EFFECT OF INCORPORATION OF CROP RESIDUES ON PRODUCTIVITY OF SUCCEEDING RICE CROP

By

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THESIS

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requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled "**Effect of incorporation of crop residues on productivity of succeeding rice crop**" 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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CERTIFICATE

Certified that the thesis entitled "**Effect of incorporation of crop residues on productivity of succeeding rice crop**" is a record of the research work done independently by **Miss.Beena Jacob** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

INTRODUCTION

Rice, which is the staple food of majority of people in Asia is the sustenance of more than half of the world population. In India, rice is grown in 42 m ha and it contributes 72 mt (40%) to the total food grain production of 180 mt (FAI, 1993). Food production has to be increased to about 225 mt to feed the estimated population of one billion by the turn of next century. As the scope for expansion of area under rice is meagre, the only alternative left is to intensify rice production and productivity with efficient use of available resources.

Nitrogen is the limiting nutrient for rice production world wide as it is the key to realise the yield potential of high yielding varieties. In Asia, where more than 90 per cent of the world's rice is produced, about 60 per cent of the nitrogen fertilizer consumed is used for rice. In India this comes to about 39 per cent (FAI, 1993).

About two third of the rice soils of India are reported to be short of adequate available N (Mahapatra *et al.*, 1985) and response of rice to N is almost universal. Even then nitrogen use efficiency is not more than 30 to 40 per cent and the rest is lost through various ways.

The use of mineral fertilizers is the quickest and surest way of boosting crop production, but their cost is escalating due to the dependence on non-renewable energy sources for their production and the gradual withdrawal of fertilizer subsidies. This, along with growing concern for environmental quality and ecological sustainability resulted in a great renewal of interest on the part of researchers and farmers to fully exploit the potential alternate sources of plant nutrients.

Green manuring is a well known practice for sustaining crop productivity. With intensification of agriculture and the large scale adoption of mineral fertilizers farmer's enthusiasm for this has declined. Moreover, they were reluctant to raise a crop just for green manuring taking into account the cost and the time involved in raising it. Inclusion of dual purpose legumes with food and manurial value is worth considering at this juncture.

Integrated nutrient supply through judicious combination of organic and biological sources along with inorganic fertilizers has a number of agronomic and environmental benefits over inorganic sources alone and it is a concept that is ecologically sound leading to sustainable agriculture (Swaminathan, 1987). In Kerala, there is a lot of scope for utilizing summer rice fallows for raising short duration pulses and oil seeds and their residues after taking the pods can be incorporated before the following rice crop.

A thorough understanding of the benefits of such an integrated system is essential. In this context, an investigation was undertaken with the following objectives:

1. To study the effect of incorporation of residues of pulses and oil seeds on growth and productivity of rice in comparison to a green manure crop and pre-rice fallow,
2. to study the mineralization pattern of organic sources, and
3. to compare the economics of various systems.

Review of Literature

The role of legumes in improving soil fertility has been well recognized and practised in many countries. Legumes with their adaptability to fit in the various cropping systems and their ability to fix atmospheric nitrogen, offer opportunities to increase and sustain productivity and income in rice-based cropping systems. Green manure legumes, forage legumes and grain legume residues can supply N to rice and improve soil fertility which inturn increase the productivity of rice. This review focuses on leguminous green manures and grain legumes in improving the fertility of wetland rice soils.

2.1 Green manuring in rice based cropping systems

In India, the importance of green manuring in agriculture has been recognized as early as 500 BC (Kadke, 1965) and since then it has been practised by rice farmers. The benefits of green manuring include increase in available plant nutrients and organic matter content, improvement in physical and biological properties of soil and the overall impact is increased crop production (Singh, 1962). Green manuring can be in situ or green leaf manuring.

Majority of rice growing areas of India were planted with green manured rice till the middle of this century. Many factors have limited wider acceptance of green manuring in rice culture in the traditional way.

Due to crop intensification and increased availability of chemical fertilizers, use of green manures declined substantially (Singh *et al.*, 1991a). Farmers were also reluctant to use on season entirely for raising a green manure crop which has neither cash nor food value (John *et al.*, 1992). But, with the advent of high yielding cultivars, increases in the cost of fertilizers and the concern for pollution and conservation of energy, use of green manures has become very significant (Kulkarni and Pandey, 1988).

2.1.1 Green manure crops

Evaluation of green manures was started in the middle of this century (Raju, 1952). Vachhani and Murty (1964) conducted extensive survey on about 100 leguminous green manure crops in India and recommended several suitable ones for rice culture. Among them, sunnhemp (*Crotalaria juncea*) and *Sesbania aculeata* Syn. *cannabina* were found to be more acceptable to the farmers of India. These were also grown in other rice growing tropical countries (Pandey and Morris, 1983; Meelu and Morris, 1986; Abrol and Palaniappan, 1988; Garrity and Flinn, 1988). Sesbania species were well adapted for use as a green manure because of their ability to withstand waterlogging and flooding, to grow on fine textured soils and to tolerate soil salinity (Evans and Rotar, 1987).

Uppal (1955) reported that among *Sesbania aculeata, Crotalaria juncea* and *Cyamopsis tetragonoloba*, sesbania was the best green manure for rice in alkali soils. Cowpea (*Vigna unguiculata*), valued both as food and green manure crop possessed higher water-use efficiency in terms of dry matter and N yield and was more suitable than sesbania under drought conditions (Singh *et al.*, 1981). In South India, *Tephrosia purpurea* under drought conditions and pillipesara (*Phaseolus trilobus*) in erosion-prone areas were found promising (Palaniappan *et al.*, 1990).

S. speciosa can grow as a perennial plant and is more drought tolerant than *S. aculeata* (Patanaik *et al.*, 1957). It is the most promising species in Sri Lanka in terms of leaf biomass production (Palm *et al.*, 1988). *S. cannabina, S.*

rostrata, V. unguiculata, V. radiata and *C. juncea* were the commonly used green manures in Philippines (Morris *et al.*, 1986a; Meelu and Morris, 1988; Morris *et al.*, 1989).

Among the stem nodulating legumes, *S. rostrata* and *Aeschynomene afraspera* had found to be promising. These were found growing wild under water-logged soils of Senegal, West Africa. These were characterized by profuse stem nodulation, fast growth and more active nitrogen fixation than most root nodulating legumes even at levels of nitrogen high enough to inhibit root nodulation (Rinaudo *et al.*, 1988).

S. rostrata thrived well under flooded, waterlogged and dry conditions (Dreyfus *et al.*, 1985; Ladha *et al.*, 1988; Manguiat *et al.*, 1988). It produced five to ten times more nodules than most legumes under waterlogged conditions (Dreyfus and Dommergues, 1981). It needed a long photoperiod and performed well when raised during summer (Ladha *et al.*, 1989; Becker *et al.*, 1990). *S. rostrata* grew well as a green manure crop before rice or in between two rice crops (Singh, 1984).

Green leaf manures are preferred when raising green manure crop in situ is not possible, especially in areas with limitations such as lack of irrigation and due loss of main crop growing season. Woody species of genera *Gliricidia, Leucaena* and *Sesbania*, which are widely used in food crop systems in the tropics, are the important green leaf manures. *S. sesban* was used as in situ green manure as well as green leaf manure (Palm *et al.*, 1988 and Rao *et al.*, 1989).

2.1.2 Biomass production and N accumulation of green manures

Leguminous green manure species differ widely in biomass production and N accumulation. The most productive green manure crops yielded about 4-5 t/ha of dry matter in 50-60 days. The biomass production and N accumulation of sesbania are mainly controlled by age factor (Singh *et al.*, 1991a).

S. speciosa accumulated the highest biomass when seeded in August and harvested at flowering. Nitrogen concentration increased up to 70 days after establishment and decreased towards flowering (Weerakoon *et al.*, 1992). *S. rostrata* under flooded conditions produced 2.5 and 7.2 t/ha of dry matter with N accumulation of 89 and 176 kg N/ha in 49 and 62 days respectively (Furoc *et al.*, 1985). According to Morris *et al.* (1986a) a fast growing tropical legume can accumulate more than 80 kg N/ha in 45 days. Kalidurai and Kannaiyan (1989) on comparing the N fixation and biomass production of *S. rostrata, S. aculeata* and *S. speciosa*, obtained maximum biomass and nitrogen yield with *S. rostrata*.

Studies on biomass production and N accumulation of green manures have shown that 60 day old cowpea, sunnhemp, sesbania and clusterbean produced 6.9, 5.4, 5.0 and 3.8 t/ha of dry matter respectively and the corresponding N additions through these green manures were 113, 110, 108 and 87 kg/ha (Beri *et al.*, 1989a). Morris *et al.* (1986a) observed that cowpea and green gram showed a linear relationship between N accumulation and dry weight. Cowpea is very sensitive to waterlogged conditions and produced significantly less biomass than sesbania and sunnhemp.

2.1.3 Incorporation of green manures

In traditional agriculture, green manures were grown in fallow fields and incorporated two to four weeks before sowing of the following crop. But in the present day intensive agriculture, this practice is not feasible, when there is a fallow period of only 40-60 days before transplanting of rice. Iso (1954) reported that the effectiveness of green manure was hindered by too early and too late ploughing in before the transplanting of rice. The best time to plough in would be 15 days before transplanting (Wen, 1984). According to Joachim (1940) green manure crops should be incorporated at the time of puddling, so that larger quantities of ammonium-N are made available to the plant at various stages of decomposition process coinciding with the period of active crop growth.

Bhardwaj and Dev (1985) studied the efficiency of *S. cannabina* as a green manure for rice after 45, 55 and 65 days of growth. Even though the dry matter production and N accumulation vary at these stages, the rice grain yield immediately after turning under the green manure, irrespective of its stage of growth, was equivalent to 100-120 kg N/ha.

On the basis of yield responses, it was found that a two week delay between incorporation of green manure and transplanting of rice was not only unnecessary but also disadvantageous (Ghai *et al.*, 1988; Beri *et al.*, 1989b; Sur *et al.*, 1993).

A large number of experiments conducted by Beri and Meelu (1979), Meelu and Rekhi (1981) and Bhardwaj and Dev (1985) revealed that burying green manure, a day before transplanting gave significantly more yield than after a time interval of one to two weeks. Williams and Finfrock (1962) and Vachhani and Murty (1964) had demonstrated that green manure could be incorporated even at the time of transplanting rice seedlings.

The reason for low efficiency of green manure when incorporated for a longer period before transplanting rice or flooding could be the loss of green manure N released during aerobic decomposition through ammonia volatilization, nitrification and denitrification and leaching after flooding of rice fields (William and Finfrock, 1962; Chapman and Myers, 1987; Ishikawa, 1988; Sur *et al.*, 1993).

Swarup (1987) showed in field experiments that allowing decomposition of sesbania green manure for one week under flooded conditions in sodic soil significantly improved rice yields over simultaneous incorporation and transplanting of rice, possibly through improvement of physico-chemical properties of sodic soils. Singh *et al.* (1991b) got higher yield when a 60 day old sesbania crop was incorporated 10 days before transplanting rice.

2.1.4 Green manuring and productivity of rice

A great deal of literature is available on direct effect of green manuring on the grain yield of wet land rice. The major effect is through N contribution but the favourable effects of organic matter addition and availability of other nutrients cannot be overlooked. Appreciable yield increase in rice with green manuring has been reported from almost all the rice growing countries.

S. rostrata incorporation significantly increased the grain yield of succeeding rice (Ventura *et al.*, 1987; Kalidurai and Kannaiyan, 1989; Ladha *et al.*, 1989; Rabindra *et al.*, 1989; Manguiat *et al.*, 1992).

In India, earlier reports of Rao and Ghosh (1952), Raju (1952) and Vachhani and Murty (1964) revealed the beneficial effects of green manuring on rice. Several recent experimental evidence showed the positive influence of green manuring in increasing the rice yield to varying magnitudes (Meelu *et al.*, 1985; Meelu and Morris, 1986; Morris *et al.*, 1986a; Singh *et al.*, 1988a; Beri *et al.*, 1989a; John *et al.*, 1989a; Singh and Singh, 1989; Singh *et al.*, 1990; Watanabe and Ventura, 1992; Balasubramaniyan *et al.*, 1993). Manguiat *et al.* (1992) obtained an yield increase of 1.8 t/ha by green manuring with *S. rostrata* alone and this increase was equivalent to that of applying 60 kg N/ha.

Coarse textured soils low in organic matter and nitrogen showed greater response to green manuring than the highly fertile soils. In China, Gu and Wen (1981) observed that in low fertility soils yields increased with green manuring by 78 per cent compared to 21.6 per cent in high fertility soils. Maskina *et al.* (1989) evaluated sesbania, sunnhemp, cowpea and mungbean as summer green manures for N substitution for the following rice. All the green manures were equally efficient in increasing the grain yield of rice, which was equivalent to that produced by applying 120 kg N/ha as urea in the fallow plots. This amount of N substitution had also been reported by Bhardwaj and Dev, 1985; Goswami *et al.*, 1988; Beri *et al.*, 1989a).

The results of all these studies indicated the potential of green manuring in increasing rice production and green manuring could be a viable component of integrated nutrient management for rice. Smith *et al.* (1987) presented three possibilities for understanding the yield responses of wet land rice to green manuring. There was yield benefit from the green manure at low N rates, suggesting that the only significant effect of the green manure was to increase N supply of the rice crop. Secondly, green manure provided benefits beyond N supply. This could be found in the works of Rekhi and Meelu (1983); Beri *et al.* (1989a); John (1987); Joshi *et al.* (1994) and many others. Green manures enhanced the P use efficiency of rice (George and Prasad, 1989a; Hundal and Dhillon, 1993 and Joseph, 1994) and increased the translocation of Zn and S to grain (Mythili *et al.*, 1993). The beneficial effects also included more favourable physical, chemical and biological conditions of the soil amended with green manures.

A third case exists when sufficient N fertilizers are applied and rice yields following green manuring are lower than those with no green manuring. The yield reduction could be due to excessive N causing lodging in rice, root toxicity due to accumulation of toxic chemicals released from green manure (Ishikawa, 1988) or Fe and Mn toxicity due to increased reduction in the presence of green manures (Katyal, 1977).

2.1.5 Green manuring and soil fertility

Tropical soils are normally low in organic matter which contributes much to the productivity of soils through mineralization of nutrients and improvement in soil physical and biological conditions. Increased organic matter status of soil due to incorporation of green manures in a crop sequence had been reported by many workers (Swarup, 1987; Sharma and Mittra, 1988; Meelu *et al.*, 1992a; Watanabe and Ventura, 1992; Kolar *et al.*, 1993).

Inbushi and Watanabe (1988) considered that the soil microbial biomass was a small but most active pool of bio-elements including N which supplies 79 to 83 per cent of the N required by rice. Legumes grown solely for incorporation as green manure could increase the soil N pool provided the legumes effectively fix N_2 and losses of legume N were minimised (Buresh and De Datta, 1991). Ammonia volatilization, which was widely recognized as an important mechanism of loss of applied N to low land rice (De Detta *et al.*, 1989) was reduced by the application of green manures (Biswas and De Datta, 1988; Khind *et al.*, 1989).

Agboola (1974) highlighted the capacity of green manure to recycle leached plant nutrients. This was accomplished by the absorption of nutrients from the lower depth by roots of legumes and translocation of them to the leaves. Legume plants have the ability to utilize insoluble phosphates through their well developed root system and upon mineralization of green manures, released P in the available form (Gu and Wen, 1981; Singh, 1984; George and Prasad, 1989a). In waterlogged soils, green manure increased availability of P through the mechanisms of reduction, chelation and favourable changes in soil pH (Hundal *et al.*., 1987; Hundal *et al.*, 1988). Tiwari *et al.* (1980), Swarup (1987) and Sharma and Mittra (1988) obtained an increase in available NPK content for green manured plots. When easily decomposable organic matter was added into the soil, rate of decomposition of native organic matter was increased releasing more N (Broadbent and Norman, 1946; Chapman and Leibig, 1947; Furoc and Morris, 1982). Leguminous green manure plants had a strong ability to absorb the rather inaccessible K in the soil (Gu and Wen, 1981). Many workers had reported increased availability of K in soils due to green manuring (Katyal, 1977; Tiwari *et al.*, 1980; Nagarajah *et al.*, 1986; Swarup, 1987). A significant increase in water soluble Ca and Mg with the application of green manures to the flooded soil had been observed by Katyal (1977) and Khind *et al.* (1987).

Volatile fatty acids, non volatile aliphatic acids, phenolic acids and alcohols accumulated in large quantities with green manure incorporation under water logged conditions (Tsatsuki, 1984; Diekmann *et al.* 1992). Organic acids could retard root elongation, restrict nutrient uptake and reduce shoot weight (Watanabe, 1984; Diekmann *et al.* 1992).

Incorporation of green manures increased porosity, hydraulic conductivity, water holding capacity and aggregate stability and decreased soil bulk density (Biswas *et al.*., 1970; Boparai *et al.*, 1992; Ventura and Watanabe, 1993; Joshi *et al.*, 1994).

2.2.1 Grain legumes in rice based cropping systems

Grain legumes are grown in rice based cropping systems for protein, fodder and green manure production. In the irrigated environments of tropics and sub tropics legumes can be grown in rotation with one or more rice crops per year (Buresh and De Datta, 1991). The ability of legumes to fix N enables them to grow on soils with low available N and to produce protein rich seed and N rich plant residue. Byth *et al.* (1987) found that about 18 grain legume species were important at various rice farming systems of Asia. Pulses, the major grain legumes grown in rice fields include soybean, green gram, black gram, groundnut and cowpea. Soybean is an important crop in rice fields in China, Indonesia, Vietnam, Thailand and India (Carangal *et al.*, 1987). Cowpea is a common crop in rice system in southern India (Singh, 1988).

The rice fallows are ideal for relay or sequential cropping of lentil, mungbean, black gram, cowpea, soybean and pigeon pea. A dual purpose grain legume with residue incorporation could increase the soil nutrient supply and rainfed rice system productivity (Kulkarni and Pandey, 1988). The amount of N contributed by the legume to the next crop varies with the type of legume, its N_2 fixation capacity and the composition of its residue.

Prasad (1985) studied the performance of soybean, green gram and black gram as pre-rice grain pulses and concluded that soybean and black gram were the beneficial dual purpose grain legumes. Alam (1989) compared cowpea and green gram as the preceding crops to rice during dry to wet season transition period in the Philippines. Cowpea and green gram yielded 0.6 and 0.7 t/ha grain and 3.5 and 2.5 t/ha of haulms respectively. Their corresponding N accumulation was 30 and 79 kg/ha.

2.2.2 Grain legumes on productivity of rice

Many studies have shown that grain legume residues, remaining after harvesting grain, increase the yield of subsequent low land rice crop substantially.

John *et al.* (1989a) concluded from a study that cowpea residue increased the yield of succeeding rice by 0.7 t/ha, which was equivalent to 47 kg N/ha. Higher agronomic efficiency and apparent recovery was observed with cowpea residue than green manure and urea-N. Thus cowpea which produced grain and crop residues were potential dual purpose grain legumes (Palaniappan and Siddeswaran, 1990; John *et al.*, 1992; Meelu *et al.*, 1992b). Siddeswaran (1992) on comparing grain legumes cowpea, black gram and soybean, haulm yield of cowpea was the highest and its incorporation resulted in an yield increase of 10.4 per cent of the following rice.

Significant increase in grain and straw were obtained when preceding crops were legumes like mungbean, cowpea and black gram (De *et al.*, 1983). Mandal and Ghosh (1984) recorded significantly higher grain yield of rice crop when it was grown after groundnut than grown after sesame. Rice yield was increased by legume residues (soybean, cowpea, groundnut and mungbean) applied as surface mulch and partially incorporated during weeding and yield was positively correlated with N added in residue (Sisworo *et al.*, 1992). Silsbury (1990) observed that incorporating the dry residues of legumes rather than removing them added about 26 kg N/ha, and they could increase the yield of succeeding rice by 10 per cent.

