

**INTEGRATED NITROGEN MANAGEMENT FOR
WET SEEDED RICE BASED CROPPING SYSTEM**

Thesis submitted in part fulfilment of the requirements for the award of the
Degree of Doctor of Philosophy (Agriculture) in Agronomy
to the Tamil Nadu Agricultural University, Coimbatore.

By

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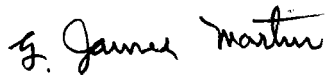
**DEPARTMENT OF AGRONOMY
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2002

CERTIFICATE

This is to certify that the thesis entitled "INTEGRATED NITROGEN MANAGEMENT FOR WET SEEDED RICE BASED CROPPING SYSTEM" submitted in part fulfillment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) in AGRONOMY to the Tamil Nadu Agricultural University, Coimbatore is a record of **bonafide** research work carried out by **Mr.P.RAJARATHINAM** under my supervision and guidance and that no part of this thesis has not been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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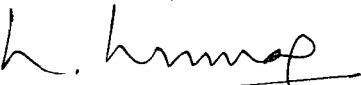
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ABSTRACT

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Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during *Kharif*, *Rabi* and Summer seasons of 2000-'01 and 2001-'02, with a view to develop integrated nitrogen management package for the wet seeded rice-rice-greengram cropping system.

The field experiments were laid out in a split plot design, keeping the layout undisturbed throughout the course of two years of experimentation and two annual cropping cycles of wet seeded rice-rice-greengram were tested. Main plot treatments consisted of, S₁ : Rice - Rice - Greengram, S₂ : Rice + *Azolla* - Rice + *Sesbania rostrata* - Greengram, S₃ : Rice + *Sesbania rostrata* - Rice + *Azolla* - Greengram, S₄ : Rice + *Sesbania rostrata* + *Azolla* - Rice + *Azolla* - Greengram, S₅ : Rice + *Sesbania rostrata* + *Azolla* - Rice + *Sesbania rostrata* - Greengram, S₆: Rice + *Sesbania rostrata* + *Azolla* - Rice + *Sesbania rostrata* + *Azolla* - Greengram. Graded levels of inorganic N viz., 0,50,75 and 100 percent recommended N were assigned to sub plots. The

treatments were imposed only to rice crops and greengram was raised as residual crop. After completing the first cropping cycle (2000-'01), the entire biomass of the greengram was incorporated into all the treatment plots. In second cropping cycle (2001-'02), greengram haulms, after picking the pods, were incorporated into the soil.

Biomass production as well as N accumulation were marginally higher in intercropped *Sesbania rostrata*, and dual cropped *Azolla* in *rabi* season than in *kharif* season in both the years.

Dual cropped *Azolla*, intercropped *Sesbania rostrata* and combination of these considerably suppressed the grass weeds, sedges and broad leaved weeds. Inorganic N levels did not vary in their weed suppression in both *kharif* and *rabi* seasons.

The flood water ammoniacal nitrogen was at its peak 15 days after incorporation of *Azolla*, green manure in *kharif* and *rabi* season of both the years of study. However, combination of these organic sources produced higher ammoniacal N than those from individual application of *Azolla* or *Sesbania rostrata*. Fertilization of 100 percent N recorded higher ammoniacal N than other lower levels.

Rice, which was intercropped with *Sesbania rostrata* and dual cropped with *Azolla*, improved the growth and yield attributes, nutrient uptake and yield of rice. Regardless of the season, the beneficial effects *Azolla* and green manure were perceptible in all the four seasons.

Fertilization of 100 percent N had remarkable effect by enhancing the growth, nutrient uptake and yield of rice. However, 50 percent recommended N was sufficient to produce the same response in growth, nutrient uptake and yield of rice. However, 50 percent recommended N was sufficient to produce the same response in growth, nutrient uptake and yield of rice when *Sesbania rostrata* intercropping and *Azolla* dual cropping combination was included in rice.

Organic sources and higher levels of N decreased the agronomic efficiency, physiological efficiency and apparent N recovery, but increased the nitrogen harvest index.

Both organic sources and inorganic N levels to preceding rice crops did not alter the growth characters, yield parameters, uptake and yield of residual greengram in summer season.

The total dry matter production (TDMP) in sole rice was significantly higher upto 100 percent N. In rice + *Sesbania rostrata* or rice + *Azolla*, the TDMP was substantially improved upto 75 percent recommended N level. In rice + *Sesbania rostrata* + *Azolla*, the TDMP markedly improved only upto 50 percent N application.

