium of the soil after the experiment are presented in Table 8.

The different levels of nitrogen in combination with the incorporation of *Sesbania rostrata* did not exert any significant influence on the available potassium content of the soil after the experiment. The treatments did not differ significantly from the control in the available potassium content of the soil after the experiment.

5.6.4 Available calcium and magnesium

The data on the available calcium and magnesium content of the soil after the experiment are presented in Table 8.

The available calcium and magnesium contents of soil after the experiment were found to be influenced significantly by the different levels of nitrogen in combination with incorporation of *Sesbania rostrata*. However, there was no regular trend of change in the content of these nutrients with difference in the dose of nitrogen.

5.7 Response curve

The response of rice crop to nitrogen supply (through fertilizers and *Sesbania rostrata* incorporation) was

SUMMARY

SUMMARY

A field investigation was undertaken at the College of Agriculture, Vellayani to assess the influence of *in situ* raising and incorporation of *Sesbania rostrata* on the growth and productivity of rice and to study the economy of nitrogen use by rice. The cultivar used for the investigation was *Jyothi*, a short duration variety of high yielding nature recommended for cultivation in Kerala. The treatments included three levels of inoculation to *Sesbania rostrata* (seed inoculation, stem inoculation and seed + stem inoculation) and five levels of nitrogen to the subsequent crop of rice (No nitrogen, 25% recommended dose of nitrogen, 50% recommended dose of nitrogen, 75% recommended dose of nitrogen and 100% recommended dose of nitrogen). One control for rice (treated as per KAU package of practices recommendations) was also included. The soil of the experimental site was sandy clay loam, medium in available nitrogen, medium in available phosphorus and low in available potassium. The experiment was laid out in a randomised block design with three replications. The results of the investigation are summarised below.

The first part of the experiment was to study the effect of the three levels of *Rhizobium* inoculation on the growth and productivity of *Sesbania rostrata*. The results

pertaining to this aspect are summarised below.

1. Plant height, green matter and dry matter yields of *Sesbania rostrata* were not influenced significantly by the different levels of inoculation. However the treatment comprising of seed + stem inoculation recorded the highest value for green matter yield and dry matter yield (4215.67 kg ha^{-1} and 1258.07 kg ha^{-1} respectively).

2. The three levels of inoculation did not exhibit any significant influence on the number of root nodules and stem nodules. Both these parameters recorded the highest value in stem inoculation (25.37/plant and 47.37/plant respectively).

3. Dry weight of root nodules and shoot nodules were not influenced significantly by the different levels of inoculation. In the case of the dry weight of shoot nodules all the three inoculation levels recorded almost similar values.

4. The different levels of inoculation did not influence the nitrogen uptake by the plants significantly. However the treatment comprising of seed + stem inoculation recorded the highest value for uptake of nitrogen (64.23 kg ha^{-1}).

5. Phosphorus uptake of plants was maximum (5.59 kg ha^{-1}) with seed + stem inoculation. But the three different levels of inoculation failed to produce any significant influence on the uptake of phosphorus by plants.

6. The three different levels of inoculation did not influence the uptake of potassium by plants significantly. However, the highest value (25.09 kg ha^{-1}) for potassium uptake by plants was recorded by the treatment, seed + stem inoculation.

7. Calcium uptake and magnesium uptake by plants were not influenced significantly by the different levels of inoculation. Seed + stem inoculation recorded the highest value for both calcium and magnesium uptake by plants (13.20 kg ha^{-1} and 5.10 kg ha^{-1}).

The second part of the experiment was to assess the effect of Sesbania rostrata incorporation on the growth and productivity of rice and to estimate the replacement value of chemical nitrogen added to rice by the nitrogen addition through the incorporation of Sesbania rostrata. The results on these aspects are summarised below.

1. The different levels of nitrogen in conjunction with Sesbania rostrata incorporation significantly influenced the plant height recorded at 60 days after transplanting

and at harvest. The maximum value for plant height at these two stages (84.92 cm and 86.25 cm respectively) was recorded by the treatment comprising of 100% recommended dose of nitrogen + Sesbania rostrata incorporation. The treatments and control (treated as per the KAU package of practices recommendations) did not differ significantly in this respect.

2. Tiller number per square metre recorded at 20 days after transplanting was significantly influenced by the different rates of nitrogen combined with the incorporation of Sesbania rostrata. 100% recommended dose of nitrogen + Sesbania rostrata recorded the maximum value (675.61/sq.m). The treatments and control did not differ significantly in the number of tillers per square metre.

3. The treatment receiving 25% recommended dose of nitrogen in conjunction with Sesbania rostrata incorporation recorded the maximum number of productive tillers per square metre (588.12/sq.m). There was no significant difference between the treatments and control.

4. The treatments did not exert any significant influence on the grain yield. However, the treatment receiving 50% recommended dose of nitrogen combined with

Sesbania rostrata incorporation recorded the maximum grain yield (2011.10 kg ha^{-1}). Although the treatments and control did not differ significantly in grain yield, control (treated as per KAU package of practices recommendations) recorded a higher grain yield (2167.33 kg ha^{-1}) than all the other treatments.