Rekhi and Meelu (1983) from a three year study reported that in addition to about 0.9 t grain/ha, green gram residues supplied about 100 kg N/ha and when incorporated into the soil along with 60 kg N/ha through urea gave as much rice yield as obtained with the application of 120 kg N/ha through urea alone. In China, incorporating a winter crop of beans, after harvesting pods, gave 19 per cent increase in yield of subsequent rice crop (Singh *et al.*, 1991a). Increased rice yield after moong crop was also reported by Anil *et al.* (1988). Of the different rabi pulse crops, chickpea, field pea and lentil, highest rice yield was obtained after preceding crop of field pea. The legume effect was found to be 40 kg N equivalent/ha over rabi cereal (Rana and Sharma, 1993). Lentil residues benefitted the succeeding rice and gave longer and heavier panicles, more grains per panicle, higher 1000 grain weight and higher straw yield of rice as compared to fallow (John *et al.*, 1989b).

2.2.3 Grain legumes and soil fertility

Legumes are considered as soil fertility restorers due to their ability to obtain N from the atmosphere in symbiosis with rhizobia. According to Faroda and Singh (1983), inclusion of grain and fodder legumes like pigeon pea, chickpea, pea, lentil, green gram, black gram, cowpea and groundnut in cropping systems reduced the need of fertilizer N in associated and succeeding cereals. The N benefit is due to lower uptake of soil N by legumes relative to cereals and a carry over of N from the legume residue, both leading to a greater uptake of soil N by the subsequent crop compared to crops grown after non-legumes (Danso and Papastylianou, 1992).

Considerable nitrate may remain in soil after a N_2 fixing legume crop. Buresh *et al.* (1989) observed 18 and 25 kg nitrate N/ha in the top 60 cm soil layer at harvest of mungbean grown after low land rice in the Philippines. Total nitrogen content of the soil was relatively higher when the preceding crop was a legume (Mandal *et al.*, 1992). According to Chakravorti *et al.* (1980) inclusion of cowpea in the cropping system benefit the next crop by improving the fertility of the soil.

On soils with less organic matter, Reddy *et al.* (1992) observed significant increase in exchangeable Mg and organic matter when cropped continuously with cowpea compared with millets. In another study Reddy *et al.*, (1994) reported that, the plots that had previously grown with cowpea had a significantly lower carbon to nitrogen ratio (7.5) than those with millet (13.6) or a traditional millet/cowpea intercrop (11.9).

Cropping sequences which included one or two legumes took less K from the soil (George and Prasad, 1989b). Rekhi and Meelu (1983) advocated the ability of greengram straw incorporation in mobilising the availability of N and micronutrients like Zn, Fe, Mn and Cu. Summer mung haulms incorporation increased infiltration rate of soil by 1:4 times, available water by 2 cm in the 180 cm depth soil profile and decreased resistance to soil penetration, apart from increasing organic C and mineral N (Sidhu and Sur, 1993).

2.3 Mineralization of legume N

Unlike inorganic fertilizers, green manures underwent microbial decomposition and mineralization before N becomes available to the crop (Biswas and De Datta, 1988; Nagarajah, 1988). During decomposition, the exchangeable ammoniacal N released had a linear relationship with the N uptake and yield of rice crop (Schon *et al.*, 1985; Ravindra and Pandey, 1987).

Models of organic matter decomposition in flooded soils have been characterized by two distinct components; one decomposing rapidly upon incorporation which accounted for 50 to 80 per cent of total N and the other decomposing slowly over several years (Bouldin, 1988). Singh *et al.* (1988b) reported that the initially fast and subsequently slow release of mineral N during decomposition of 7 week old *S. aculeata* could be described by two simultaneous first order reactions. Nitrogen content, C/N ratio and lignin content of legumes influenced N mineralization rate in flooded soils (Frankenberger and Abdelmajid, 1985). According to Janzen and Radder (1989) short term N mineralization was favoured by fallowing soil after green manure application whereas N retention in organic matter, was favoured by immediate cropping. High concentration of lignin or polyphenol could reduce N mineralization (Fox *et al.*, 1990; Palm and Sanchez, 1991). Under flooded soil conditions, the N released from legume residue accumulates as ammonical N, but in aerobic soil, the ammonical N formed by mineralization of legume N readily oxidised to nitrate (Beri *et al.*., 1989a).

Following incorporation of *S. rostrata* in tropical low land rice fields, the accumulation of soil ammonium peaked at 7 to 20 days after rice transplanting and then gradually declined (Becker *et al.*, 1990). For *S. aculeata* the peak ammonium occurred during the first 10-14 days of green manure incorporation (Beri *et al.*, 1989; Sur *et al.*, 1993). When incorporated 70 per cent of N content of *S. rostrata* became available within 20 days, sufficient to meet the N needs of rice plant at early stages (Ventura *et al.*., 1987), but Buresh *et al.* (1993) observed that ammonium-N after *S. rostrata* reached a maximum by 36 days after incorporation which correlated with N accumulation by rice at 45 days after transplanting. Eighty per cent of N gained through N fixation was transferred to the successive rice crop (Ladha *et al.*, 1989). Furoc and Morris (1989) compared three sesbania species and reported that the yield of low land rice was a direct function of soil extractable ammonium at 10 days after green manure incorporation. After incorporating 60 day-old cowpea, sunnhemp, sesbania and clusterbean, all green manures decomposed rapidly and about 40 per cent of the added carbon was lost as CO_2 in 7-15 days. The mineralization rate constant of green manures was 0.022-0.013/day. A peak in the formation of KCl extractable NH_4^+-N from the soils amended with different green manures was observed between 7-15 days period and there was not much difference in the mineralization of N among different green manures (Beri *et al.*, 1989a).

Residues of grain legumes, which frequently have a lower N content than that of green manures, also rapidly release ammonium in tropical flooded soils. John *et al.* (1989a) reported that initially, N mineralization from cowpea green manure (C:N ratio 15:1) was faster than from cowpea residue (C:N ratio 21:1) but at 30 days after transplanting, mineral N was higher in residue incorporated plots. Nagarajah (1988) determined the net N release of five legume residues (cowpea, green gram, groundnut, pigeonpea and soybean) after 50 days incubation in flooded soils. Net recovery of plant N as ammonium at 50 days ranged from 16 to 26 per cent and it correlated directly with plant N and inversely with C:N ratio. The amount of mineral N and biomass N was significantly larger in the cowpea straw incorporated soil as compared to wheat incorporation (Patra *et al.*, 1992).

Das *et al.* (1993) observed relatively higher amount of N release in the case of legume residues like mungbean, subabul and pigeonpea although the rate of N release was more with low N concentration residues. An intervening period of 30-45 days would be required for the residues (Moong straw, soybean hay) to release plant utilizable NO_3-N in sufficient quantities (Nair and Ghosh, 1984).

2.4 Integrated use of legume N and fertilizer N

Considering the very low efficiency of applied N fertilizers and the possibility of only a partial substitution to the rice crop in a system, it has become imperative to integrate the use of organic and inorganic sources of N for higher N use efficiency, more yield and sustained fertility (Swaminathan, 1987). Integrated use of green manures, including grain legumes and incorporating their residues after harvesting pods and inorganic N fertilizer, have received attention in recent years for efficient and economic management of N in rice based cropping systems (Meelu and Morris, 1987; De Datta, 1988; Furoc *et al.*, 1988).

Experimental evidences showed that green manure can substitute 20 to 80 kg N/ha (Bhardwaj *et al.*, 1981; De *et al.*, 1983). In most instances it was around 50-60 kg N/ha. But a substitution of 120 kg N/ha by incorporation of cowpea, sesbania, sunnhemp and clusterbean was reported by Khind *et al.* (1983) and Beri *et al.* (1989a).

Green manure plus 50 per cent of the recommended fertilizer N resulted in higher rice yields than when recommended N rates alone were applied (Rekhi and Meelu, 1983; Mahapatra and Sharma, 1989). In soils testing low in N and organic carbon, combined use of green manure with 60 kg N/ha through mineral fertilizer gave rice yields comparable with 100 kg fertilizer N/ha (Mahapatra *et al.*, 1981).

Incorporating the haulms of grain legumes, after harvesting their pods, could reduce the fertilizer N requirement to the subsequent rice crop. Nitrogen from green gram haulms incorporated one day before transplanting rice substituted for about an equal or slightly higher amount of urea N (Rekhi and Meelu, 1983). Cowpea haulms reportedly reduced the fertilizer N requirement of the following rice crop by 37.44 kg N/ha (Kulkarni and Pandey, 1988; John *et al.*, 1989a).

Khind *et al.* (1989) observed no ammonia volatilization in soil amended with green manures. Application of green manure at lower level of N (up to 40 kg N/ha) reduced the volatilization loss, whereas the trend was reverse at higher levels of N (120 kg/ha) (Chakravorti *et el.*, 1989). John *et al.* (1989c) and John *et al.* (1989d) observed that either cowpea green manure or residue, incorporated 15 days before transplanting had no effect on losses of applied urea-N.

Experiments by Morris *et al.* (1986b) suggested that apparent recovery and utilization of N from short duration green manures were similar to those from inorganic N fertilizers. Since a major fraction of green manure N was released and became available to the rice plant within 2 to 3 weeks of its incorporation, the N requirement of the rice in the early growth period could be met by green manure

(Singh *et al.*, 1991b). Thus N applied in a single dose at panicle initiation stage increased rice yield more than the split applied N (Meelu and Morris, 1988). Results of field experiments conducted on a coarse-textured soils showed that sesbania N was sufficient for rice at early growth stages, and application of fertilizer N at transplanting could be delayed without any adverse effects on rice yield (Khind *et al.*, 1987; Singh *et al.*, 1987).

2.5 Economics of grain legumes and leguminous green manures in rice based cropping systems

Substantial information is available on the positive contribution of green manures and grain legumes towards increased yield of crops and improved soil physical, chemical and biological conditions resulting in sustained productivity. But the economic and practical feasibility of this technology should be thoroughly investigated for its adoption at farm level.

Reddy (1988) noted that net returns from rice-rice-green gram system were increased considerably by green manuring to either of the rice crops in the system. Green gram haulms as organic source gave net returns comparable to that with green manuring. Green manuring with *S. rostrata* recorded the highest net return and benefit-cost ratio followed by incorporation of cowpea/black gram haulms in the rice-rice-pulse/green manure cropping system (Siddeswaran, 1992).

The review so far indicated the possibility of improving the productivity of rice by various leguminous N sources.

Materials and Methods

3. MATERIALS AND METHODS

Field experiments were conducted during the summer and kharif seasons of 1993 to evaluate the effect of incorporation of grain legume residues on the productivity of succeeding rice crop in comparison to a green manure crop and fallow. The details of the materials used and the methods followed are presented.

3.1 Details of the field experiment

3.1.1 Site, climate and soil

The experiment was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University. The research station is located at 12° 32' N latitude and 74° E longitude. The experimental field lies at an altitude of 22 m above MSL. This area enjoys a typical humid tropical climate. The meteorological data for the period of investigation are given in Fig.1 and Appendix I.

The experimental area is a double cropped irrigated paddy and has been under vegetables during the previous season.

The soil of the experimental field was sandy loam in texture. The physical and chemical properties of the soil are presented in Table 1.

3.1.2 Variety

Cowpea variety Kanakamony, Groundnut variety VRI-3 and *Sesbania rostrata* were used as preceding crops.

Rice variety Annapurna with a duration of 90-100 days was used. This

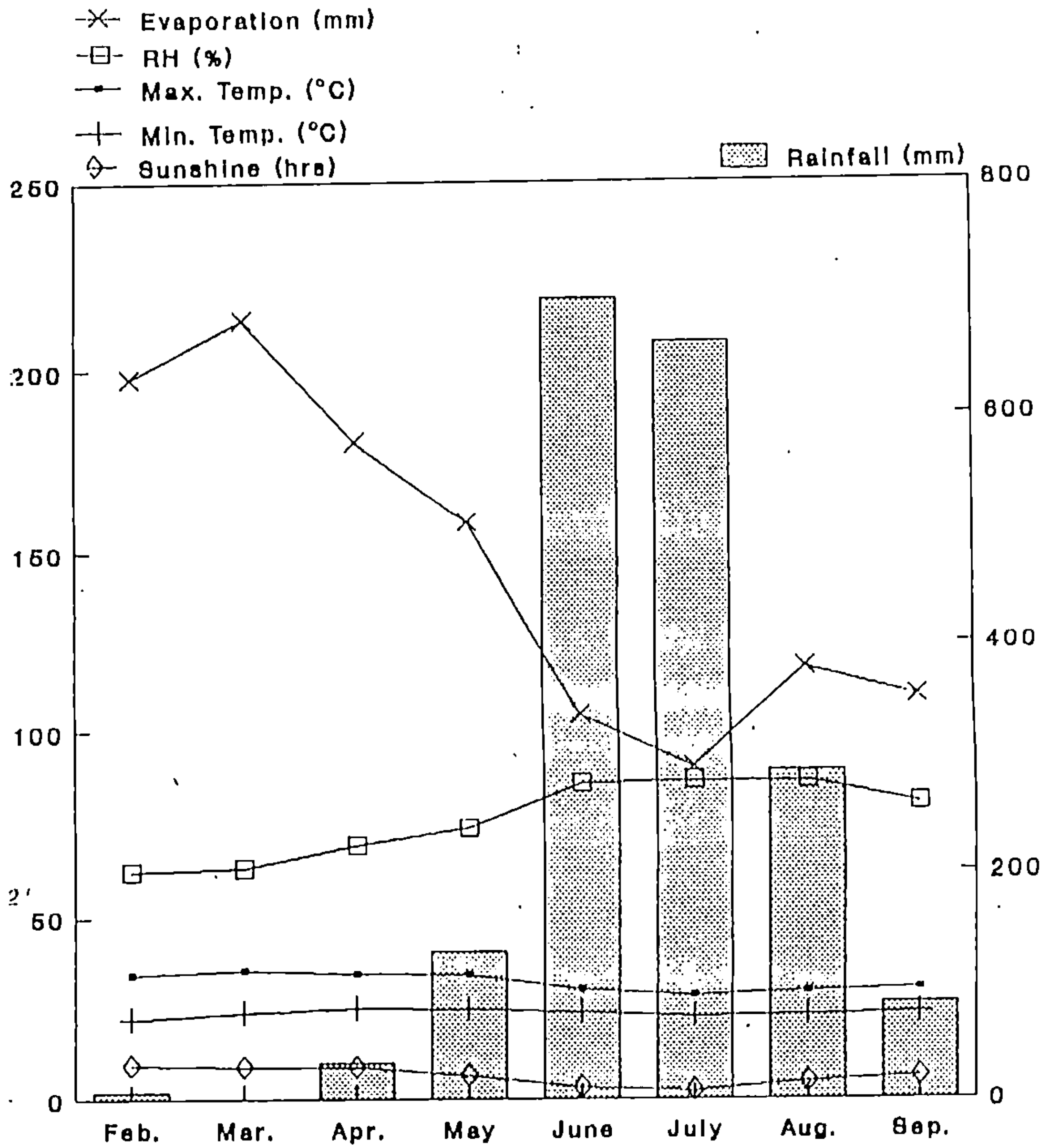

Fig.1.Meteorological data (monthly average) for the crop period (Feb. 93 to Sep. 93)

Table 1. Physico-chemical characteristics of the soil in the experimental field

Particulars	Value	Method	Reference
A. Mechanical composition			
Coarse sand	40.6%	Robinson's International Pipette method	Piper (1942)
Fine sand	22.1%		
Silt	18.3%		
Clay	17.5%		
Texture	Sandy loam		
B. Chemical composition			
pH	5.5	pH meter	Jackson (1973)
Organic C	0.7%	Walkely-Black	Jackson (1973)
Available P	75 kg/ha	Ascorbic acid-blue	Watanabe and Olsen (1965)
Available K	196 kg/ha	Direct reading	Jackson (1973)

variety evolved at the Rice Research Station, Pattambi, possessed red kernal and short bold grains.

3.1.3 Design and treatments

The experiment was laid out in a split plot design with four replications. Pre-rice treatments were allocated in four main plots and four levels of N in sub plots. The lay out plan is presented in Fig.2. The treatment details are given below.

Pre-rice treatments (Main plot)

1. Cowpea
2. Groundnut
3. *Sesbania rostrata*
4. Fallow

N levels (Sub plot)

1. 0 kg N/ha
2. 35 kg N/ha
3. 70 kg N/ha
4. 105 kg N/ha

3.1.4 Plot size

Main plot	:	16 x 4 m
Sub plot	:	4 x 4 m
Area for destructive	:	An area in one metre width all around each plot was left for destructive sampling of rice plants and soil

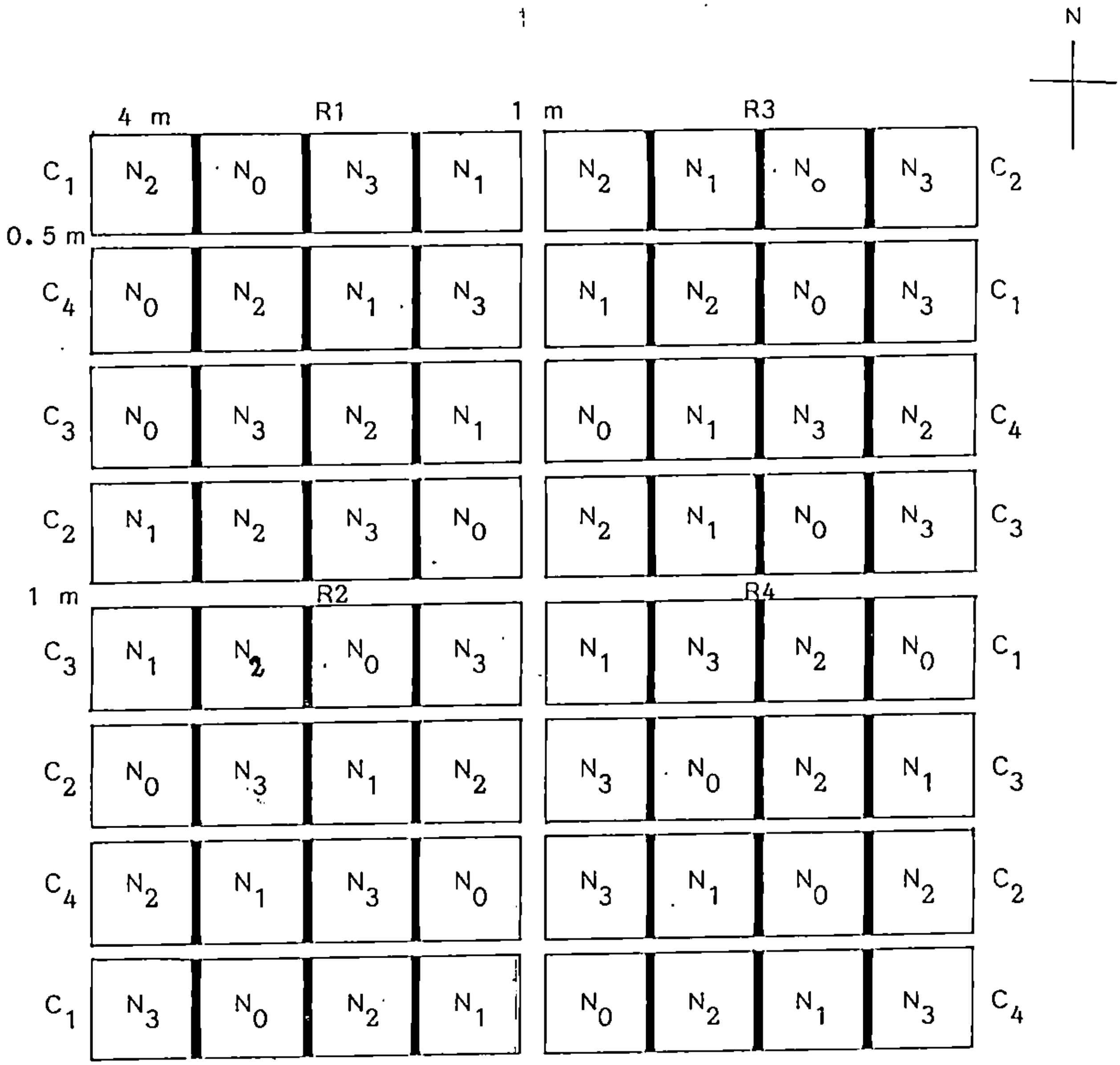

Fig.2. PLAN OF LAY OUT

Main plot treatments
Preceding crops

C_1 - Cowpea
C_2 - Groundnut
C_3 - Sesbania
C_4 - Fallow

Sub plot treatments
N levels

N_0 - 0 kg N/ha
N_1 - 35 kg N/ha
N_2 - 70 kg N/ha
N_3 - 105 kg N/ha

3.1.5 Spacing and seed rate

Season	Crop	Spacing (cm)	Seed rate (kg/ha)
Summer	Cowpea	25 x 15	50
	Groundnut	15 x 15	100
	S. rostrata	10 x 10	20
Kharif	Rice	15 x 10	80

3.1.6 Establishment of main plot treatments

The field was disc harrowed, then ploughed twice by a tractor and levelled. Cowpea and groundnut seeds were planted in the respective plots on February 20th, 1993. Furrows of five to six cm depth were made and seeds were dibbled. Gap filling was done a week after planting to maintain uniform plant population. After two months the plots for sesbania were ploughed, levelled and seeds were dibbled. Gap filling was done after one week of planting. Fertilizer application was done in cowpea and groundnut crops as per package of practices (KAU, 1993). Plots were irrigated after planting and later weekly irrigations were given. Pests and diseases were controlled as and when noticed.