Fertilization of 100 percent N to rice considerably improved the total grain production (TGP) of the cropping system. But rice, either intercropped with *Sesbania rostrata* or dual cropped with *Azolla*, registered marked increase in TGP upto 75 percent inorganic N. Rice + *Sesbania rostrata* + *Azolla* in both the seasons recorded higher TGP only upto 50 percent N application and beyond that the TGP was comparable with 75 and 100 percent inorganic N levels.

Marginal improvement in soil organic carbon content was observed after first cropping cycle, where either *Sesbania rostrata* or *Azolla* was used individually. Higher magnitude of improvement was observed when both the sources were included. There was substantial improvement in organic carbon status after harvest of summer greengram.

Marginal improvement in soil available N was observed where both green manure and *Azolla* were included in *kharif* rice and *Azolla* or *Sesbania rostrata* in *rabi* rice. Combination of these two organic sources to both the rice crops improved the soil available N considerably.

Rice intercropped with *Sesbania rostrata* and dual cropped with *Azolla* in both *kharif* and *rabi* seasons recorded the highest soil available N indicating the largest net gain from the initial N status.

The soil available P improved after *kharif* and *rabi* rice. But it decreased after summer greengram in all the treatments during both the years of study.

There was a gradual reduction in soil available K in all the treatments after two rice crops and very marginal improvement after summer residual greengram.

The highest net returns from wet seeded rice-rice-greengram system were obtained when rice was intercropped with *Sesbania rostrata* and dual cropped with *Azolla* along with 100 percent inorganic N application. However, this was comparable with 75 percent and 50 percent inorganic N application.

Partial budgeting analysis of using different organic sources and inorganic N levels in cropping system showed that inclusion of organic sources either individually or in combination improved the profitability. Combination of organic sources with progressive increase in inorganic N levels also improved the profitability. However, estimated profit increased at a decreasing rate beyond 50 percent inorganic N level.

Combination of *Sesbania rostrata* intercropping and *Azolla microphylla* dual cropping in rice along with 50 percent inorganic N application in both *kharif* and *rabi* season followed by summer residual greengram is the best integrated nitrogen management package for wet seeded rice - rice - greengram cropping system considering higher productivity, greater profitability and sustainable soil fertility.

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INTRODUCTION

CHAPTER I

INTRODUCTION

Rice is the most important staple food for more than half of the world's population, including regions of high population density and rapid growth. It provides about 21 percent of the total caloric intake of the world population. In India, it is grown in area of 43 million hectares (nearly 22 percent of total cropped area) with a production of 86 million tonnes in the year 2000 and it contributes 20-25 percent of the agricultural GDP. India has to produce 135-145 million tonnes by 2020 to feed the additional 350 million people. To achieve this stupendous task we have to increase the productivity of rice by vertical expansion through high intensive cropping.

Direct seeding of sprouted seeds onto puddled soil, which is called wet seeding, holds special significance in the present day production systems with regard to saving time, labour, energy, profitability and to increase cropping intensity by reducing the turn around period and to avoid arduous operations like nursery preparation and hand transplanting (Subbaiah and Balasubramanian, 2000). Wet seeded rice cultivation could be a viable alternative to transplanted rice (Rachel Sophia Alexander and James Martin, 1995).

Nitrogen is the key to any fertilizer management programme, for it is the means by which the yield potential of modern rice genotypes can be achieved.

In India, 67 per cent of rice soils are estimated to be short of adequate N (Mahapatra *et al.*, 1985). Hence, response of rice to N is almost universal and its adequate supply is to be ensured. Numerous nitrogen response experiments have shown that the recovery of fertilizer nitrogen applied to the rice crop is seldom more than 30-40 per cent. Nitrogen is supplied through the chemical fertilizers which on excess use pollutes underground water and increases the cost of production. Hence, there is renewed interest in organic manuring to partially substitute the fertilizer N and to achieve sustainable productivity.

Green manures and biofertilizers offer good potential along with inorganic fertilizers for sustained high yields of lowland rice. Intercropping of green manure like *Sesbania rostrata* along with wet seeded rice is a new practice for sustaining crop productivity. When allotment of separate land and season for its cultivation and bulkiness of the material for its transport are impracticable, intercropping of *Sesbania rostrata* in wet seeded rice offers tremendous scope.