5. Straw yield was not influenced significantly by the application of different rates of nitrogen in conjunction with the incorporation of *Sesbania rostrata*. The treatment receiving 25% recommended dose of nitrogen along with *Sesbania rostrata* incorporation recorded the highest value (5298.2 kg ha^{-1}) for straw yield. Further, the treatments and control did not differ significantly in straw yield.

6. The other yield attributes such as panicle weight, thousand grain weight, percentage of filled grains and percentage of unfilled grains were not influenced significantly by the treatments. There was no significant difference between the treatments and control.

7. Nitrogen uptake was not influenced significantly by the different treatments. But the treatment which gave the highest dry matter production (treated with 25% recommended dose of nitrogen + *Sesbania rostrata*) gave the

highest value (77.22 kg ha^{-1}) for nitrogen uptake by rice. Nitrogen uptake did not show significant difference when the treatments were compared against control.

8. The different rates of nitrogen combined with the incorporation of Sesbania rostrata did not exert any significant influence on the uptake of phosphorus and potassium by rice. The difference between the various treatments and control was also not significant.

9. Protein content of rice was found to be influenced significantly by the different treatments. Among the different treatments, 75% recommended dose of nitrogen combined with the incorporation of Sesbania rostrata recorded the highest value (9.33 percent) for protein content. When the treatments were compared against control (treated as per the KAU package of practices recommendations), it was seen that the difference was significant and control recorded a higher value (10.33 percent) than all the other treatments.

10. The available nitrogen and phosphorus content of the soil after the experiment was found to be influenced significantly by the different levels of nitrogen in conjunction with Sesbania rostrata incorporation. The available potassium content of the soil after the

experiment was not influenced significantly by the different treatments.

It can be expected that incorporation of *Sesbania rostrata* before rice can substitute about 50 percent of the recommended dose of nitrogen for rice. But the same experiment should be repeated for two or three seasons to confirm the trend of results obtained in the present experiment.

Future line of work

(i) Experiments may be conducted to assess the growth performance and nitrogen fixation of *Sesbania rostrata*, when planted as an alley crop along with low land rice.

(ii) Experiments may be carried out to find out the effect of *Sesbania rostrata* as a green manure on the physico-chemical properties of soil.

(iii) Crop rotation studies by including *Sesbania rostrata* in the rotation.

(iv) The same experiment may be repeated for two or three seasons to confirm the trend of results obtained in the present experiment.

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* Originals not seen

APPENDICES

APPENDIX

Weather data during the cropping period (June 1991 to 23 December 1991)

Standard week	Period From	Period To	Rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
23	June 04	June 10	32.07	29.95	22.78	77.21
24	June 11	June 17	16.40	30.10	23.86	87.36
25	June 18	June 24	17.76	29.47	24.08	81.43
26	June 25	July 01	11.31	29.11	23.39	85.50
27	July 02	July 08	1.61	29.69	23.89	83.93
28	July 09	July 15	2.16	28.39	23.19	86.50
29	July 16	July 22	0.37	28.01	23.43	78.29
30	July 23	July 29	8.36	29.38	23.46	86.00
31	July 30	Aug. 05	19.09	29.34	23.57	81.93
32	Aug. 06	Aug. 12	0.47	29.77	23.71	77.29
33	Aug. 13	Aug. 19	8.30	28.55	23.03	82.79
34	Aug. 20	Aug. 26	0.43	29.79	23.23	77.57
35	Aug. 27	Sep. 02	2.90	29.22	23.63	82.79
36	Sep. 03	Sep. 09	0.00	30.42	23.74	74.00
37	Sep. 10	Sep. 16	7.34	31.07	24.36	76.14
38	Sep. 17	Sep. 23	0.00	30.50	23.93	79.00
39	Sep. 24	Sep. 30	0.00	31.00	24.50	78.07
40	Oct. 01	Oct. 07	0.00	30.89	24.61	79.71

(1)	(2)	(3)	(4)	(5)	(6)	(7)
41	Oct. 08	Oct. 14	1.56	30.29	23.61	79.21
42	Oct. 15	Oct. 21	10.57	30.29	23.21	80.57
43	Oct. 22	Oct. 28	8.63	28.66	23.19	80.14
44	Oct. 29	Nov. 04	9.59	29.60	23.79	83.07
45	Nov. 05	Nov. 11	1.50	30.09	23.34	83.57
46	Nov. 12	Nov. 18	28.77	29.82	23.24	87.14
47	Nov. 19	Nov. 25	3.89	30.38	22.63	77.21
48	Nov. 26	Dec. 02	0.00	30.51	23.56	78.00
49	Dec. 03	Dec. 09	0.00	30.58	20.33	70.43
50	Dec. 10	Dec. 16	0.00	30.55	21.31	76.07
51	Dec. 17	Dec. 23	1.14	30.40	23.70	79.43

Source: Meteorological Observatory, College of Agriculture, Vellayani.