Groundnut pods were harvested at 95 days after planting. For cowpea dry pods were harvested thrice. The yields were recorded in terms of dry weight (t/ha).

3.1.7 Incorporation of residue and green manure

After partial flooding, all the main plots were ploughed using a tractor and later puddled. The treatments received a turn around period of 10 days.

3.1.8 Rice crop establishment

The soil was ploughed and puddled twice with tractor within each main plot and then levelled. Sub plot treatments were allocated randomly to each main plot. Seedlings raised by wet nursery method using the seeds obtained from the Agricultural Research Station, Mannuthy were used for the study. Twenty three day old seedlings of uniform growth were transplanted on 3rd July 1993 at the rate of two to three seedlings per hill.

Fertilizer application was done according to the package of practices (KAU, 1993) for high yielding short duration varieties. Nitrogen was applied as per treatments and P and K were applied at the rate of 35 kg/ha. Fertilizer materials used were Urea, Superphosphate and Muriate of Potash. On the third day after transplanting, water was drained out and basal dose of fertilizer (half N and full dose of P and K) were applied along with home made granular preparation of herbicide butachlor @ 1.5 kg a.i./ha. Remaining half dose of N was topdressed at maximum tillering stage.

Gap filling of the missing or dead hills was done on the tenth day. Water level was maintained at five to six cm depth. Suitable control measures were taken against pests and diseases.

Harvesting was done 90 days after transplanting (DAT) and the area for destructive sampling was harvested and removed first. The individual plots were then harvested and threshed separately.

3.2 Details of data collection

3.2.1 Initial soil sampling

Soil samples were taken from four locations with the help of a spade and were mixed to make one composite sample and a representative sub sample was drawn for each replication.

3.2.2 Collection of main plot data

3.2.2.1 Grain/pod yield

Cowpea harvesting was done thrice, dry pods were harvested, dried, threshed, cleaned and weighed. Groundnut harvesting was done on 95 days after planting. Four samples were taken from each replication using a quadrat of size 0.25 m^2, pods were separated, dried, shelled and weighed. Weight of grains was expressed at 14 per cent moisture.

3.2.2.2 Green manure and residue biomass

Green manure and residue biomass were recorded from the sample obtained by quadrat method from all the main plots. Fresh weight was recorded. Dry weight was found out using 500 g fresh samples of each plot by drying to a constant weight in the oven at 70°C and expressed in t/ha. Remaining biomass was returned back to sample cut area.

3.2.3 Collection of sub plot data

3.2.3.1 Soil

Soil samples were collected on the day of transplanting, 5, 15, 25, 40 and 60 DAT and at harvest from all the treatments to a depth of 15 cm for the estimation of ammonium-N, nitrate-N and available P and K.

For soil sample collection, a PVC circular pipe of 15 cm diameter and 20 cm length was pushed into the soil between four hills of rice and the flood water was removed without soil disturbance by sucking into a wash bottle. The soil to a depth of 15 cm was scooped out into a plastic bag. At each sampling time two samples were taken from each plot and combined, mixed and then subsampled for extraction and moisture determination.

3.2.3.2 Plant

Four hills were collected randomly from the destructive area of each plot on 15, 25, 40 and 60 DAT and at harvest, roots washed and kept for recording growth characters, then dried to a constant weight.

3.2.3.2.1 Growth characters

a) Plant height

Plant height was measured from the bottom of the culm to the tip of the longest leaf at the above mentioned intervals. Mean height of four hills was recorded as plant height.

b) Number of tillers

The number of tillers were counted on the above dates and then average was expressed as number of tillers per hill.

c) Dry matter production

The dry weights of samples collected at different interval were taken as the dry matter production at the respective stages expressed on per hectare basis.

The dry weights of grain and straw were added together to get the total dry matter production at harvest.

d) Leaf Area Index (LAI)

From one randomly selected plot, the leaf area of four hills was recorded by plotting on the graph and then measured by leaf area meter. Corresponding leaf dry weight was also recorded. Leaf dry weight of four hills per plot was recorded at 15, 25, 40 and 60 DAT. From the area-weight relationship, the leaf area per hill of all the plots was worked out. Then leaf area index was calculated by the formula

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

3.2.3.2.2 Yield attributing characters

a) Number of productive tillers per hill

The number of productive tillers of four hills were counted at harvest and the mean was worked out.

b) Length of panicle

The length in cm from the neck to the tip of all the panicle of four hills was recorded at harvest and the average length per panicle was calculated.

c) Number of spikelets per panicle

Total number of spikelets were taken from the selected four hills and the spikelets per panicle was averaged out.

d) Per cent fertile spikelets

From the number of total spikelets and filled spikelets, the fertility percentage was worked out.

$$\%\ \text{fertile spikelets} = \frac{\text{Number of fertile spikelets x 100}}{\text{Total spikelets}}$$

e) Test weight

Thousand filled grains were collected randomly from samples taken from each plot and the weight was recorded in grams.

3.2.3.2.3 Yield of grain and straw

All the hills in the net plot area were harvested at the base and threshed. The grain yield was expressed at 14 per cent moisture. The straw was weighed after achieving constant weight.

3.2.3.2.4 Harvest Index and grain straw ratio

Harvest Index (HI) was calculated by using the formula

$$\text{HI} = \frac{\text{Grain yield (t/ha)}}{\text{Grain yield + straw yield (t/ha)}}$$

The ratio of grain weight to straw weight was expressed as grain straw ratio.

3.2.3.2.5 Apparent N recovery (AR)

Apparent N recovery was calculated by the formula

$$AR = \frac{\text{(Total N uptake in fertilized plot - total N uptake in control plot)}}{\text{N applied (kg/ha)}} \times 100$$

3.2.3.2.6 Agronomic efficiency (AE)

Agronomic efficiency was calculated using the formula

$$AE = \frac{\text{(Grain yield in fertilized plot - grain yield in control plot)}}{\text{N applied (kg/ha)}} \times 100$$

3.3 Laboratory studies

3.3.1 Soil analysis

3.3.1.1 Ammonium-N and Nitrate-N

For the determination of ammonium-N and nitrate-N steam distillation method (Bremner, 1965) was followed. Wet soil samples were used for extraction and distillation. The values were expressed either in $\mu g/g$ or kg/ha by using the formula.

$$\mu g/g = \frac{\text{ppm in extract x volume of extract in ml}}{\text{Soil dry weight (g)}}$$

$$kg/ha = \frac{\mu g/g \text{ N x bulk density x depth of soil in cm}}{10}$$

3.3.1.2 Available P and K

The soil samples were air dried, powdered gently and passed through a two mm sieve and kept for available P and K determination.

Available P in the soil was extracted by Bray No.1 extractant and the P content was determined by ascorbic acid blue colour method (Watanabe and Olsen, 1965) in a spectronic-20 spectrophotometer. Available K in the soil was extracted by neutral normal ammonium acetate and was read in EEL flame photometer (Jackson, 1973).

3.3.2 Plant analysis

Plant samples were dried in a hot air oven at 70°C and the dry weights recorded. The samples were powdered and composite samples were stored for analysis.

Total nitrogen content of the sample was determined by microkjeldahl digestion and distillation method (Jackson, 1973). For the estimation of total phosphorus and potassium, triacid extract (HNO_3 : H_2SO_4 : $HClO_4$ in the ratio of 10:1:4) of the plant material was made use of. Phosphorus was determined by vanado-molybdo-phosphoric yellow colour method (Jackson, 1973). Potassium was determined using EEL flame photometer. Analysis of grain was done in the same way as that of plant samples.

Nitrogen, phosphorus and potassium uptake by the crop at different intervals were computed from their respective chemical concentrations and dry matter production.

Chlorophyll content of the fresh leaf was determined at 15, 30 and 75 DAT by using acetone extraction and determined in a Spectonic-20 Spectrophotometer (Starner and Hardley, 1967).

3.4 Statistical analysis

The data relating to each character were analysed statistically by applying the technique of analysis of variance and the significance was tested by'F' test (Panse and Sukhatme, 1985).

Results and Discussion

4. RESULTS AND DISCUSSION

The results obtained from the study are presented and discussed in this chapter under the following heads:

1. Biomass yield and nutrient accretion of preceding crops
2. N mineralization from green manure and residues
3. Effect of incorporation of green manure and residues with inorganic N on growth and yield of rice
4. Soil fertility in the cropping systems
5. Economics of cropping systems

4.1 Biomass yield and nutrient accretion of preceding crops

The grain yield of cowpea grown as a preceding crop to rice was 0.7 t/ha (Table 2) and the residue added was 6.8 t/ha contributing 133.3 kg N, 8.8 kg P and 131.2 kg K to the soil (Table 3). The N content in cowpea residue was 1.96 per cent with a C:N ratio of 18:1. For groundnut grain yield was 1.4 t/ha and the residue added 117.6 kg N, 7.7 kg P and 138.6 kg K. The N content and C:N ratio were 1.68 per cent and 28:1 respectively. The green manure crop *S. rostrata* produced 7 t/ha dry matter and added 117.6 kg N, 15.4 kg P and 194.6 kg K. Its N content was 1.68 per cent with C:N ratio of 16:1.

Among the crops evaluated, biomass accumulation was higher for green manure sesbania and oil seed groundnut than grain cowpea, but the difference was only slight. *S. rostrata* being a short-day plant (Visperas *et al.*, 1987) the longer day length (>12 hours) during the summer extended the vegetative phase resulting in

Table 2. Grain yield, N, P and K content and uptake by cowpea and groundnut pods

Crops	Grain yield t/ha	Nutrient content (%)			Nutrient uptake (kg/ha)		
		N	P	K	N	P	K
Cowpea	0.7	3.85	0.27	1.65	27.5	1.9	11.6
Groundnut	1.4	4.31	0.20	0.80	60.3	2.8	11.2

Table 3. Biomass accumulation, N, P and K content and uptake of preceding crops

Crops	Biomass (t/ha)		Nutrient content (%)			C:N ratio	Nutrient accretion (kg/ha)		
	Fresh	Dry	N	P	K		N	P	K
Cowpea	34.3	6.8	1.96	0.13	1.93	18:1	133.3	8.8	131.2
Groundnut	28.5	7.0	1.68	0.11	1.98	28:1	117.6	7.7	138.6
Sesbania	24.0	7.0	1.68	0.22	2.78	16:1	117.6	15.4	194.6

higher biomass production. According to Palaniappan and Reddy (1990), Palaniappan *et al.* (1990) and Siddeswaran (1992) March to July was the best period fro raising *S. rostrata*.

Among the two legumes viz. cowpea and groundnut, groundnut produced higher amount of dry matter. The cowpea variety used 'Kanakamony' is characterized by indeterminate growth habit. All the cowpea pods were not ready for harvesting at the time of incorporation. That may be the reason for low grain yield of cowpea.

Nitrogen contribution through green manure or crop residue is a function of total drymatter and N content. Cowpea residue contributed greater amount of N (133.3 kg/ha), while sesbania contributed more P (15.4 kg/ha) and K (194.6 kg/ha). Due to weekly irrigation, cowpea continued flowering even at the time of incorporation, resulting in higher N content of cowpea than sesbania and groundnut. The N content of sesbania was comparatively poor may be because of the reason that no N fertilizer was given to sesbania.

4.2 Nitrogen mineralization from green manure and residue

Extractable ammonium-N and nitrate-N were determined from plots of all the pre-rice treatments on the day of rice transplanting (10 days after incorporation of biomass) but before the application of nitrogen fertilizer) and from all the N applied rice plots on 5, 15, 25, 40 and 60 days after transplanting (DAT) and at harvest.

Sesbania incorporated treatments recorded higher amount of ammonium-N in soil than groundnut and cowpea residue incorporation till 25 days after transplanting of rice crop (Table 4 and Fig.3). The ammonium-N present in rice soil after

Table 4. Extractable ammonium in the soil as influenced by preceding crops and N levels (kg/ha)

Treatments	On the day of transplanting	5 DAT	15 DAT	25 DAT	40 DAT	60 DAT	Harvest
Preceding crops (C)							
Cowpea	29.57	64.82	56.15	19.50	17.58	6.94	3.75
Groundnut	24.03	59.06	45.98	18.44	12.89	7.17	2.79
Sesbania	31.69	64.59	60.36	22.31	15.96	6.77	3.36
Fallow	19.67	48.71	35.83	12.96	12.36	5.50	3.24
N levels (kg/ha)							
0		48.34	32.75	15.83	11.81	6.50	3.20
35		57.12	42.75	16.80	12.10	7.03	2.91
70		66.36	55.20	19.02	15.77	6.39	3.38
105		65.35	67.82	21.55	19.09	6.47	3.64
SEm± for C	2.17	3.70	3.22	1.28	0.91	0.60	0.51
SEm± for N		3.46	2.50	0.99	1.36	0.43	0.21
CD (0.05) for C	6.94	10.37	9.23	3.67	2.61	NS	NS
CD (0.05) for N		9.92	7.17	2.84	3.90	NS	NS

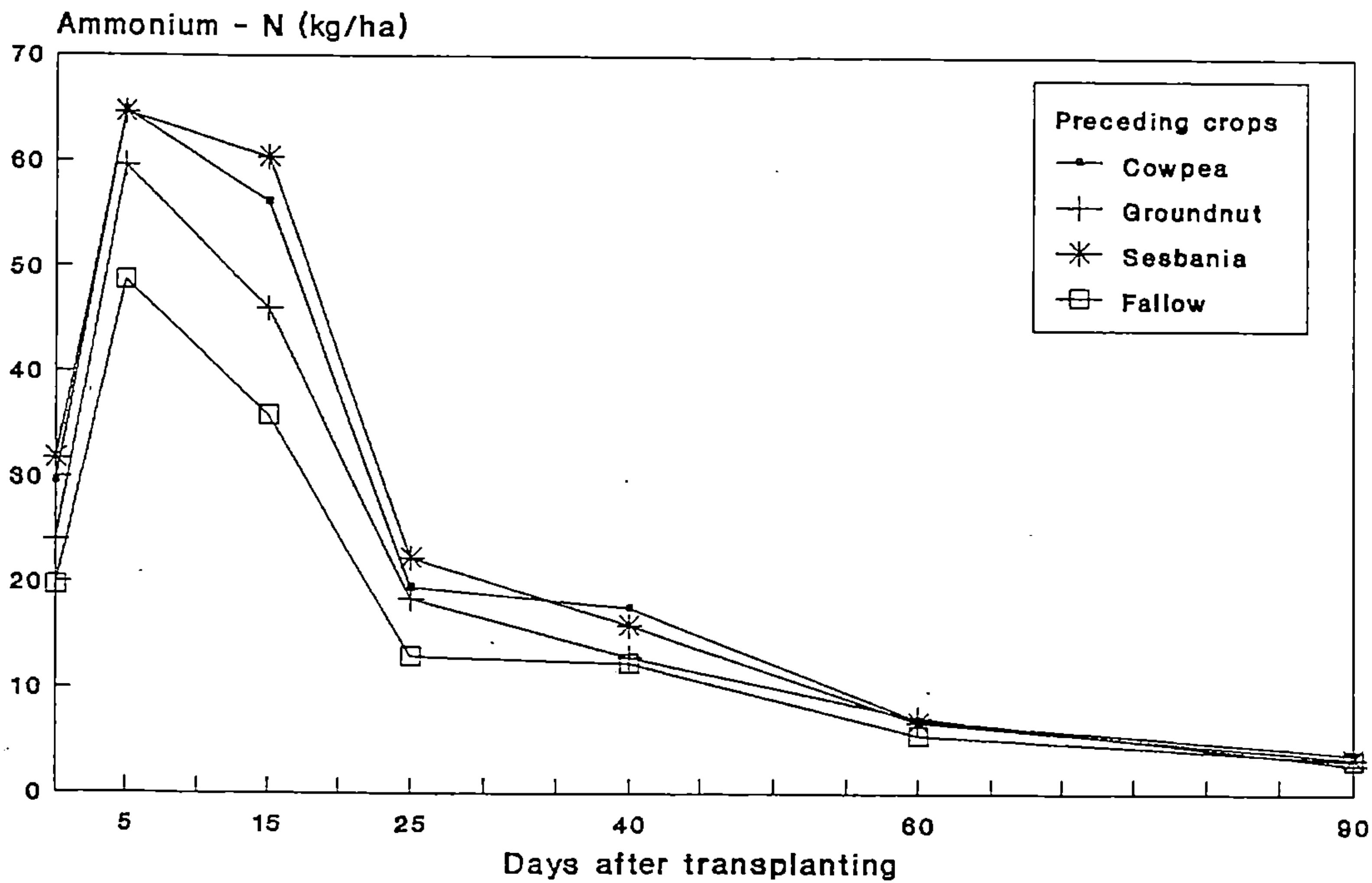

Fig.3. Extractable Ammonium in the soil as influenced by preceding crops(kg/ha)

fallow was significantly less than the other treatments till 25 DAT but the difference was narrowed down at the later stages.

Significantly higher ammonium-N was observed in sesbania incorporated treatments on the day of rice transplanting. Incorporation of cowpea and groundnut residues did not show any significant difference. At 5 DAT, ammonium-N in cowpea residue and sesbania incorporated plots were similar and higher than groundnut residue incorporated plots, however, all these were significantly superior to fallow. At 15 DAT also, highest amount of ammonium-N was observed in plots incorporated with sesbania and significantly higher than groundnut residue incorporation. Similar trend was followed in 25 DAT. But at 40 DAT, cowpea residue incorporation accumulated more ammonium-N than sesbania, however, the difference was not significant. Groundnut residue and fallow treatments recorded a significantly lower value. Towards later stages, no significant difference was noticed among the treatments with regard to ammonium-N accumulation.

N levels had a significant positive influence on ammonium-N accumulation in the soil, showing higher values with increasing levels of N in general (Table 4 and Fig.4).

An increasing trend in ammonium-N accumulation was found upto 25 DAT in all the pre-rice treatments. As flooded condition was maintained during this stage after rice transplanting, nitrification and subsequent loss by denitrification or leaching might be minimum. Ammonium-N accumulation was at a peak at 5 DAT in all the treatments and steadily declined due to increased rate of biomass accumulation by rice plants. These results confirm the finding of Beri *et al.* (1989b) and Sur *et al.* (1993) that the peak ammonium-N occurred at 15 days of green manure incorporation.

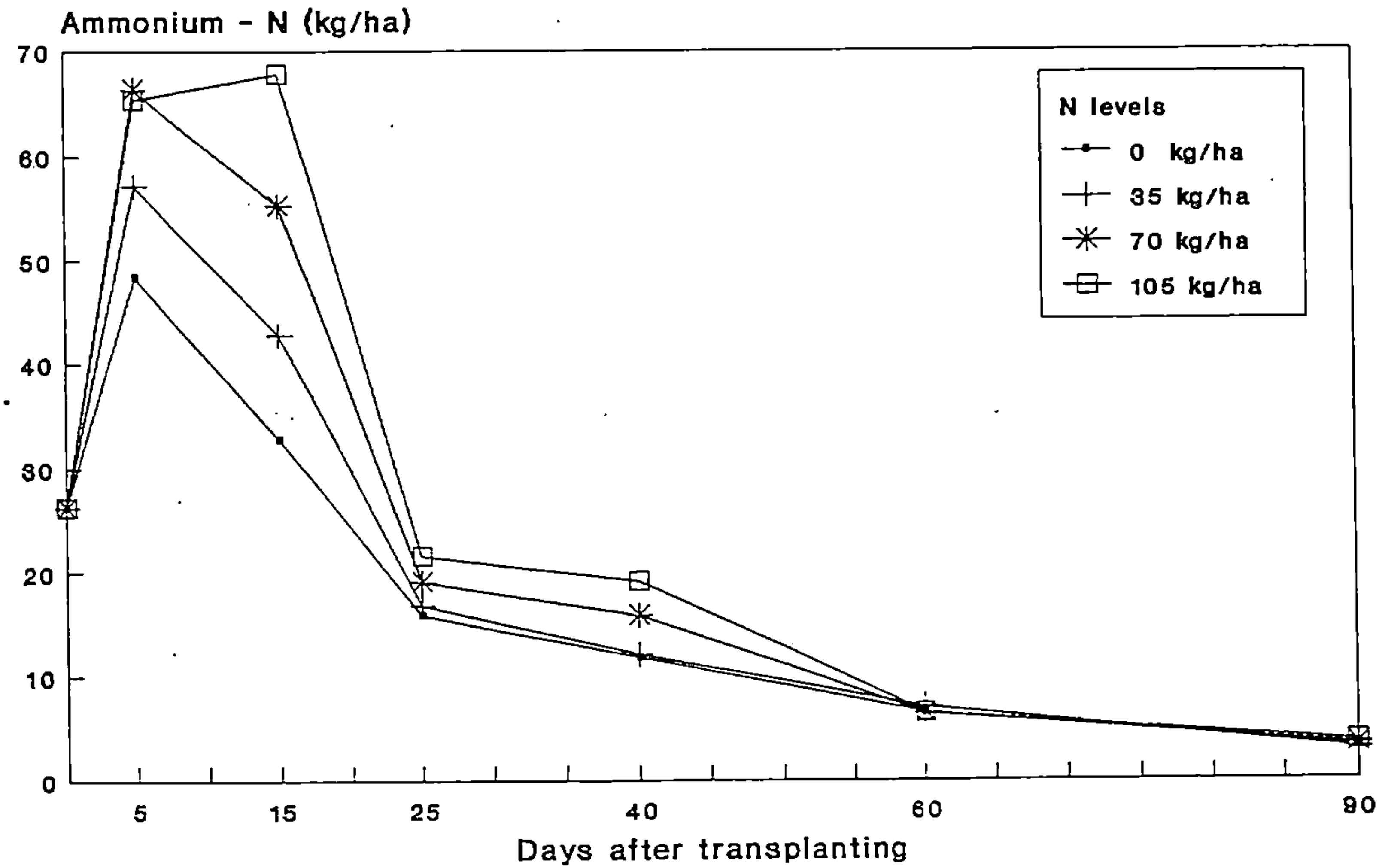

Fig.4. Extractable Ammonium in the soil
as influenced by N levels (kg/ha)

Ammonium-N accumulation pattern in the soil may reflect the N mineralization pattern of the green manure and residue. N added through cowpea residue, groundnut residue and sesbania green manure were 133.3, 117.6 and 117.6 kg/ha respectively. After 10 days of turn around time (on the day of rice transplanting), the net accumulation of ammonium-N from cowpea, groundnut and sesbania over fallow was 9.9, 4.4 and 12.0 kg/ha respectively and this accounted to 7.5, 3.7 and 10.1 per cent of the N added through green manure and residue (Table 5). At 5 DAT, the corresponding figures were 16.1, 10.4 and 15.9 kg/ha. Assuming a similar N uptake of the mineralized N during this period, this was 12.2, 8.8 and 13.4 per cent of N added through cowpea and groundnut residues and sesbania respectively. At 15 DAT, per cent net mineralization was higher for sesbania (20.7 per cent) with a corresponding net ammonium-N accumulation of 24.5 kg/ha followed by cowpea residue with 20.3 kg/ha which was 15.3 per cent of the N added by cowpea residue. However, the net accumulation of ammonium from groundnut residue was only 10.2 kg/ha which was only 8.6 per cent of N added through its incorporation. This mineralization pattern was indicative of the slow decomposition and N mineralization from groundnut residue compared to green manure or cowpea residue. The reason is attributed to wide C:N ratio of groundnut residue (28:1) and narrow C:N ratio of cowpea residue (18:1) and sesbania (16:1).

Joachim and Kandiah (1929), Ponnamperuma (1955), John *et al.* (1989a), Nagarajah *et al.* (1989) and Buresh and De Datta (1991) stated that C:N ratio of the material has a marked influence on the rate of decomposition and release of ammonium-N.

Interaction between pre-rice treatments and N levels was significant at 5, 15 and 40 DAT and at harvest (Table 6) and it was not significant in the other stages and hence not included in the table. At 15 DAT, ammonium-N accumulation was

Table 5. Net accumulation of ammonium N due to preceding crops over fallow during rice crop (kg/ha)

Crops	N accumulation by preceding crops (kg/ha)	Net accumulation of ammonium-N from preceding crops over fallow (kg/ha)					Ammonium-N produced from N added through the preceding crop (%)				
		0 DAT	5 DAT	15 DAT	25 DAT	40 DAT	0 DAT	5 DAT	15 DAT	25 DAT	40 DAT
Cowpea	133.3	9.9	16.1	20.3	6.5	5.2	7.5	12.2	15.3	4.9	3.9
Groundnut	117.6	4.4	10.4	10.2	6.1	0.5	3.7	8.8	8.6	5.1	0.4
Sesbania	117.6	12.0	15.9	24.5	9.4	3.6	10.1	13.4	20.7	7.9	3.0

Table 6. Extractable ammonium in the soil as influenced by interaction between levels of N and preceding crops (kg/ha)

Treatments	5 DAT	15 DAT	40 DAT	Harvest
C_1N_0	57.58	38.77	13.09	3.87
C_1N_1	77.98	48.59	14.96	2.25
C_1N_2	63.79	58.04	18.72	4.36
C_1N_3	59.94	79.21	23.54	4.51
C_2N_0	51.36	33.83	11.66	3.26
C_2N_1	39.19	38.00	9.41	2.68
C_2N_2	76.90	60.58	10.44	3.15
C_2N_3	68.78	51.50	20.04	2.05
C_3N_0	49.70	56.05	12.38	2.69
C_3N_1	67.01	50.98	11.40	3.23
C_3N_2	63.76	62.98	20.29	2.77
C_3N_3	77.90	91.45	19.78	4.75
C_4N_0	34.73	22.38	10.13	2.96
C_4N_1	44.32	33.43	12.65	3.47
C_4N_2	61.02	39.20	13.64	3.25
C_4N_3	54.79	48.33	13.01	3.27
SEm±	6.92	5.00	2.72	0.42
CD (0.05)	19.84	14.34	7.80	1.20

C_1 - Cowpea — N_0 - 0 kg N/ha

C_2 - Groundnut — N_1 - 35 kg N/ha

C_3 - Sesbania — N_2 - 70 kg N/ha

C_4 - Fallow — N_3 - 105 kg N/ha

maximum with highest level of N (105 kg/ha) in plots preceded by cowpea, sesbania and fallow. In general, with all the preceding treatments, ammonium-N accumulation increased with higher levels of N.

At 40 days after transplanting of rice with 105 kg N/ha, there was maximum content of NH_4-N, where cowpea and groundnut were grown previously. But the interaction effect at 105 kg N/ha was on par with 70 kg N/ha in the case of cowpea, sesbania and fallow. At the stage of harvest the interaction effect was not showing any particular trend with respect to the levels of nitrogen.

The extractable nitrate-N content in soil was low compared to ammonium-N (Table 7 and Fig. 5). No significant difference was seen among pre-rice treatments, however, the nitrate-N content in the rice plots after a fallow was lower during most of the growth stages than biomass incorporated plots. Even at the time of harvest sesbania incorporated plots showed a significantly higher nitrate-N content in the soil. The extractable nitrate-N content increased from the day of transplanting to 15th day in all the treatments and till 25th day in cowpea incorporated plots but declined towards later period, possibly due to higher plant uptake.

In continuously flooded soil the nitrate-N content is expected to be minimum due to denitrification of the nitrate present initially and stopping of the nitrification due to the anaerobic situation. Low level of nitrification, however, is possible in the oxidised layer of flooded soil and in the rhizosphere. Ponnamperuma (1955) reported nitrification in the flooded soil due to the oxygen transport to the rhizosphere through rice culm and roots.

N levels found to have no significant influence on extractable nitrate-N content of the soil (Table 7 and Fig. 6).

Table 7. Extractable nitrate-N in the soil as influenced by preceding crops and N levels (kg/ha)

Treatments	On the day of transplanting	5 DAT	15 DAT	25 DAT	40 DAT	60 DAT	Harvest
Preceding crops (C)							
Cowpea	2.27	4.57	4.49	5.56	3.40	1.55	1.39
Groundnut	3.43	3.60	5.58	5.20	3.66	2.01	1.33
Sesbania	2.37	3.07	5.36	3.63	3.51	2.24	3.76
Fallow	1.81	3.34	4.50	3.81	2.58	1.91	1.09
N levels (kg/ha)							
0		3.13	3.92	4.45	2.53	1.61	1.63
35		3.00	3.87	5.35	2.91	1.75	2.11
70		3.78	5.53	4.43	3.92	2.15	2.52
105		4.67	6.62	3.96	3.79	2.20	2.29
SEm± for C	0.37	0.42	0.64	0.77	0.45	0.33	0.14
SEm± for N		0.47	0.75	0.51	0.51	0.22	0.25
CD (0.05) for C	NS	NS	NS	NS	NS	NS	0.40
CD (0.05) for N		NS	2.15	NS	NS	NS	NS

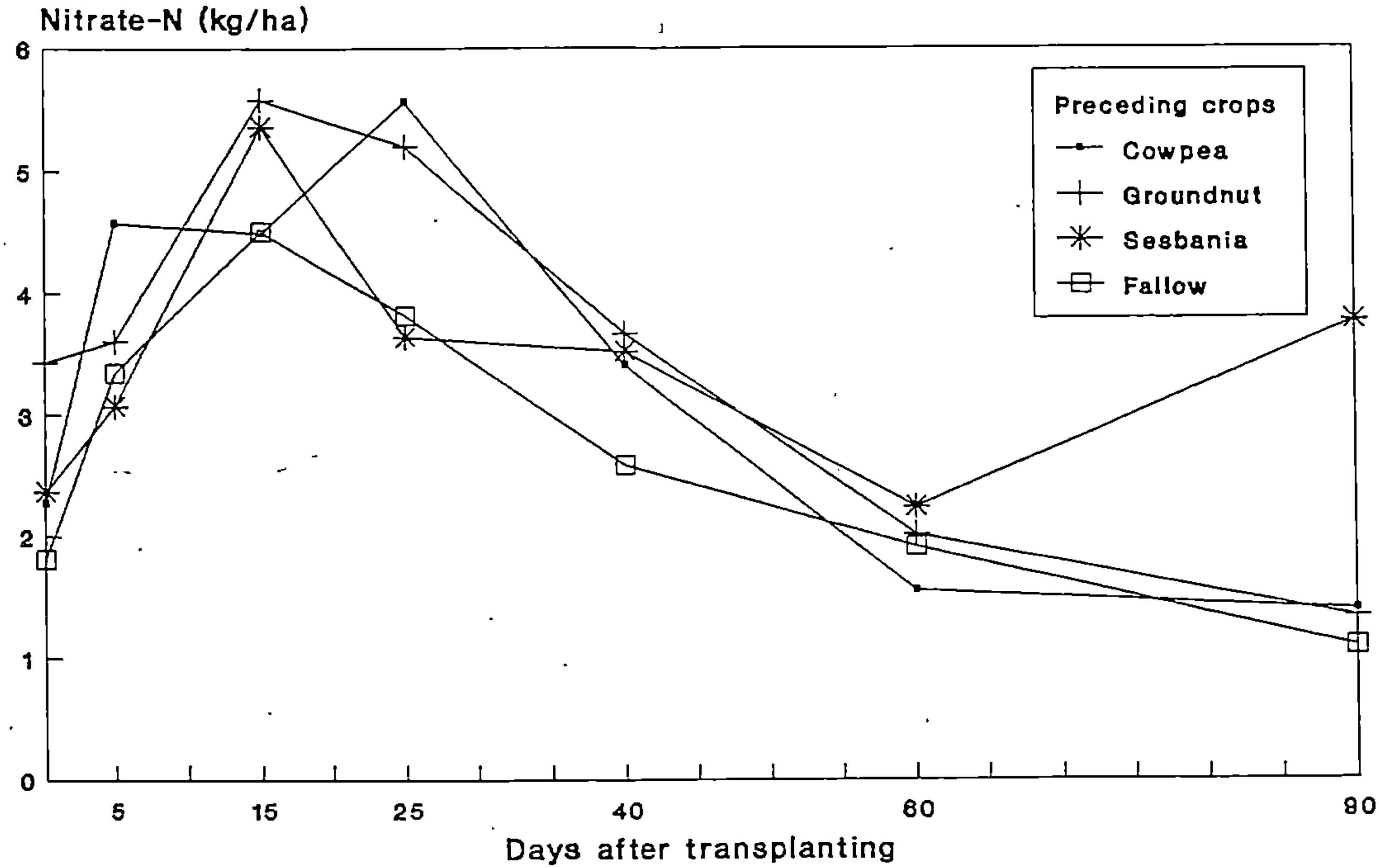

Fig.5. Nitrate-N in the soil as influenced by preceding crops(kg/ha)

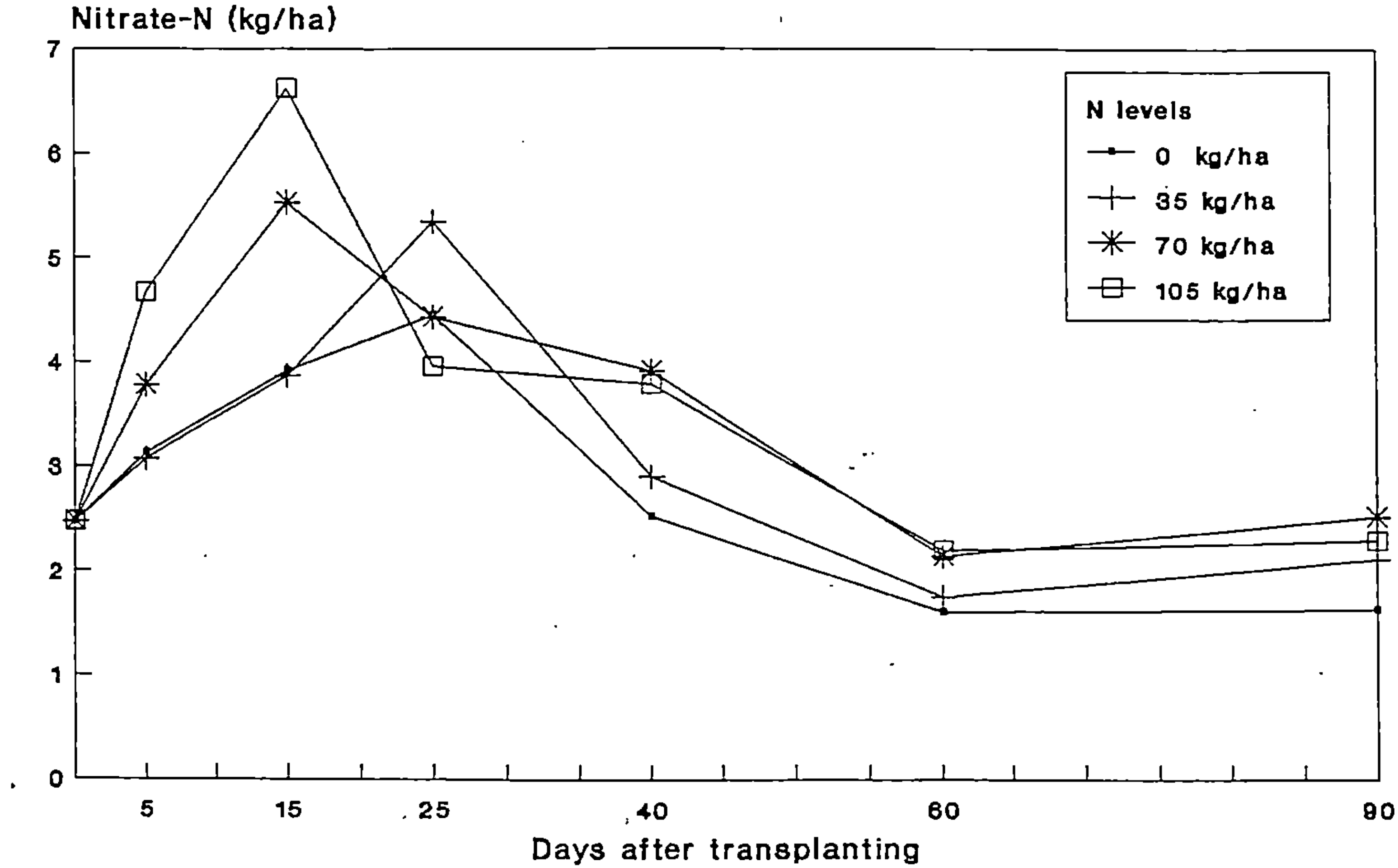

Fig.6. Nitrate-N in the soil as influenced by N levels (kg/ha)

The interaction between pre-rice treatments and N levels on nitrate-N content was significant only at the time of harvest (Table 8). The maximum effect was seen in sesbania incorporated plots at higher levels of N than without N application.

Soil mineral N (ammonium-N + nitrate-N) during rice crop followed similar trends as ammonium-N (Table 9 and Fig.7). On the day of rice transplanting soil mineral N was higher for all the preceding crops than for pre- rice fallow. A peak in mineral N accumulation was observed at 5 DAT for all the treatments i.e., around 15 days after incorporation. Mineral-N in sesbania and cowpea residue incorporated treatments showed almost similar values till 15 DAT, thereafter the values were on par. At harvest the lowest mineral N content was there in pre-rice fallow treatment. It was also observed that a sudden decline in total mineral N took place in all the plots 15 days after transplanting (25 days after incorporation). This was in accordance with the report of Sur *et al.* (1993).

Total mineral N accumulation in the soil showed significant increase with levels of applied fertilizer N (Table 9, Fig. 8).

Total mineral N accumulation pattern in the soil follow the same trend as that of ammonium-N accumulation (Table 10). The mineralization of green manure and residue N increased in the initial stages and it was at its peak level around 15 DAT. Later on it decreased. Even at the later stages cowpea and sesbania incorporated plots showed a high rate of mineralization than groundnut incorporated plots. After 15 DAT, recovery of applied N reduced, may be because of rapid mineralization at initial stages and increased N uptake by plants in the later stages of plant growth.