APPENDIX II

Weather conditions at Vellayani (Average of 5 years, 1986-1990)

Standard week	Period From	Period To	Rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
23	June 04	June 10	8.28	30.70	23.75	75.20
24	June 11	June 17	9.32	30.08	22.12	79.48
25	June 18	June 24	5.62	29.96	24.08	81.58
26	June 25	July 01	6.26	30.02	22.52	81.93
27	July 02	July 08	5.29	30.44	23.56	76.78
28	July 09	July 15	5.68	30.24	23.48	81.73
29	July 16	July 22	7.07	30.12	23.44	81.46
30	July 23	July 29	1.92	29.84	23.48	77.98
31	July 30	Aug. 05	4.52	30.08	23.58	79.34
32	Aug. 06	Aug. 12	10.16	29.40	23.20	79.12
33	Aug. 13	Aug. 19	5.60	29.58	22.92	80.24
34	Aug. 20	Aug. 26	3.72	30.17	23.56	77.96
35	Aug. 27	Sep. 02	2.68	30.46	23.66	78.12
36	Sep. 03	Sep. 09	5.24	30.56	23.30	76.62
37	Sep. 10	Sep. 16	3.58	30.90	23.66	78.12
38	Sep. 17	Sep. 23	8.56	30.12	23.54	77.62

(1)	(2)	(3)	(4)	(5)	(6)	(7)
39	Sep. 24	Sep. 30	5.78	29.98	23.44	80.06
40	Oct. 01	Oct. 07	5.20	30.54	23.80	77.46
41	Oct. 08	Oct. 14	2.36	30.62	23.80	80.52
42	Oct. 15	Oct. 21	5.04	30.84	23.96	79.86
43	Oct. 22	Oct. 28	5.48	30.46	23.72	82.10
44	Oct. 29	Nov. 04	14.98	30.40	23.24	79.86
45	Nov. 05	Nov. 11	8.94	30.46	23.36	80.22
46	Nov. 12	Nov. 18	3.64	30.74	23.24	76.52
47	Nov. 19	Nov. 25	4.66	30.86	22.66	73.32
48	Nov. 26	Dec. 02	2.24	30.98	22.28	76.92
49	Dec. 03	Dec. 09	4.60	30.96	22.72	74.18
50	Dec. 10	Dec. 16	1.26	31.18	22.42	71.14
51	Dec. 17	Dec. 23	2.68	31.30	22.34	71.24

Source: Meteorological Observatory, College of Agriculture, Vellayani.

ECONOMISING NITROGEN IN RICE PRODUCTION WITH *Sesbania rostrata*

By

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ABSTRACT OF THESIS

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ABSTRACT

With a view to assessing the influence of in situ growing and incorporation of Sesbania rostrata on the growth and productivity of rice and to study the economy of nitrogen use by rice, a field experiment was conducted at College of Agriculture, Vellayani during the period from July 1991 to December 1991. The experiment was laid out in Randomised Block Design with three replications. Three levels of Rhizobium inoculation for Sesbania rostrata (i_1 - seed inoculation, i_2 - stem inoculation, i_3 - seed + stem inoculation), five levels of nitrogen to succeeding crop of rice raised after incorporation of Sesbania rostrata (n_0 - no nitrogen, n_1 - 25 percent of the recommended dose, n_2 - 50 percent of the recommended dose, n_3 - 75 percent recommended dose, n_4 - 100 percent recommended dose) and one control plot of rice (treated as per KAU package of practices recommendations) were fixed as treatments. The rice variety used was Jyothi. The soil of the experimental site was sandy clay loam, medium in available nitrogen and phosphorus and low in available potassium. An abstract of the results is given below.

Among the three different levels of inoculation, seed + stem inoculation was found to influence, the green matter and dry matter yields of Sesbania rostrata positively,

though not significantly. The number and dry weight of root nodules and shoot nodules, nitrogen uptake, phosphorus uptake, potassium uptake, calcium uptake and magnesium uptake were not found to be influenced significantly by the different inoculation levels. From these results, it can be concluded that, the easiest method of inoculation viz. seed inoculation is sufficient for satisfactory growth and nitrogen fixation by *Sesbania rostrata*. The present study also revealed that the growth and nodulation of *Sesbania rostrata* is not satisfactory under conditions of continuous submergence, as that prevailed during the cropping period of the present experiment. *Rhizobium* being an aerobic bacteria might have got inhibited under the anaerobic conditions created by continuous water logging. Furthermore, the acidic condition of the soil of the experimental site might have also inhibited the activity of *Rhizobium*. Thus it shows that liming is absolutely necessary for the satisfactory growth of *Sesbania rostrata* in acid soils.

Among the different treatments tried, though the control (KAU package of practices recommendations) gave the maximum yield, it was on par with the treatment comprising 50 percent of the recommended dose of nitrogen along with *Sesbania rostrata* incorporation. This shows that there is considerable scope for economising nitrogen by the substitution of chemical nitrogen applied to rice by *Sesbania rostrata*.