Table 8. Extractable nitrate in the soil as influenced by interaction between levels of N and preceding crops (kg/ha)

Treatments	5 DAT	15 DAT	40 DAT	Harvest
C_1N_0	4.85	3.27	2.39	2.23
C_1N_1	3.04	3.80	3.57	1.09
C_1N_2	3.53	3.94	4.30	1.08
C_1N_3	6.87	6.97	3.35	1.14
C_2N_0	1.93	5.29	2.60	2.17
C_2N_1	4.08	5.29	2.46	2.79
C_2N_2	4.60	5.94	5.09	1.58
C_2N_3	3.79	5.80	4.50	2.77
C_3N_0	2.93	4.54	3.26	1.07
C_3N_1	2.62	4.59	3.27	3.50
C_3N_2	2.69	7.32	4.02	6.34
C_3N_3	4.03	5.01	3.48	4.13
C_4N_0	2.84	2.59	1.86	1.06
C_4N_1	2.27	1.80	2.34	1.07
C_4N_2	4.29	4.93	2.28	1.10
C_4N_3	3.97	8.69	3.82	1.20
SEm±	0.93	1.50	1.00	0.50
CD (0.05)	NS	NS	NS	1.43

C_1 - Cowpea
C_2 - Groundnut
C_3 - Sesbania
C_4 - Fallow

N_0 - 0 kg N/ha
N_1 - 35 kg N/ha
N_3 - 70 kg N/ha
N_4 - 105 kg N/ha

Table 9. Mineral N (NH_4^+-N + NO_3-N) in the soil as influenced by preceding crops and N levels (kg/ha)

Treatments	On the day of transplanting	5 DAT	15 DAT	25 DAT	40 DAT	60 DAT	Harvest
Preceding crops (C)							
Cowpea	31.84	69.39	60.65	25.06	20.98	8.49	5.13
Groundnut	27.45	62.65	51.55	23.64	16.55	9.19	5.11
Sesbania	34.06	67.66	65.69	25.93	19.47	9.01	7.12
Fallow	21.48	52.06	40.34	16.76	14.93	7.41	4.33
N levels (kg/ha)							
0		51.47	36.68	20.28	14.34	8.11	4.83
35		60.13	46.62	22.15	15.01	8.78	5.03
70		70.14	60.73	23.45	19.69	8.54	5.90
105		70.02	74.20	25.51	22.88	8.67	5.93
SEm± for C	2.29	3.86	3.53	1.46	1.04	0.51	0.55
SEm± for N		3.64	2.49	1.01	1.52	0.43	0.39
CD (0.05) for C	7.32	11.07	10.12	4.19	2.98	NS	1.58
CD (0.05) for N		10.44	7.14	2.90	4.36	NS	NS

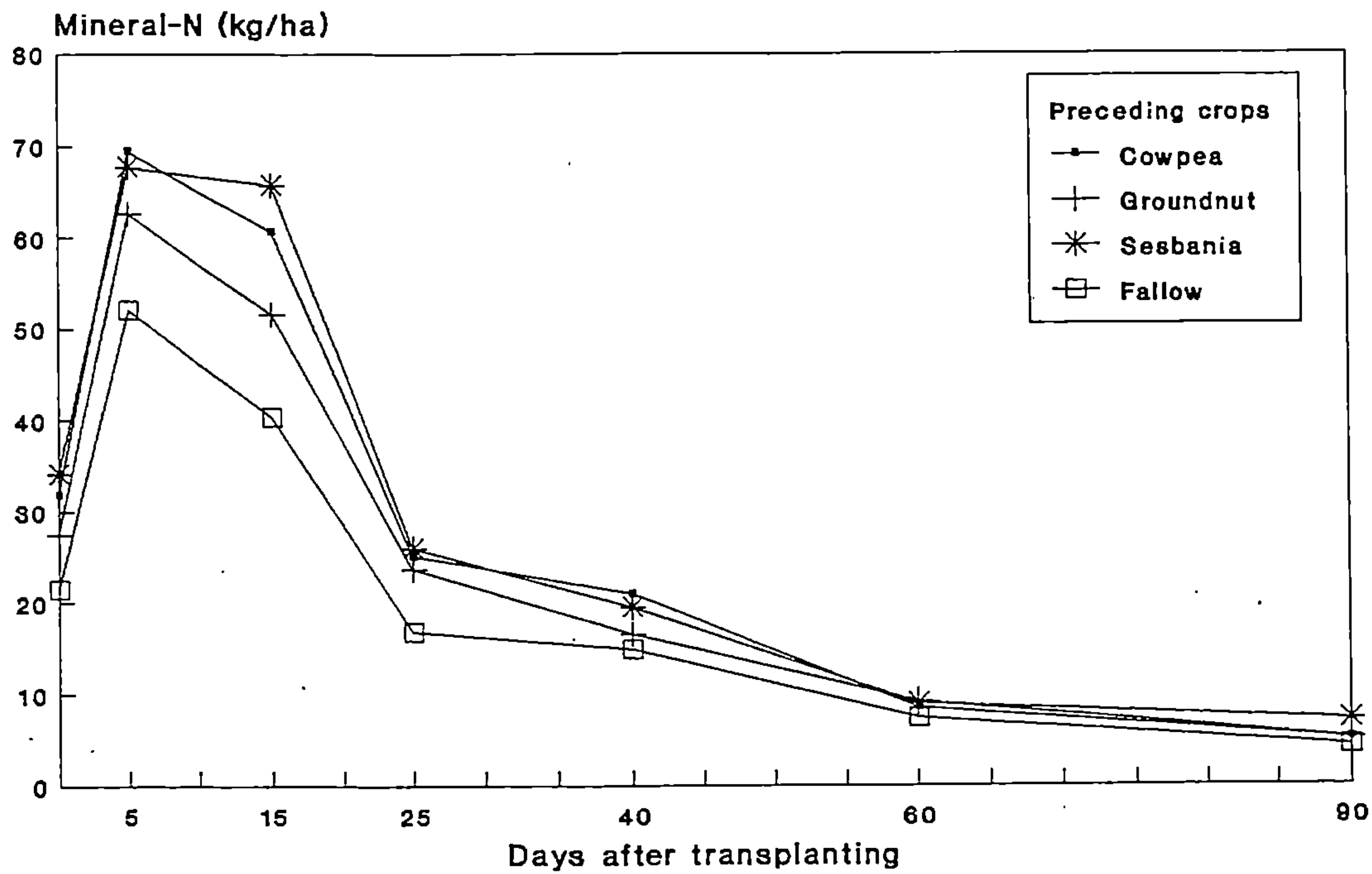

Fig.7. Mineral N in the soil as influenced by preceding crops(kg/ha)

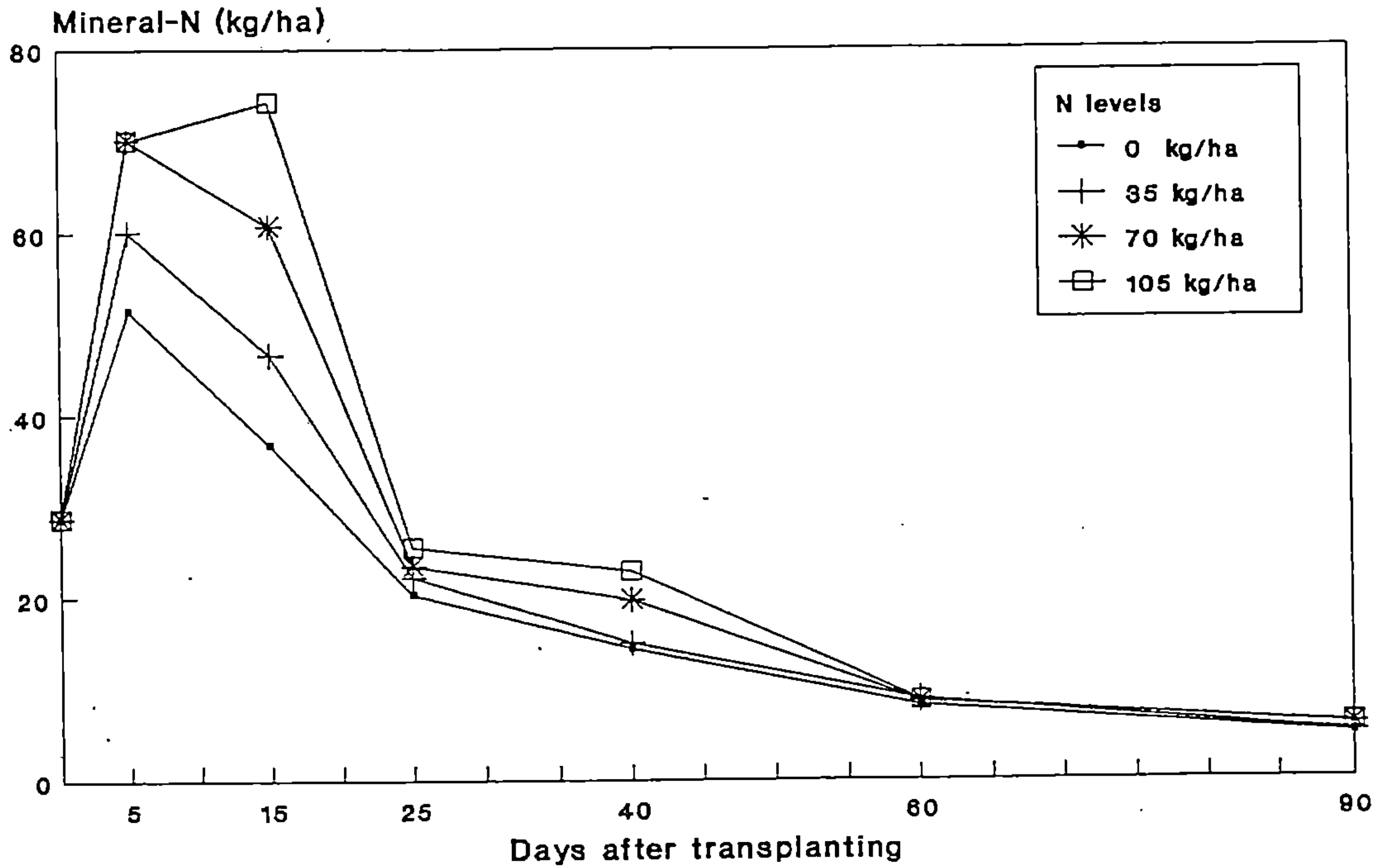

Fig.8. Mineral N in the soil as influenced by N levels (kg/ha)

Table 10. Net accumulation of mineral-N (NH_4 –N + NO_3-N) due to preceding crops over fallow during rice crop (kg/ha)

Crops	N accumulation by preceding crops (kg/ha)	Net accumulation of mineral-N from preceding crops over fallow (kg/ha)					Mineral-N produced from N added through the preceding crop (%)				
		0 DAT	5 DAT	15 DAT	25 DAT	40 DAT	0 DAT	5 DAT	15 DAT	25 DAT	40 DAT
Cowpea	133.3	10.5	17.3	20.3	8.3	6.1	7.9	13.1	15.3	6.3	4.6
Groundnut	117.6	6.0	10.6	11.2	6.9	1.6	5.1	8.9	9.5	5.8	1.4
Sesbania	117.6	12.5	15.6	25.3	9.2	4.5	10.6	13.2	21.4	7.7	3.8

The interaction between pre-rice treatments and N levels on mineral N content was significant only at 5 and 15 DAT and at the time of harvest (Table 11). At 5 DAT, mineral N accumulation was maximum in plots receiving highest rate of N fertilizer application and sesbania incorporation, but it was statistically on par with cowpea and groundnut residue incorporated plots along with 35 and 70 kg N/ha respectively. At 15 days after transplanting of rice, with 105 kg N/ha there was maximum production of mineral N where sesbania and cowpea were grown previously and significantly superior to all other treatments. But at the time of harvest it was noted that there was not much variation in the rice soil with levels of N if it was left as a fallow in the previous season or where groundnut was grown. In all other treatments there was significant interaction between the type of preceding crop and level of fertilizer application. The maximum mineral N at the time of harvest was in the plot where rice was grown with 70 kg N along with the incorporation of sesbania green manure.

4.3 Effect of incorporation of green manure and residues with inorganic N on growth and yield of rice

4.3.1 Crop growth characters

4.3.1.1 Height of plant

Incorporation of preceding crops significantly increased plant height at all stages compared to pre-rice fallow (Table 12). The effect of cowpea residue and sesbania green manure was higher than groundnut residue incorporation eventhough they were at par. For all the treatments, plant height was increased up to 60 DAT. The plant height of rice was always low after a fallow season.

Table 11. Mineral N (NH_4^+ + NO_3-N) in the soil as influenced by interaction between levels of N and preceding crops (kg/ha)

Treatments	5 DAT	15 DAT	40 DAT	Harvest
C_1N_0	62.42	42.03	15.48	6.10
C_1N_1	81.02	52.41	18.53	3.34
C_1N_2	67.32	61.98	23.02	5.43
C_1N_3	66.81	86.18	26.88	5.65
C_2N_0	53.29	39.12	14.26	5.43
C_2N_1	43.27	43.28	11.86	5.47
C_2N_2	81.49	66.52	15.52	4.73
C_2N_3	72.57	57.29	24.54	4.82
C_3N_0	52.62	40.59	15.64	3.76
C_3N_1	69.63	55.56	14.67	6.76
C_3N_2	66.44	70.30	24.31	9.11
C_3N_3	81.93	96.31	23.27	8.88
C_4N_0	37.56	24.97	11.98	4.02
C_4N_1	46.59	35.23	14.99	4.54
C_4N_2	65.31	44.13	15.92	4.35
C_4N_3	58.77	57.02	16.83	4.39
SEm±	7.29	4.98	3.05	0.79
CD (0.05)	20.90	14.28	NS	2.27

C_1 - Cowpea
C_2 - Groundnut
C_3 - Sesbania
C_4 - Fallow

N_0 - 0 kg N/ha
N_1 - 35 kg N/ha
N_2 - 70 kg N/ha
N_3 - 105 kg N/ha

Table 12. Height of rice plant as influenced by preceding crops and N levels (cm)

Treatment	15 DAT	25 DAT	40 DAT	60 DAT	Harvest
Preceding crops (C)					
Cowpea	34.83	58.52	64.16	82.09	78.03
Groundnut	35.11	55.58	62.25	78.09	74.59
Sesbania	34.51	58.64	64.41	81.25	77.59
Fallow	33.61	54.09	57.66	72.72	71.33
N levels (kg/ha)					
0	34.78	54.36	58.59	73.34	69.41
35	34.58	56.64	61.84	77.81	76.06
70	33.73	57.03	62.13	80.38	77.41
105	34.97	58.80	65.91	82.63	78.67
SEm± for C	0.73	0.93	1.11	1.48	1.37
SEm± for N	0.66	0.97	1.12	1.10	1.11
CD (0.05) for C	NS	2.67	3.18	4.24	3.93
CD (0.05) for N	NS	2.78	3.21	3.15	3.18

N levels exerted a significant influence on plant height. Even with the lowest level of 35 kg N/ha, plant height increased significantly compared to no N treatment. At 25 and 40 DAT, 35 and 70 kg N/ha produced almost similar plant height. The tallest plants were produced by the highest rate of 105 kg N/ha but it was statistically on par with the lower levels.

4.3.1.2 Number of tillers

Mean number of tillers per hill increased upto 25 DAT and decreased towards harvest (Table 13). Residue and green manure incorporated treatments were superior to fallow, which recorded the lowest number of tillers at all stages.

N levels had a significant influence on number of tillers per hill. At all stages of observation, no N treatment produced the minimum number of tillers and tiller production increased with increasing rate of N. Number of tiller produced at higher N levels, 70 and 105 kg/ha, were statistically on par. Maximum tillers were produced around 25 DAT. But the number of productive tillers were almost half of the total number of tillers produced as reported by De Datta (1981).

4.3.1.3 Leaf area index

There was significant difference between treatments on the leaf area index of rice (Table 14). Leaf area index was minimum in plots followed by fallow at all stages of crop growth. At 25 and 40 DAT cowpea incorporation produced maximum leaf area, but at later stages, sesbania had more favourable effect. Leaf area index exhibited an increasing trend up to 40 DAT, i.e., up to 4.0 and thereafter decreased slightly towards maturity.

N levels also had a significant positive influence on leaf area index. No

Table 13. Number of tillers per hill of rice as influenced by preceding crops and N levels

Treatment	15 DAT	25 DAT	40 DAT	60 DAT	Harvest
Preceding crops (C)					
Cowpea	2.13	9.59	8.69	8.09	4.95
Groundnut	2.19	9.91	8.63	6.91	4.61
Sesbania	2.28	9.50	7.69	7.97	5.03
Fallow	1.97	8.22	7.50	6.00	4.19
N levels (kg/ha)					
0	2.13	7.66	7.09	6.53	4.16
35	2.16	9.31	7.72	6.75	4.61
70	2.03	9.78	8.66	7.59	4.97
105	2.25	10.47	9.03	8.09	5.05
SEm± for C	0.08	0.37	0.26	0.44	0.23
SEm± for N	0.09	0.35	0.36	0.25	0.17
CD (0.05) for C	NS	1.06	0.75	1.26	NS
CD (0.05) for N	NS	1.00	1.03	0.72	0.49

Table 14. Leaf area index of rice as influenced by preceding crops and N levels

Treatments	15 DAT	25 DAT	40 DAT	60 DAT
Preceding crops (C)				
Cowpea	0.54	3.06	4.00	3.34
Groundnut	0.55	2.47	3.79	3.32
Sesbania	0.53	2.83	3.90	3.88
Fallow	0.53	2.11	3.02	2.71
N levels (kg/ha)				
0	0.47	2.22	2.99	2.71
35	0.54	2.58	3.57	3.08
70	0.58	2.63	3.85	3.41
105	0.57	3.03	4.31	4.05
SEm± for C	0.04	0.09	0.13	0.12
SEm± for N	0.03	0.10	0.21	0.14
CD (0.05) for C	NS	0.26	0.38	0.34
CD (0.05) for N	0.08	0.27	0.60	0.40

N treatment recorded the lowest leaf area index and increased with higher levels of N, however, the effect of 35 and 70 kg N/ha were statistically similar at all stages of crop growth.

4.3.1.4 Chlorophyll content

Data on chlorophyll 'a', chlorophyll 'b' and total chlorophyll content of the crop at different stages are given in Table 15. Preceding crops had no significant effect on chlorophyll 'a'. However, chlorophyll 'b' and total chlorophyll were influenced by pre-rice treatments at 30 DAT, with maximum content after cowpea residue incorporation and minimum being in plots after fallow. Chlorophyll 'b' and total chlorophyll increased up to 30 DAT and decreased towards boot leaf stage and significantly influenced by preceding crop at 30 DAT. The absence of significant effect on chlorophyll 'a' may be due to relatively less proportion of chlorophyll 'a' to 'b'.

Chlorophyll 'b' and total chlorophyll increased with increasing rate of N application. Significant interaction was noticed between N levels and preceding crops on chlorophyll 'a' and total chlorophyll contents at boot leaf stage (Table 16) and maximum value was in plots incorporated with sesbania and applied with 105 kg N/ha.

The results on chlorophyll clearly indicated the importance of chlorophyll development in yield expression. On comparing chlorophyll content with yield, the higher yield in cowpea and sesbania incorporated plots may be due to its higher chlorophyll content at boot leaf stage. A positive correlation between chlorophyll content and yield was also reported by Bridgit *et al.* (1992) and Singh (1970).

Table 15. Chlorophyll content ($\mu g/g$) of rice leaf blade as influenced by preceding crops and N levels

Treatments	15 DAT			30 DAT			Boot leaf stage		
	Chl. a	Chl.b	Total	Chl.a	Chl.b	Total	Chl.a	Chl.b	Total
Preceding crops (C)									
Cowpea	-0.222	2.273	1.784	0.020	3.035	3.054	0.928	0.633	1.564
Groundnut	-0.132	2.017	1.867	0.029	2.423	2.451	0.806	0.555	1.360
Sesbania	-0.174	2.047	1.644	0.015	2.537	2.607	0.884	0.567	1.451
Fallow	-0.188	2.032	1.710	0.051	2.237	2.245	0.744	0.447	1.213
N levels (kg/ha)									
0	-0.177	1.996	1.682	0.013	2.395	2.414	0.766	0.490	1.254
35	-0.150	1.996	1.751	0.055	2.451	2.463	0.810	0.577	1.414
70	-0.196	2.196	1.789	0.016	2.600	2.665	0.797	0.516	1.314
105	-0.194	2.180	1.782	0.030	2.785	2.815	0.987	0.619	1.606
SEm± for C	0.021	0.189	0.113	0.017	0.102	0.102	0.072	0.055	0.107
SEm± for N	0.011	0.101	0.074	0.013	0.079	0.079	0.038	0.037	0.061
CD(0.05) for C	NS	NS	NS	NS	0.292	0.292	NS	NS	NS
CD(0.05) for N	0.03	NS	NS	NS	0.227	0.227	0.109	NS	0.175

Table 16. Chlorophyll content ($\mu g/g$) of boot leaf as influenced by interaction between levels of N and preceding crops

Treatments	Chlorophyll A	Chlorophyll B	Total chlorophyll
C_1N_0	0.817	0.549	1.361
C_1N_1	0.954	0.661	1.629
C_1N_2	0.919	0.659	1.579
C_1N_3	1.022	0.664	1.686
C_2N_0	0.857	0.635	1.489
C_2N_1	0.824	0.614	1.438
C_2N_2	0.769	0.346	1.115
C_2N_3	0.773	0.625	1.398
C_3N_0	0.742	0.398	1.139
C_3N_1	0.728	0.564	1.292
C_3N_2	0.806	0.577	1.382
C_3N_3	1.259	0.731	1.989
C_4N_0	0.648	0.378	1.026
C_4N_1	0.736	0.468	1.294
C_4N_2	0.695	0.483	1.178
C_4N_3	0.895	0.458	1.353
SEm±	0.076	0.075	0.122
CD (0.05)	0.218	NS	0.350

C_1 - Cowpea N_0 - 0 kg N/ha
C_2 - Groundnut N_1 - 30 kg N/ha
C_3 - Sesbania N_2 - 70 kg N/ha
C_4 - Fallow N_3 - 105 kg N/ha

4.3.1.5 Dry matter production

Data on dry matter production of rice are presented in Table 17 and Fig. 9 and 10. Incorporation of residues and green manure significantly increased dry matter production over fallow. Among the three preceding crops, dry matter was maximum in cowpea residue incorporated treatments and on par with sesbania incorporated treatments.

The lowest dry matter production of rice was in the plots were nitrogen was not supplied and increased with increasing rate of N application. There was no significant effect either due to preceding crops or N levels in the initial stages. But dry matter production increased at a faster rate from 15 DAT to 60 DAT and after that the rate of increase was comparatively less. Application of more than 70 kg N/ha had no significant effect on dry matter production at later stages of crop growth. It is because the height of plants and tiller number were also on par at the higher levels of N application.

Significant interaction was noticed between pre-rice crops and N levels on dry matter production of rice at harvest (Table 18). Maximum dry matter production was recorded after sesbania and cowpea residue incorporation along with 70 kg N/ha and it was on par with 105 kg N/ha. In the case of rice crop taken after a fallow the dry matter production increased with increasing levels of N up to 105 kg N/ha.

These results showed that when pre-rice crops like cowpea and sesbania were incorporated into the rice soil only 70 kg N/ha was required for a short duration variety like Annapurna. When no green manure was applied there was significant increase in dry matter production till 105 kg N/ha but the dry matter yield was less than the green manured plots at all levels of N application. There was a saving of around 35 kg N by incorporation of green manure or residue.

Table 17. Dry matter production of rice as influenced by preceding crops and N levels (t/ha)

Treatments	15 DAT	25 DAT	40 DAT	60 DAT	Harvest
Preceding crops (C)					
Cowpea	0.42	2.07	4.10	6.32	6.64
Groundnut	0.39	1.72	4.08	5.54	5.67
Sesbania	0.40	1.75	3.78	6.18	6.53
Fallow	0.36	1.30	3.20	4.74	5.51
N levels (kg/ha)					
0	0.37	1.49	3.03	4.56	4.86
35	0.38	1.67	3.86	5.78	6.06
70	0.42	1.69	4.05	6.14	6.60
105	0.41	1.98	4.21	6.30	6.82
SEm± for C	0.01	0.11	0.15	0.22	0.22
SEm± for N	0.02	0.07	0.19	0.23	0.15
CD (0.05) for C	NS	0.32	0.43	0.63	0.63
CD (0.05) for N	NS	0.20	0.54	0.66	0.43

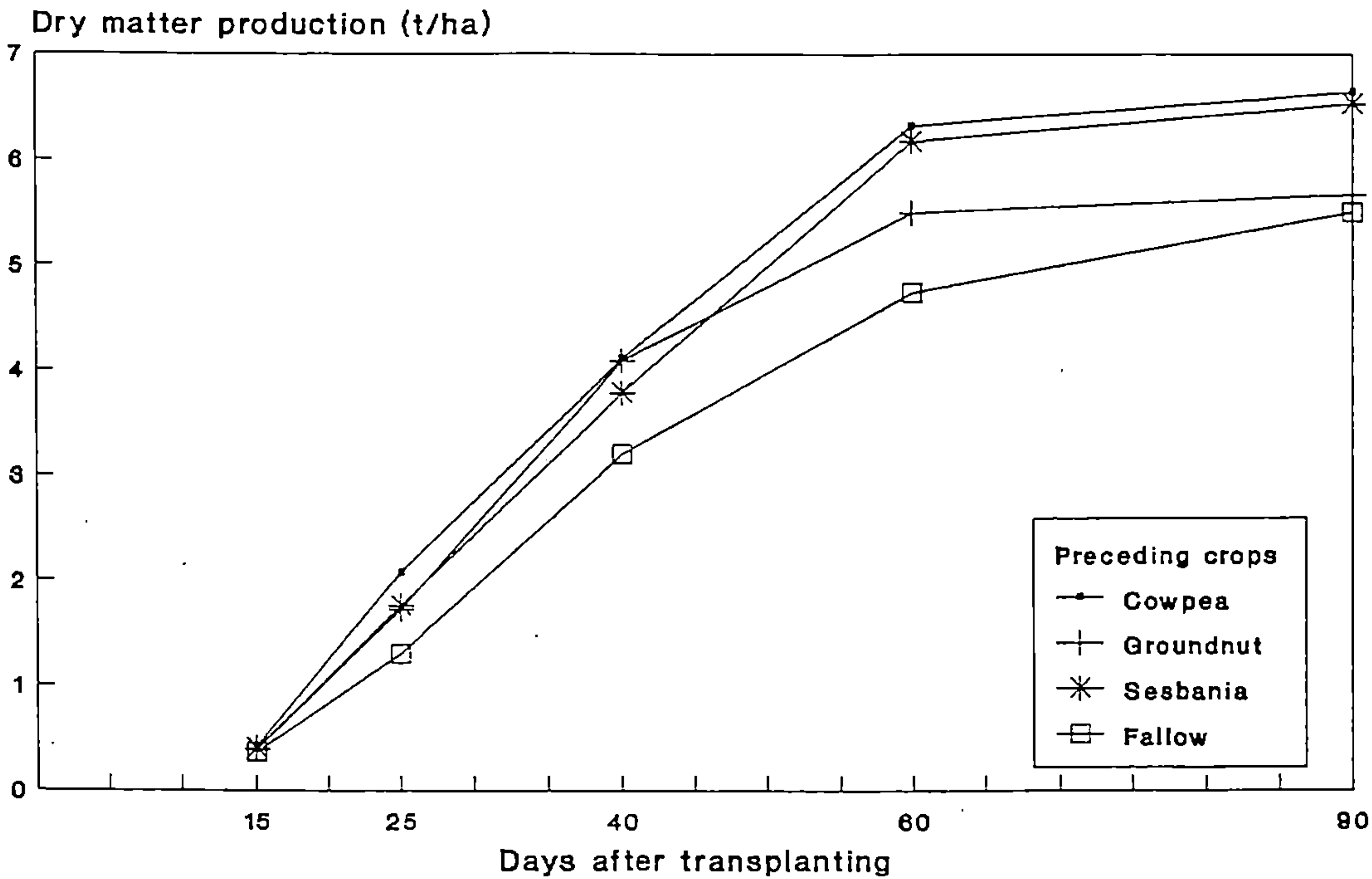

Fig.9. Dry matter production of rice
as influenced by preceding crops(t/ha)

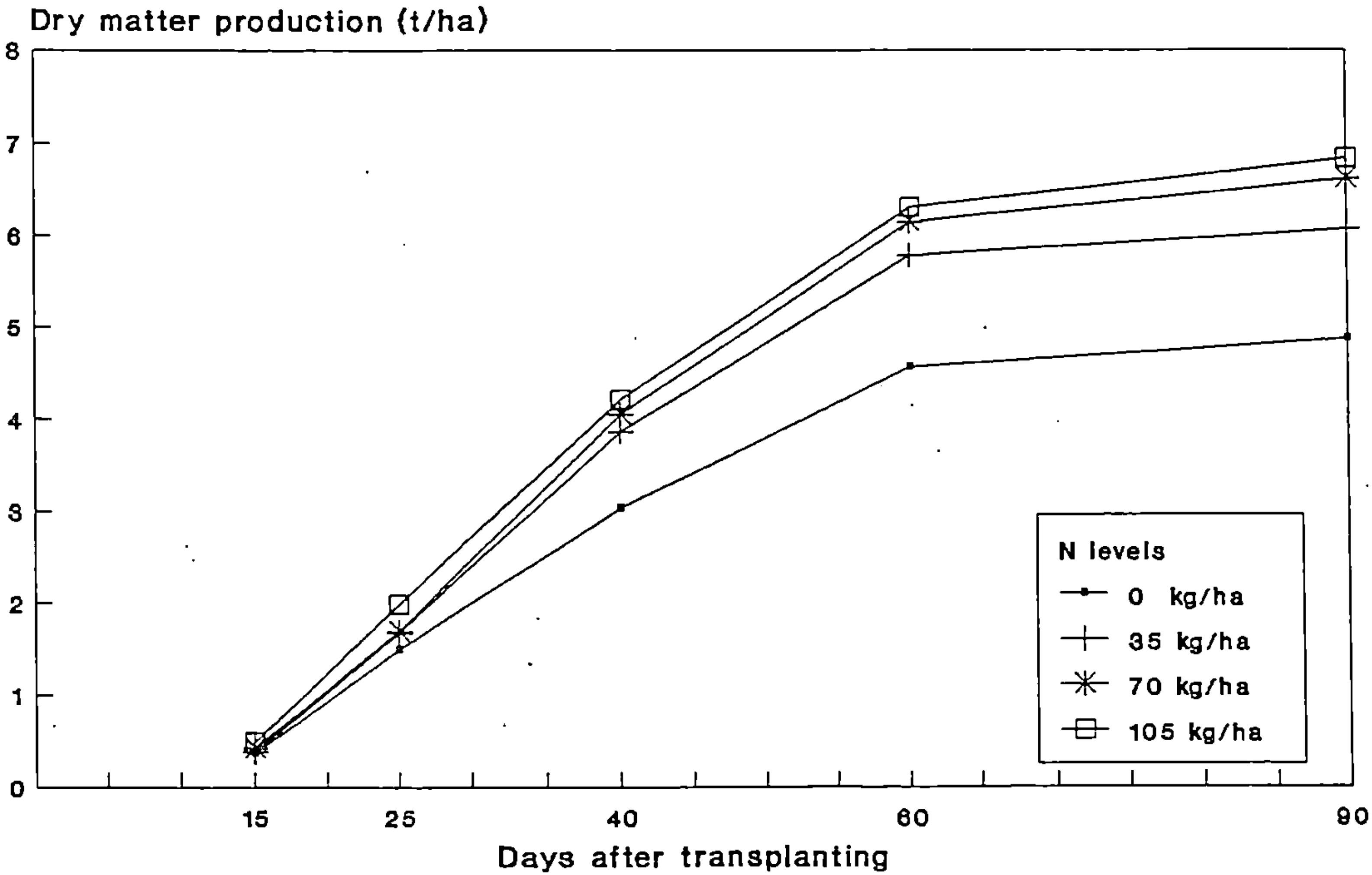

Fig.10. Dry matter production of rice as influenced by N levels (t/ha)

Table 18. Dry matter production of rice at harvest as influenced by interaction between levels of N and preceding crops (t/ha)

Treatments	0 kg/ha	35 kg/ha	70 kg/ha	105 kg/ha	Mean
Cowpea	5.57	6.76	7.30	6.97	6.65
Groundnut	5.04	5.56	5.76	6.31	5.67
Sesbania	5.05	6.16	7.67	7.22	6.53
Fallow	3.79	5.77	5.68	6.79	5.51
Mean	4.86	6.06	6.60	6.82	
SEm±			- 0.31		
CD (0.05)			- 0.89		

4.3.2 Yield attributes and yield

4.3.2.1 Number of panicles per hill

The data on number of panicles per hill are presented in Table 19. Even though there was no significant difference between treatments with regard to number of panicles produced per hill, crop grown after sesbania and cowpea residue incorporation produced more number of panicles than the rest of the treatments.

Higher levels of N significantly increased the number of panicles produced per hill, maximum number obtained with 105 kg N/ha. However, this was on par with the two lower N levels, 35 and 70 kg N/ha.

4.3.2.2 Number of spikelets per panicle

The data on number of spikelets per panicle are presented in Table 19. Significant difference was noticed between different pre-rice crops with respect to number of spikelets per panicle. Maximum spikelets were produced by sesbania incorporation which was statistically similar to that of cowpea residue incorporation. Rice taken after a fallow recorded the minimum value.

N application did not significantly influence the number of spikelets produced per panicle, even though higher levels of N increased the production of spikelets.

4.3.2.3 Fertility percentage

Pre-rice treatments had no significant influence on fertility percentage (Table 19). However, fertility per cent was minimum in the plots preceded by fallow. N levels also, did not show any significant influence on fertility percentage.

Table 19. Yield attributes of rice as influenced by preceding crops and N levels

Treatments	No. of productive tillers per hill	Total No. of spikelets per panicle	Fertility %	1000 grain weight (g)
Preceding crops (C)				
Cowpea	4.95	65.41	74.31	24.85
Groundnut	4.61	62.77	75.03	25.19
Sesbania	5.03	67.53	74.44	25.00
Fallow	4.19	58.64	72.96	24.28
N levels (kg/ha)				
0	4.16	60.96	73.85	24.40
35	4.61	62.83	75.24	24.70
70	4.97	64.58	73.63	25.36
105	5.05	66.00	74.02	24.86
SEm± for C	0.23	1.09	1.18	0.27
SEm± for N	0.17	1.48	1.48	0.24
CD (0.05) for C	NS	3.13	NS	NS
CD (0.05) for N	0.49	NS	NS	0.69

4.3.2.4 Test weight of grains

With respect to 1000 grain weight, no significant difference was noticed by the preceding crops over fallow. But N application could improve the test weight even though different levels could be make any significant difference.

4.3.2.5 Grain and straw yield

The data on grain and straw yield (t/ha) are presented in Table 20. Sesbania and cowpea residue incorporation resulted in a significant grain yield increase of 26 and 25 per cent respectively over fallow. But groundnut residue incorporation increased yield by only 10 per cent. Cowpea and sesbania increased straw yield by 16 and 12 per cent respectively through its incorporation.

N application markedly increased the grain and straw yield. Higher N levels (70 and 105 kg N/ha) produced statistically similar results.

There was significant interaction between N levels and pre-rice crops with regard to straw yield, but not in the case of grain yield (Table 21). Grain yield (3.74 t/ha) and straw yield (3.93 t/ha) was maximum with the incorporation of sesbania + 70 kg N/ha followed by sesbania + 105 kg N/ha, but were on par (Fig. 11).

4.3.2.6 Harvest index and grain-straw ratio

Grain-straw ratio was significantly influenced by preceding legume crops, with groundnut and sesbania incorporation recording the maximum ratio and crop following fallow recording the minimum (Table 20). Harvest index did not show any significant difference due to the preceding crops.

Table 20. Grain yield, straw yield, harvest index and grain-straw ratio of rice as influenced by preceding crops and N levels

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	Grain-srtraw ratio
Preceding crops (C)				
Cowpea	3.23	3.42	0.48	0.95
Groundnut	2.82	2.84	0.50	1.00
Sesbania	3.24	3.29	0.50	0.99
Fallow	2.57	2.94	0.47	0.89
N levels (kg/ha)				
0	2.39	2.47	0.49	0.97
35	2.95	3.11	0.49	0.95
70	3.18	3.42	0.48	0.93
105	3.34	3.49	0.49	0.96
SEm± for C	0.12	0.11	0.01	0.02
SEm± for N	0.09	0.09	0.01	0.02
CD (0.05) for C	0.34	0.32	0.03	0.06
CD (0.05) for N	0.26	0.26	NS	NS

Table 21. Grain yield and straw yield as influenced by interaction between levels of N and preceding crops (t/ha)

Treatments	Grain yield	Straw yield
C_1N_0	2.70	2.87
C_1N_1	3.24	3.52
C_1N_2	3.51	3.79
C_1N_3	3.48	3.49
C_2N_0	2.52	2.51
C_2N_1	2.87	2.69
C_2N_2	2.84	2.92
C_2N_3	3.06	3.25
C_3N_0	2.50	2.56
C_3N_1	3.08	3.07
C_3N_2	3.74	3.93
C_3N_3	3.64	3.59
C_4N_0	1.87	1.93
C_4N_1	2.62	3.16
C_4N_2	2.64	3.05
C_4N_3	3.17	3.62
SEm±	0.17	0.18
CD (0.05)	NS	0.52

C_1 - Cowpea; N_0 - 0 kg N/ha

C_2 - Groundnut; N_1 - 35 kg N/ha

C_3 - Sesbania; N_2 - 70 kg N/ha

C_4 - Fallow; N_3 - 105 kg N/ha

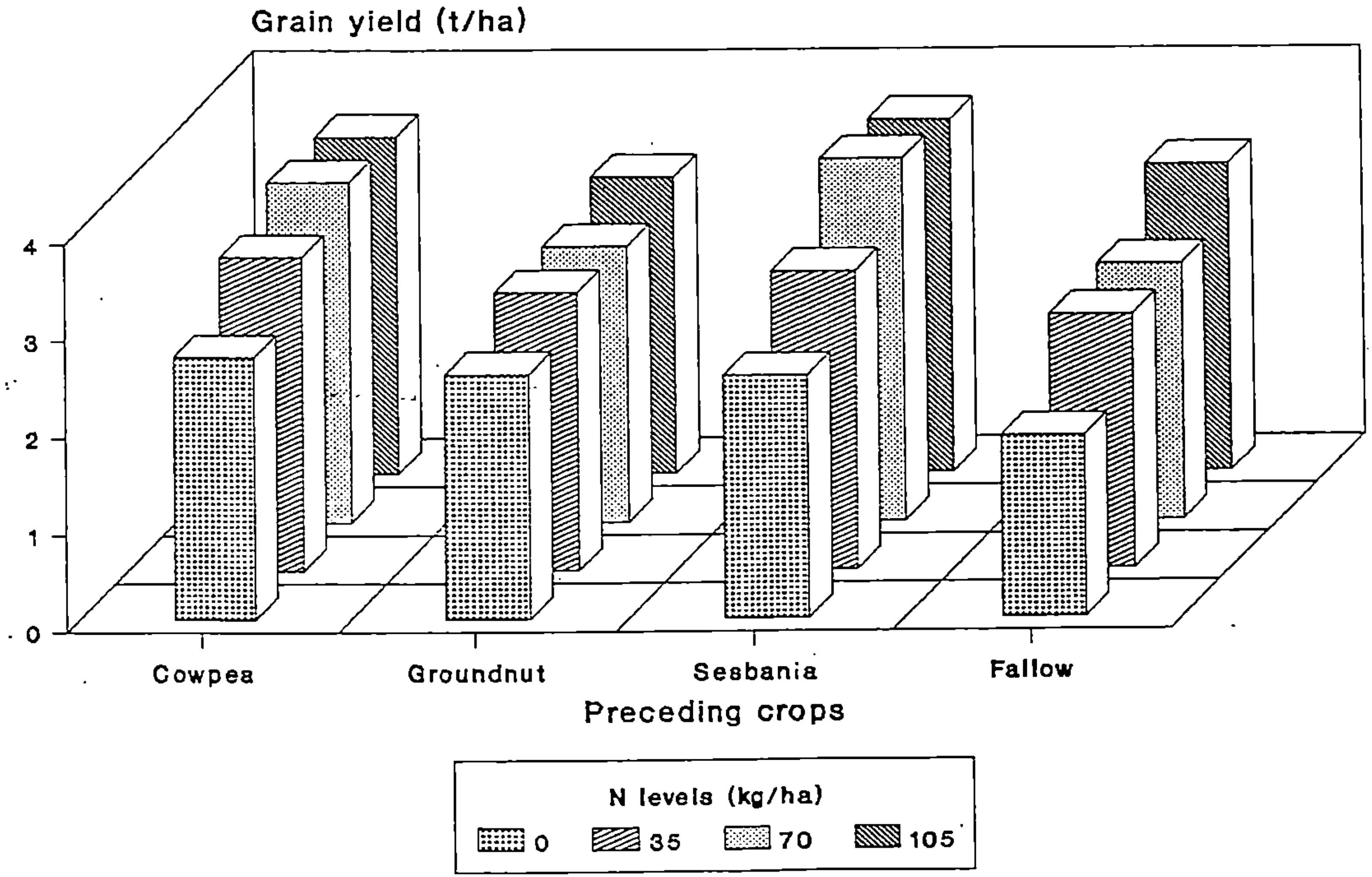

Fig.11. Grain yield of rice as influenced by N levels and preceding crops (t/ha)

N application had no marked influence on grain-straw ratio and harvest index.

These results indicated the favourable effect of incorporating residues of cowpea and groundnut and green manure, sesbania on improving the growth characters and yield of rice. Cowpea residue and sesbania had almost similar effect on improving the yield of rice.

During the decomposition of green manure and legume residues, N availability in the rhizosphere enhanced resulting in increased N uptake which would promote vegetative growth. The organic N sources incorporated before transplanting rice crop undergo decomposition, releasing ammonium-N into the soil solution which is readily used by the rice plant (Westcott and Mikkelsen, 1987; Nagarajah, 1988).

The enhanced growth reflected by the increased height and tiller number is a direct effect of N absorption by rice. Due to steady supply of N, leaf area, the photosynthesising surface increased, resulting in a faster rate of dry matter accumulation. Improved vegetative growth along with more number of tillers, in turn produced more number of panicles with more spikelets. Higher yield of rice was always associated with better yield attributing characters (Mandal *et al.*, 1991; Mandal *et al.*, 1992).

Nitrogen absorbed by the plant from tillering to panicle initiation tends to increase the number of panicles and that absorbed from panicle initiation to flowering increases filled spikelets per panicle (De Datta, 1978). Results from this study is an indication of the availability of N from green manure and residue even after panicle initiation in rice.

Increase in rice yield due to green manuring was reported by several workers (Williams *et al.*, 1957; Tiwari *et al.*, 1980; Manguiat *et al.*, 1988). John *et al.* (1989d) reported that incorporation of cowpea residue increased the grain yield of succeeding rice by about 15 per cent over no green manuring. Using cowpea residues, no significant reduction in N contribution to rice was observed when compared with cowpea green manure treatment (John *et al.*, 1989a).

Yield increase in rice due to incorporation of crop residues of preceding legumes was reported by Xiao (1981), Rekhi and Meelu (1983), Chapman and Myers (1987) and John *et al.* (1989b).

Fertilizer N levels exerted a significant favourable influence on the growth characters and yield of rice. Growth parameters showed a gradual increase with increased N rates. Due to steady and enhanced N supply, more number of tillers and more number of leaves were produced leading to increased LAI (Venkitaswamy, 1986). Larger leaf area enhanced photosynthesis, in turn improving dry matter production. At high N levels N uptake increased, resulting in higher plant height, tiller production and yield (Matsushima, 1980; Yoshida, 1981). Thus the results obtained from the study are in conformity with the reports of Mani (1979) and Bathkal and Patil (1970).

The mean yield increase for the application of 35 kg N/ha was 16 kg grain per kg of N over control whereas it was only 6.6 kg grain for the next 35 kg and further declined to 4.6 kg grain for the last 35 kg N. Declining rate of response of rice to increasing levels of added N has been well documented (Savant and De Datta, 1982; Salam, 1986; Reddy, 1988).

4.3.3 Nutrient content and uptake

4.3.3.1 Nitrogen content

Nitrogen content of rice was determined at 15, 25, 40 and 60 DAT and at harvest. It was lowest in the crop raised after fallow at all stages of crop growth (Table 22) until harvest. The grain N content was maximum when rice was grown after cowpea. There was no significant change in the nitrogen content in straw due to the various pre-rice treatments. The different levels of N had no significant influence in the N contents of grain or straw even though it had influenced the N content of the crop till 60th day. But levels of N higher than 70 kg/ha did not significantly affect N content. Plant N content decreased as the plant matured.

4.3.3.2 Nitrogen uptake

The data on nitrogen uptake by rice are presented in Table 23 and there was significant difference between treatments. At all stages of observation, highest uptake was recorded in plots incorporated with cowpea residue. All the three preceding crops were superior to fallow and cowpea and sesbania incorporated plots were comparable.

The various levels of N significantly influenced the N uptake by the crop. In general, N uptake by crop was higher in plots with higher levels of N.

Significant interaction between pre-rice crops and N levels was observed in plant uptake of N (Table 24). Maximum uptake was in plots incorporated with sesbania along with 70 kg N/ha closely followed by cowpea residue incorporated plots with the same level of N. Further increase in N levels could not produce an increase in N uptake. But with increasing levels of N, a rice crop after fallow showed an increasing trend in N uptake even at 105 kg N/ha.

Table 22. Nitrogen content of rice as influenced by preceding crops and N levels (%)

Treatments	15 DAT	25 DAT	40 DAT	60 DAT	Harvest	
					Grain	Straw
Preceding crops (C)						
Cowpea	3.13	2.26	2.00	1.24	1.32	0.86
Groundnut	3.23	2.02	1.82	1.12	1.25	0.88
Sesbania	3.06	2.23	1.87	1.28	1.16	0.85
Fallow	2.97	1.91	1.79	0.98	1.21	0.81
N levels (kg/ha)						
0	2.85	2.00	1.51	0.96	1.23	0.82
35	3.11	2.00	1.92	1.09	1.16	0.82
70	3.16	2.17	2.07	1.22	1.28	0.85
105	3.27	2.26	2.08	1.34	1.26	0.91
SEm± for C	0.05	0.07	0.09	0.04	0.03	0.04
SEm± for N	0.08	0.06	0.04	0.04	0.04	0.04
CD (0.05) for C	0.14	0.20	NS	0.11	0.09	NS
CD (0.05) for N	0.23	0.17	0.11	0.11	NS	NS

Table 23. Nitrogen uptake by rice as influenced by preceding crops and N levels (kg/ha)

Treatments	15 DAT	25 DAT	40 DAT	60 DAT	Harvest		
					Grain	Straw	Total
Preceding crops (C)							
Cowpea	13.14	46.70	81.94	77.33	42.53	29.23	71.77
Groundnut	12.87	35.17	74.93	63.09	35.36	25.41	60.79
Sesbania	12.30	39.21	70.57	79.71	38.59	28.03	66.56
Fallow	10.65	24.85	61.66	48.55	30.30	24.19	54.49
N levels (kg/ha)							
0	10.49	30.02	45.14	45.38	30.00	20.22	50.26
35	11.73	33.51	72.52	63.25	34.29	25.98	60.27
70	13.34	37.15	85.88	75.80	40.87	29.01	69.90
105	13.39	45.26	87.56	84.25	41.52	31.65	73.17
SEm± for C	0.47	3.30	3.36	2.35	1.59	1.21	1.83
SEm± for N	0.75	1.65	3.67	2.88	1.46	1.20	2.05
CD (0.05) for C	1.35	9.46	9.64	6.74	4.56	NS	5.25
CD (0.05) for N	2.15	4.73	10.52	8.26	4.19	3.44	5.88

Table 24. Total nitrogen uptake by rice at harvest as influenced by interaction between levels of N and preceding crops (kg/ha)

Treatments	0 kg/ha	35 kg/ha	70 kg/ha	105 kg/ha	Mean
Cowpea	64.01	69.13	77.04	76.90	71.77
Groundnut	55.10	55.22	60.44	72.40	60.79
Sesbania	47.33	60.47	84.22	74.21	66.56
Fallow	34.62	56.27	57.90	69.18	54.49
Mean	50.26	60.27	69.90	73.17	
SEM±			- 4.10		
CD (0.05)			- 11.76		

The general decrease in the percentage N content of plants as they mature may attributed to dilution effect (Dubey and Bisen, 1989) because of the improvement in dry matter accumulation as the plants grow.

N uptake is the product of dry matter accumulation and N content. Increased dry matter production as a result of better absorption of N mineralized from green manure and residue along with higher N content contributed to greater N uptake (Siddeswaran, 1992) in plants compared to those grown after a fallow under the same level of N application.

The increased N content in rice with increasing levels of N was observed which is in accordance with the reports of De Datta *et al.* (1968) and John (1987).

Application of fertilizer N found to have a favourable effect on the N uptake by the plant. The increase in N uptake with increased application of N is quite natural as it favoured a higher N content and dry matter accumulation.

4.3.3.3 Phosphorus content

Data on P content presented in Table 25 showed that the preceding crops and levels of applied N were not able to improve P content in rice plant till 60th day.

But at the time of harvest, the grain P content was maximum in treatments incorporated with cowpea residue.

Application of N exerted a negative influence on P content of straw with maximum values observed in plots where N was not supplied.

Table 25. Phosphorus content of rice as influenced by preceding crops and N levels (%)

Treatments	15 DAT	25 DAT	40 DAT	60 DAT	Grain	Straw
Preceding crops (C)						
Cowpea	0.32	0.38	0.34	0.30	0.15	0.25
Groundnut	0.35	0.39	0.34	0.31	0.14	0.25
Sesbania	0.32	0.38	0.35	0.29	0.13	0.25
Fallow	0.34	0.39	0.34	0.29	0.14	0.26
N levels (kg/ha)						
0	0.33	0.38	0.34	0.30	0.14	0.27
35	0.34	0.38	0.34	0.30	0.13	0.26
70	0.33	0.39	0.34	0.30	0.13	0.25
105	0.34	0.39	0.34	0.30	0.15	0.24
SEm± for C	0.01	0.01	0.01	0.01	0.004	0.01
SEm± for N	0.01	0.01	0.01	0.01	0.01	0.007
CD (0.05) for C	NS	NS	NS	NS	0.01	NS
CD (0.05) for N	NS	NS	NS	NS	NS	0.02

4.3.3.4 Phosphorus uptake

Preceding crops and levels of N applied to rice showed significant differences in uptake of P over control (Table 26). Even though uptake was higher in cowpea residue incorporated plots, it was statistically on par with sesbania incorporated plots. Uptake was minimum in the crop after fallow.

Application of more than 70 kg N/ha had no marked effect on total P uptake by the crop even though the removal by grain was significantly higher in rice crop receiving 105 kg N/ha.

Increased uptake of P in green manure and residue incorporated treatments along with higher N levels was a direct effect of greater dry matter accumulation even though the P content under various treatments were non-significant except at the harvest stage.

P absorption reached the maximum value by 60 DAT (flowering time), however the rate was low during the ripening stage. The translocation of nutrients from the leaves and culms to the panicles continued after the flowering stage. This coincided with the translocation and accumulation of starch in the grain showing a close relationship between carbohydrate metabolism and phosphorus (Ishizuka, 1964; Chatterjee and Maiti, 1981).

4.3.3.5 Potassium content

Potassium content of rice crop showed a decreasing trend from 15 DAT to 60 DAT (Table 27). At the time of harvest it was seen that only 12 per cent of total K in the plant was present in the grains and the major part was seen in the straw. At all stages, K content was minimum in crop grown after fallow. But the

Table 26. Phosphorus uptake by rice as influenced by preceding crops and N levels (kg/ha)

Treatments	15 DAT	25 DAT	40 DAT	60 DAT	Harvest		
					Grain	Straw	Total
Preceding crops (C)							
Cowpea	1.34	7.90	13.92	18.65	4.78	8.62	13.40
Groundnut	1.39	6.67	14.02	17.18	3.96	7.12	11.09
Sesbania	1.30	6.72	13.10	17.74	4.12	8.40	12.53
Fallow	1.22	5.01	10.69	13.65	3.58	7.15	10.73
N Levels (kg/ha)							
0	1.20	5.68	10.23	13.38	3.35	6.50	9.85
35	1.27	6.38	13.24	17.04	3.93	7.89	11.82
70	1.39	6.56	13.80	18.21	4.13	8.61	12.74
105	1.39	7.68	14.46	18.59	5.04	8.29	13.34
SEm± for C	0.05	0.39	0.52	0.58	0.25	0.40	0.45
SEm± for N	0.06	0.28	0.67	0.73	0.22	0.31	0.43
CD (0.05) for C	NS	1.12	1.49	1.66	0.72	1.15	1.29
CD (0.05) for N	NS	0.80	1.92	2.09	0.63	0.89	1.23

Table 27. Potassium content of rice as influenced by preceding crops and N levels (%)

Treatments	15 DAT	25 DAT	40 DAT	60 DAT	Harvest	
					Grain	Straw
Preceding crops (C)						
Cowpea	3.40	3.81	2.99	2.02	0.31	2.53
Groundnut	3.48	3.79	2.91	2.02	0.30	2.37
Sesbania	3.42	3.88	2.99	2.01	0.29	2.44
Fallow	3.34	3.69	2.82	1.85	0.31	2.23
N levels (kg/ha)						
0	3.41	3.73	2.89	1.90	0.32	2.23
35	3.49	3.71	2.91	1.95	0.30	2.33
70	3.43	3.93	2.91	2.03	0.31	2.47
105	3.31	3.81	3.00	2.02	0.29	2.53
SEm± for C	0.07	0.08	0.03	0.05	0.01	0.05
SEm± for N	0.07	0.05	0.05	0.05	0.01	0.05
CD (0.05) for C	NS	NS	NS	NS	NS	0.14
CD (0.05) for N	NS	NS	NS	NS	NS	0.14

effect was significant only in the case of straw, where K content in cowpea residue incorporated treatments were significantly superior to all other treatments.

Similar to preceding crops N application did not exert any significant influence on K content except in the case of straw at harvest where K content showed an upward trend with higher levels of N.

Significant interaction was noticed between N levels and preceding crops only on K content of straw (Table 28). The maximum content was observed in rice incorporated with cowpea residue + 105 kg N/ha.

4.3.3.6 Potassium uptake

The data on K uptake by rice are presented in Table 29 and significant difference was noticed between treatments at all stages of crop growth except in the initial stage. Uptake was maximum in plots incorporated with cowpea residue, which was on par with the effect produced by incorporation of sesbania. Uptake was minimum in plots preceded by fallow.

N levels also had a significant influence on K uptake and uptake increased with higher rates of N, however the two higher levels were statistically on par.

Significant interaction was noticed between N levels and preceding crops on K uptake at harvest (Table 30). Incorporation of cowpea residue and sesbania along with 70 kg N/ha resulted in maximum uptake of K which was on par with 105 kg/ha. In the plots preceded by fallow K uptake increased with increasing levels of N up to 105/ha.

Table 28. Potassium content of rice straw as influenced by interaction between levels of N and preceding crops (%)

Treatments	0 kg/ha	35 kg/ha	70 kg/ha	105 kg/ha	Mean
Cowpea	2.23	2.58	2.63	2.68	2.53
Groundnut	2.35	2.20	2.43	2.50	2.37
Sesbania	2.30	2.43	2.50	2.53	2.44
Fallow	2.05	2.13	2.33	2.40	2.23
Mean	2.23	2.33	2.47	2.53	
SEm±			- 0.10		
CD (0.05)			- 0.29		

Table 29. Potassium uptake by rice as influenced by preceding crops and N levels (kg/ha)

Treatments	15 DAT	25 DAT	40 DAT	60 DAT	Harvest		
					Grain	Straw	Total
Preceding crops (C)							
Cowpea	14.15	72.78	122.75	126.55	9.82	86.66	96.50
Groundnut	13.69	64.98	118.58	111.04	8.53	67.58	76.11
Sesbania	13.68	67.48	113.51	123.74	9.47	80.39	89.86
Fallow	11.98	47.76	90.47	88.13	7.99	66.03	74.01
N levels (kg/ha)							
0	12.47	55.18	87.36	86.42	7.65	55.38	63.04
35	13.15	62.04	112.13	111.52	8.85	72.85	81.70
70	14.32	66.44	118.87	125.27	9.73	84.73	94.45
105	13.55	69.34	126.95	126.24	9.58	87.70	97.30
SEm± for C	0.66	4.37	4.62	3.47	0.40	3.32	3.55
SEm± for N	0.67	3.59	6.24	4.85	0.45	2.45	2.71
CD (0.05) for C	NS	12.53	13.25	9.95	1.15	9.52	10.18
CD (0.05) for N	NS	10.29	17.89	13.91	1.29	7.05	7.77

Table 30. Total potassium uptake by rice at harvest as influenced by interaction between levels of N and preceding crops (kg/ha)

Treatments	0 kg/ga	35 kg/ha	70 kg/ha	105 kg/ha	Mean
Cowpea	73.18	100.60	109.49	102.72	96.50
Groundnut	66.46	67.44	80.27	90.30	76.11
Sesbania	66.62	83.76	109.48	99.59	89.86
Fallow	45.90	75.00	78.57	96.59	74.01
Mean	63.04	81.70	94.45	97.30	
SEm±		- 5.42			
CD (0.05)		- 15.54			

Incorporation of legume had some effect on the K content as is evident from the lower K content in rice grown after fallow. Significant difference noticed in the K uptake by rice straw indicated increased availability of K due to application of green manure and residue. Increased K availability in the soil due to green manuring was reported by many workers (Tiwari *et al.*, 1980; Swarup, 1987; Sharma and Mittra, 1988). Marked increase in soil solution K with the addition of sesbania green manure was reported by Nagarajah *et al.* (1986). Application of N may have resulted in increased plant growth, thereby increasing K uptake.

The comparison between yield and uptake of nutrients is given in Fig.12. From the graph is clear that higher yield of rice was always associated with higher uptake of nutrients. NPK uptake were higher in sesbania and cowpea residue incorporated plots. Similarly yield was also higher in these plots.

4.3.4 Apparent N recovery and agronomic efficiency

Apparent recovery of applied N was influenced by pre-rice treatments (Table 31) and it was maximum in plots preceded by fallow. Sesbania incorporation resulted in higher apparent recovery than cowpea and groundnut residue incorporation. The recovery of N showed a decreasing trend with higher levels of fertilizer N.

Agronomic efficiency was also higher in plots preceded by fallow (Table 31). Among the green manure and residue incorporation, no significant difference was noticed. Agronomic efficiency decreased with increasing levels of N.

Apparent recovery indicated the efficiency of absorption of applied N and agronomic efficiency indicated the quantity of rice produced per unit quantity of N applied, which is the product of efficiency of absorption as well as utilization. Incorporation of green manure and residue resulted in a decrease in the apparant

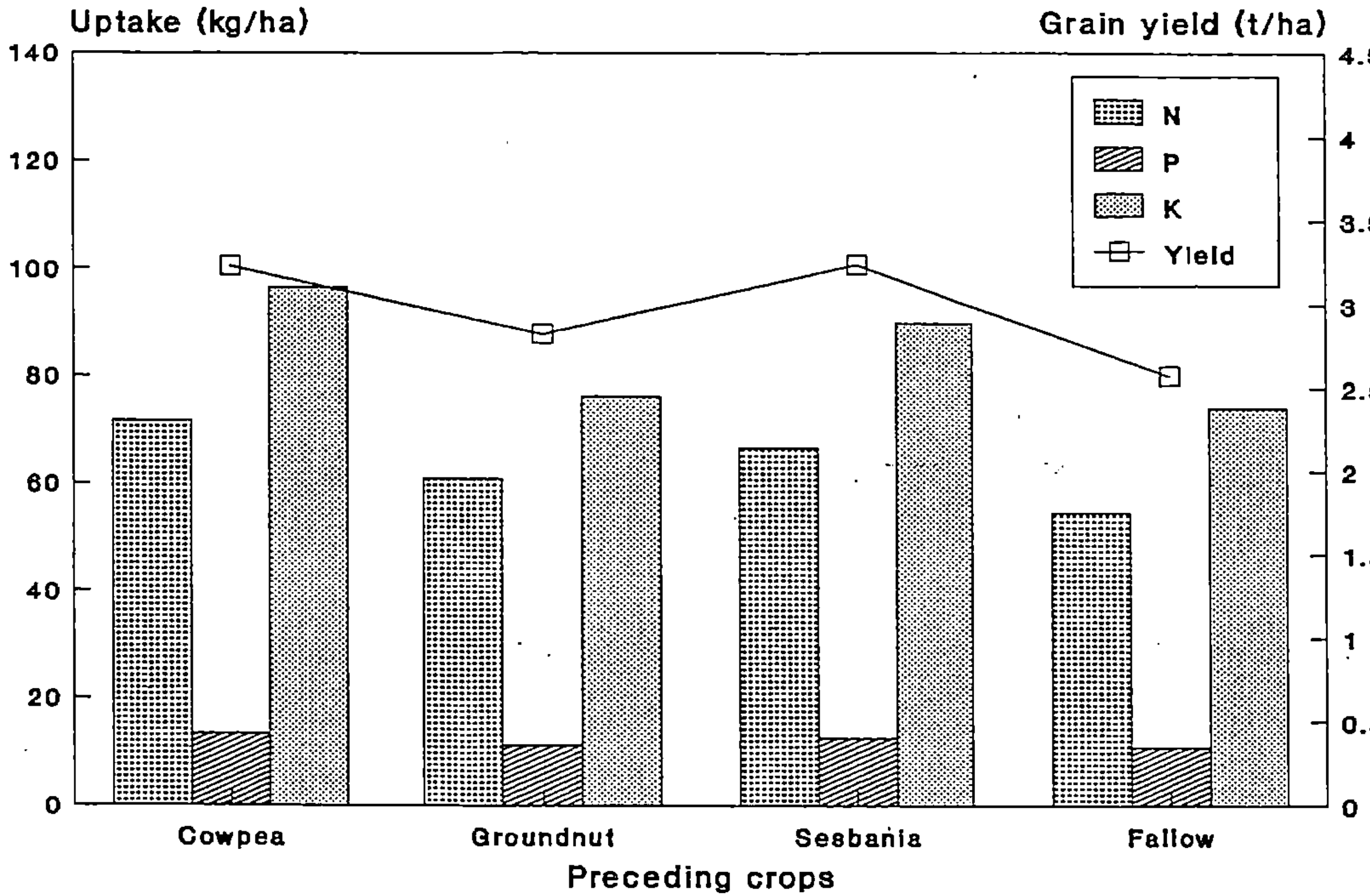

Fig.12. NPK uptake and grain yield of rice as influenced by preceding crops

Table 31. Apparent N recovery and agronomic efficiency in rice as influenced by preceding crops and N levels

Treatments	Apparent N recovery	Agronomic efficiency
Preceding crops (C)		
Cowpea	19.78	7.71
Groundnut	14.79	5.71
Sesbania	20.31	8.58
Fallow	43.02	13.98
N levels (kg/ha)		
35	28.32	10.31
70	23.69	8.56
105	21.43	8.12
SEm± for C	2.18	1.77
SEm± for N	2.11	1.30
CD (0.05) for C	6.36	5.17
CD (0.05) for N	NS	NS

recovery and agronomic efficiency, which can be attributed to their high contribution of N, making more N available to the plant upon mineralization. Naturally, the nitrogen use efficiency would be lower with increased N availability (Siddeswaran, 1992). Westcott and Mikkelson (1987) attributed the lower recovery of green manure N to slow mineralization compared to chemical N.

With increased quantity of N application, the losses of N from the rice soil became larger, thus reducing the recovery of N with corresponding reduction in utilization efficiency.

4.4 Soil fertility in the cropping systems

Data on ammonium-N and nitrate N at various stages of crop growth and at harvest were presented in Table 4 and 7 and discussed thereunder.

Data on available P and K content of the soil after rice crop are presented in Table 32. Available P was maximum in plots receiving groundnut residue incorporation, but on par with plots preceded by sesbania and fallow. N levels found to have no significant effect on available P content of the soil after rice harvest.

Available K was also maximum in treatments incorporated with groundnut residue and sesbania. Available P and K were lower in plots preceded by cowpea residue incorporation. This can be attributed to the increased removal of P and K by grain and straw in cowpea residue incorporated treatments.

The available P content was increased slightly after the different cropping systems even though the available K content was decreased.

Table 32. Available P and K content of soil after rice crop as influenced by preceding crops and N levels (kg/ha)

Treatments	Available P	Available K
Preceding crops (C)		
Cowpea	69.56	149
Groundnut	80.25	187
Sesbania	79.75	188
Fallow	77.31	162
N levels (kg/ha)		
0	76.81	177
35	76.75	163
70	74.69	154
105	77.63	191
SEm± for C	2.39	9.2
SEm± for N	1.54	6.05
CD (0.05) for C	6.85	26.38
CD (0.05) for N	NS	17.35

4.5 Economics of cropping systems

The economic analysis of the cropping systems is given in Table 33 and Appendix II to V. Of the four cropping systems followed, highest net profit (Rs.13847/ha) was obtained from groundnut - rice system along with 105 kg N/ha. But when return from rice alone was considered, maximum profit was obtained from sesbania incorporated treatment with 70 kg N/ha. Since, sesbania did not produce any economic yield, net profit was lower in sesbania-rice cropping system. On comparing groundnut and cowpea, net profit was higher for groundnut, which was the reason for higher net profit for groundnut-rice cropping system, even though rice yield was higher after cowpea residue incorporation.

Thus, additional economic returns from the grain legumes and the beneficial effect of incorporation of their residues on the yield of succeeding rice crop increased the net returns of the cropping systems involving grain legumes.

Return per rupee invested was the highest for cowpea-rice system followed by groundnut-rice system. The higher productivity of the cropping system with integrated nutrient management practices resulted in increased return per rupee invested. From the economic analysis it was obvious that dual purpose grain legumes like cowpea and groundnut were advantageous to farmers in increasing grain yield and net returns.

Future line of work

The regulation of mineralization characteristics in relation to absorption by the plant may be studied.

Table 33. Economics of cropping systems (per ha)

Treatments	Cost of cultivation of rice including fertilizer	Total cost of cultivation of the system	Return from rice			Total return from the system	Net return from the system	Return per rupee invested in the system
			Grain	Straw	Total			
C_1N_0	8910	12010	9450	2296	11746	21546	9536	1.79
C_1N_1	9128	12228	11340	2816	14156	23956	11728	1.96
C_1N_2	9345	12445	12285	3032	15317	25117	12672	2.02
C_1N_3	9563	12663	12180	2792	14972	24772	12109	1.96
C_2N_0	8910	18410	8820	2008	10828	30428	12018	1.65
C_2N_1	9128	18628	10045	2152	12197	31797	13169	1.71
C_2N_2	9345	18845	9940	2336	12276	31876	13031	1.69
C_2N_3	9563	19063	10710	2600	13310	32910	13847	1.73
C_3N_0	8910	9830	8750	2048	10798	10798	968	1.10
C_3N_1	9128	10048	10780	2456	13236	13236	3188	1.32
C_3N_2	9345	10265	13090	3144	16234	16234	5969	1.58
C_3N_3	9563	10483	12740	2872	15612	15612	5129	1.49
C_4N_0	8910	8910	6545	1544	8089	8029	-881	0.90
C_4N_1	9128	9218	9170	2528	11698	11698	2480	1.27
C_4N_2	9345	9345	9240	2440	11680	11680	2335	1.25
C_4N_3	9563	9563	11095	2896	13991	13991	4428	1.46

Cost of cultivation of rice excluding N fertilizer Rs.8910/ha

Preceding crops	Cost of cultivation	Gross return	Level of N for paddy
C_1 Cowpea	Rs.3100/ha	Rs. 9800/ha	N_0 - Nil
C_2 Groundnut	Rs.9500/ha	Rs.19600/ha	N_1 - 35 kg - 78 kg Urea/ha
C_3 Sesbania	Rs. 920/ha	Nil	N_2 - 70 kg - 156 kg Urea/ha
C_4 Fallow	Nil	Nil	N_3 - 105 kg - 233 kg Urea/ha

Price of urea Rs.2.80/kg

Price of paddy Rs.350/q

Summary

SUMMARY

Field experiments were conducted in a sandy loam soil of the Agricultural Research Station, Mannuthy during the summer and kharif seasons of 1993 to evaluate the effect of incorporation of cowpea and groundnut residues on the productivity of succeeding rice crop in comparison to a green manure, sesbania and pre-rice fallow along with different levels of N. Mineralization pattern of organic sources during the growth of rice was also analysed.

The experiment was laid out in a split plot design with 16 treatments replicated four times. The main plot treatments were cowpea, groundnut, sesbania and fallow during the first season of the experiment. In the next season, these plots were split into four, where four levels of N i.e., 0, 35, 70 and 105 kg N/ha were applied after incorporating the green manure and residue.

Biomass yield was higher for groundnut and sesbania which added 7.0 t/ha dry matter and cowpea added 6.8 t/ha. Cowpea produced an economic yield of 0.7 t/ha and groundnut produced 1.4 t/ha. N content was higher for cowpea residue (1.96 per cent) but P (0.22 per cent) and K (2.78 per cent) contents were maximum in sesbania.

For sesbania, C:N ratio was only 16:1 whereas it was 18:1 for cowpea residue and 28:1 for groundnut residue. Cowpea contributed 133 kg N/ha, which was higher than sesbania and groundnut. Sesbania contributed more P (15.4 kg/ha) and K (195 kg/ha) compared to other crops.

Sesbania incorporated treatments recorded higher amount of ammonium-N in soil than groundnut and cowpea residue incorporation till 25 days after transplanting of rice crop and later the difference was narrowed down. Nitrate-N was at its peak 15 DAT i.e., 25 days after incorporation except in the plot where cowpea was incorporated. Here it took 25 DAT to reach the maximum value. Ammonium-N and nitrate-N were minimum in rice plots preceded by fallow.

A peak in mineral N accumulation was observed at 5 days after transplanting or 15 days after incorporation and declined to lower values after 15 days of transplanting i.e., 25 days after incorporation.

Mineralization was faster from sesbania because of its lower C:N ratio and it was the lowest from groundnut residue.

Growth characters like plant height, tiller number, leaf area index and dry matter production were significantly higher in residue and green manure incorporated treatments compared to fallow. These growth characters showed significant response with increasing levels of N.

Leaf area index exhibited an increasing trend up to 40 DAT, and thereafter decreased slightly towards maturity.

Chlorophyll content of rice was more after the incorporation of cowpea residue. Total chlorophyll increased up to 30 DAT and then increased.

Maximum dry matter production was recorded after sesbania and cowpea residue incorporation along with 70 kg N/ha, but in the absence of biomass incorporation there was significant response up to 105 kg N/ha. This showed a saving of around 35 kg N/ha by incorporation of green manure and cowpea residue.

Even though the number of panicles per hill was increased by sesbania and residue incorporation, significant response was absent, but N levels caused significant increase. Sesbania and cowpea residue incorporation produced maximum number of spikelets per panicle and was significantly superior to the rest of the treatments.

Fertility percentage and 1000 grain weight were not affected by preceding crops.

Sesbania and cowpea residue incorporation resulted in a significant grain yield increase of 26 and 25 per cent over fallow and straw yield increase was 12 and 16 per cent respectively for sesbania and cowpea.

For the crop preceded by sesbania and cowpea there was grain yield response only up to 70 kg N/ha but after fallow yield increased up to 105 kg N/ha.

N, P and K contents of grain were maximum when rice was grown after cowpea residue incorporation and the nutrient concentration decreased as the plant matures. K content of straw was significantly superior in cowpea residue incorporated plots.

Total uptakes of N, P and K at harvest were maximum in plots incorporated with cowpea residue which were on par with that of sesbania incorporation.

Nutrient uptake increased with increasing levels of N up to 105 kg N/ha, but application of more than 70 kg N/ha had no significant influence in increasing uptake of nutrients.

Available P and K contents of soil were the lowest after cowpea-rice system closely followed by fallow-rice system. Groundnut-rice and sesbania-rice system were comparable in retaining a higher level of soil fertility.

On analysing the various systems, it was seen that maximum gross return and net return were from groundnut-rice system whereas return per rupee invested was higher for cowpea-rice system.

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* Originals not seen

Appendices

APPENDIX-I

Meteorological data (weekly average) for the experimental period (from 20-2-1993 to 27-9-1993)

Standard week No.	Month and date	Total rainfall (mm)	No. of rainy days	Temperature Max. °C	Temperature Min. °C	Relative humidity Fore-noon %	Relative humidity After noon %	Sun-shine hours	Evaporat-ion mm/day
8	Feb 19-25	2.6	1	34.3	21.9	85	47	8.5	5.1
9	Feb 26-Mar 4	4.0	1	34.0	22.5	77	47	8.3	5.9
10	Mar 5-11	0.0	0	36.4	23.0	73	27	10.3	8.2
11	Mar 12-18	0.0	0	35.1	23.9	85	51	8.9	6.1
12	Mar 19-25	0.0	0	35.3	24.3	84	50	8.7	6.9
13	Mar 26 Apr 1	0.0	0	35.4	24.1	83	52	8.6	6.9
14	Apr 2-8	2.2	1	36.3	23.9	80	54	10.0	6.4
15	Apr 9-15	25.3	1	34.5	24.4	84	56	9.2	5.8
16	Apr 16-22	0.0	0	35.5	25.7	83	54	9.3	5.9
17	Apr 23-29	4.6	2	36.6	26.0	84	55	8.6	6.0
18	Apr 30-May 6	3.0	0	35.3	25.7	84	55	7.9	5.9
19	May 7-13	1.4	1	35.4	25.9	82	56	8.6	6.0
20	May 14-20	31.9	3	34.1	23.8	86	65	6.0	5.1
21	May 21-27	6.0	2	34.5	24.4	88	62	6.6	4.6
22	May 28-June 3	103.8	4	32.8	24.0	90	69	4.3	3.8
23	June 4-10	236.6	6	29.6	23.3	95	80	1.8	3.5
24	June 11-17	237.9	7	29.2	23.8	95	80	1.8	3.5
25	June 18-24	85.5	4	30.4	24.5	94	73	4.4	3.8
26	June 25-July 1	186.4	5	29.2	23.6	94	82	2.9	3.3
27	July 2-8	188.9	6	28.6	22.7	95	78	2.0	3.1
28	July 9-15	167.8	7	28.7	22.6	92	83	1.8	3.1
29	July 16-22	128.1	6	28.9	22.9	94	76	2.8	2.9
30	July 23-29	101.0	6	28.0	23.1	94	80	2.9	3.1
31	July 30-Aug 5	96.4	6	29.1	23.7	95	76	3.6	3.8
32	Aug 6-12	54.9	4	29.9	23.5	95	75	4.6	3.9
33	Aug 13-19	66.3	6	29.2	23.1	93	78	3.3	3.7
34	Aug 20-26	61.9	4	29.8	23.2	96	74	5.6	4.0
35	Aug 27-Sept 2	33.6	2	29.8	23.5	95	73	6.5	3.4
36	Sept 3-9	23.7	2	29.4	23.0	93	75	3.9	3.05
37	Sept 10-16	11.5	1	30.7	23.1	93	69	7.5	3.45
38	Sept 17-23	23.2	3	31.7	23.4	94	63	8.3	4.1
39	Sept 24-30	14.9	1	31.0	23.2	91	65	6.7	3.9

APPENDIX-II

Cost of cultivation and net returns of preceding crops - cowpea (Rs./ha)

Particulars	Cost of materials	Labour charges			Total
		Tractor	Men	Women	
1. Land preparation (Tractor 3 hrs + 2 M)	-	420	100	-	520.00
2. Seed 50 kg @ Rs.14/kg	700	-	-	-	700.00
3. Sowing (1 M)	-	-	50	-	50.00
4. Fertilizer					
Urea (44 kg)	124	-	-	-	124.00
SP (187.5 kg)	656	-	-	-	656.00
MOP (16 kg)	80	-	-	-	80.00
Application (1 M)	-	-	50	-	50.00
5. Irrigation (4 M)	-	-	200	-	200.00
6. Harvesting (13 W)	-	-	-	520	520.00
7. Shelling (5 W)	-	-	-	200	200.00
Total	1560	420	400	720	3100.00

Total return = 700 kg @ Rs.14/kg = Rs.9800
Net return = Rs.6700

Fertilizer

Urea Rs.2.80/kg
SP Rs.3.50/kg
MOP Rs.4.80/kg

Labour charges

Men (M) @ Rs.50/day
Women (W) @ Rs.40/day
Tractor @ Rs.140/hr

APPENDIX-III

Cost of cultivation and net returns of preceding crop - Groundnut (Rs./ha)

Particulars	Cost of materials	Labour charges			Total
		Tractor	Men	Women	
1. Land preparation (Tractor 3 hrs + 2 M)	-	420	100	-	520.00
2. Seed 100 kg @ Rs.14/kg	1400	-	-	-	1400.00
3. Sowing (2 M + 2 W)	-	-	100	80	180.00
4. Fertilizer					
Urea (22 kg)	62	-	-	-	62.00
SP (468 kg)	1638	-	-	-	1638.00
MOP (125 kg)	600	-	-	-	600.00
Application (2 M)	-	-	100	-	100.00
5. Lime (100 kg)	2500	-	-	-	2500.00
Liming and earthing up (15 W)	-	-	-	600	600.00
6. Irrigation (6 M)	-	-	300	-	300.00
7. Harvesting (20 W)	-	-	-	800	800.00
8. Dehulling (20 W)	-	-	-	800	800.00
Total	6200	420	600	2280	9500.00

Total return 1400 kg @ Rs.14/kg = Rs.19600

Net return = Rs.10100

APPENDIX-IV

Cost of cultivation and net returns of preceding crop - Sesbania (Rs./ha)

Particulars	Cost of materials	Labour charges			Total
		Tractor	Men	Women	
1. Land preparation (Tractor 3 hrs + 1 M)	-	420	50	-	470.00
2. Seed 20 kg @ Rs.15/kg	300	-	-	-	300.00
3. Sowing (1 M)	-	-	50	-	50.00
4. Irrigation (2 M)	-	-	100	-	100.00
Total	300	420	200	-	920.00

Net return - Nil

APPENDIX-V

Cost of cultivation of paddy excluding cost of N fertilizers (Rs./ha)

Particulars	Cost of materials	Labour charges			Total
		Tractor	Men	Women	
1. Nursery preparation (3 m)	-	-	150	-	150.00
2. Seed 80 kg @ Rs.6.50/kg	520	-	-	-	520.00
3. Uprooting (7 W)	-	-	-	280	280.00
4. Main field prepartion (Tractor 10 hrs + 10 M + 4 W)	-	1400	500	160	2060.00
5. Transplanting (25 W)	-	-	-	1000	1000.00
6. Fertilizer					
SP (219 kg)	765	-	-	-	765.00
MOP (58 kg)	280	-	-	-	280.00
Application (2 M)	-	-	100	-	100.00
7. Herbicide					
Butachlor (2 kg)	540	-	-	-	540.00
Application (1 M)	-	-	50	-	50.00
8. Plant protection					
Dimacron (500 ml)	240	-	-	-	240.00
Hinosan (500 ml)	225	-	-	-	225.00
Application (2 M)	-	-	100	-	100.00
9. Water management (8 M)	-	-	400	-	400.00
10. Harvesting (20 W)	-	-	-	800	800.00
Threshing (4 M + 20 W)	-	-	200	800	1000.00
Cleaning and drying (10 W)	-	-	-	400	400.00
Total	2570	1400	1500	3440	8910.00

Pesticides

Butachlor	Rs.180/kg
Dimacron	Rs.48/100 ml
Hinosan	Rs.45/100 ml

ABSTRACT

An experiment was conducted at the Agricultural Research Station, Mannuthy during the summer and kharif seasons of 1993 to evaluate the effect of cowpea and groundnut residue incorporation on the productivity of succeeding rice crop in comparison to a green manure *Sesbania rostrata* and a pre-rice fallow under four levels of N (0, 35, 70 and 105 kg/ha). The experiment was laid out in a split plot design with four replications.

Biomas yield on dry weight basis was higher for groundnut and sesbania (7.0 t/ha) while N accretion was higher from cowpea (133 kg N/ha).

Extractable ammonium in the soil was the highest in sesbania incorporated treatments and minimum in plots preceded by fallow. Sesbania underwent faster mineralization compared to residues and mineral-N accumulation reached a peak 15 days after incorporation.

Cowpea residue and sesbania incorporation resulted in higher plant height and tiller production. The dry matter production of rice by incorporation of sesbania was on par with cowpea residue when 70 kg N/ha was applied for rice. Sesbania incorporated treatments recorded the highest leaf area index whereas chlorophyll content at boot leaf stage was maximum in cowpea residue treated plots.

Number of spikelets per panicle and total number of spikelets per panicle were higher in sesbania incorporated treatments which was on par with that of cowpea residue treated plots.

Grain yield was higher after sesbania (3.24 t/ha) and cowpea residue (3.23 t/ha) incorporation and sesbania along with 70 kg N/ha produced the highest grain yield of 3.74 t/ha.

N, P and K contents of grain were maximum when rice was grown after cowpea residue incorporation. Total uptakes of N, P and K at harvest were also the highest after cowpea residue incorporation which was statistically similar to that of sesbania incorporation.

Even though NPK uptake increased by application of 105 kg N/ha, they were on par with 70 kg N/ha.

Groundnut-rice system and sesbania-rice system were comparable in retaining a higher level of soil fertility.

Net income was higher from groundnut-rice system whereas return per rupee invested was higher for cowpea-rice system.