Biological nitrogen fixation has the potential to meet the substantial portion of the nitrogen required by rice. *Azolla* is a free floating water fern which fixes atmospheric nitrogen in association with the N fixing cyanobacterium. *Azolla-Anabaena* symbiosis fixes considerable amounts of nitrogen in flooded rice field ecological condition and contributes 40-60 kg N ha⁻¹ per rice crop (Kannaiyan, 1992).

In canal irrigated deltaic area of southern India, rice-rice-pulse is a popular rice based cropping system with a greater production potential. It is beneficial to include pulses as the component crops in rice based cropping systems and to utilize the stover as organic manure for the succeeding rice crop. Encouraging results of using greengram haulm as organic source of N to rice have been obtained from different parts of India with fertilizer N economy ranging from 26 to 60 kg ha⁻¹ for rice (Rekhi and Meelu, 1983; Rajendra Prasad, 1985).

An integrated package of biofertilizers, N fixing green manure and inorganic fertilizers will be considered as a holistic approach to maintain soil fertility and sustainability in rice based cropping system (Kannaiyan, 2001). Results of various investigations in India amply indicate the differential magnitudes of complimentary effect through conjunctive use of green manures, biofertilizers and mineral fertilizers to rice (Meelu and Morris, 1987).

Each crop is only a component of cropping system, and nutrient prescription for individual crops and cropping system should consider the residual effects of previous crops. Research work on integrated nitrogen management in wet seeded rice based cropping systems is almost non existing. It is in this context that studies were made on the integrated N management practices involving intercropping of green manure with wet seeded rice fitted in the cropping system along with

biofertilizer and graded doses of inorganic N in wet seeded rice - rice - greengram cropping system with the following objectives:

1. To study the effect of organics with inorganic N levels on the growth and yield of crops in wet seeded rice-rice-greengram cropping system
2. To determine the uptake pattern of major nutrients in wet seeded rice based cropping system
3. To assess the effect of organics and inorganic N levels in wet seeded rice based cropping system on soil fertility
4. To work out the economics of integrated nitrogen management in wet seeded rice based cropping system
5. To develop integrated nitrogen management for wet seeded rice based cropping system.

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REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Wet seeding is becoming increasingly popular in Asia due to increasing labour cost and availability of improved rice varieties for direct seeding and effective herbicide for weed control. Wet seeding technique is an alternative to the labour intensive transplanting of rice. Wet seeding has become an eco-friendly method when sprouted seeds are sown in rows and rotary / conical weeders are used to eradicate weeds, instead of applying herbicide for weed control (IRRI, 2000). Long term trends in the Asian rice farmers' economic environment that also encourage the practice of direct seeding include declining real prices of rice and herbicides and increasing labour costs for transplanting and weeding (De Datta and Flinn, 1986).

De Datta (1986, 1990) reported that the availability of good water supplies through an expanded area under irrigation, relatively inexpensive herbicides, short duration modern varieties and increased labour costs have encouraged many farmers in Malaysia, The Philippines, Thailand and other rice growing countries in both tropical and temperate areas, to switch over from transplanting to broadcast seeding their flooded rice crops. Direct sowing of rice is practiced in Tamil Nadu under conditions of delayed receipt of canal water or due to uncertain monsoon and scarcity for farm labour (Muthukrishnan *et al.*, 1997). Integrated use of organic and biological sources of N with mineral fertilizers is a possible way of not only substituting at least part of the fertilizer N, but also achieving ecologically

sound and sustainable agriculture. The available information on integrated use of different N sources for wet seeded rice and rice based cropping system is briefly reviewed in this chapter.

2.1. Potential advantages

Direct wet seeding offers the advantages of faster and easier crop establishment, reduced labour use, lesser drudgery, earlier crop maturity (8-10 days over transplanted rice), more efficient water use, higher tolerance to water deficit and increased benefit cost ratio (Subbaiah and Balasubramanian, 2000).

Pandey and Velasco (1999) stated that i) depending on the nature of the production system, direct seeding can reduce the labour requirement by as much as 50 per cent, ii) in situations where no substantial reduction in labour requirement occurs, direct seeding can still be beneficial because the demand for labour is spread out over a long time than with transplanting which needs to be completed within a short time, iii) when rainfall at planting time is highly variable, direct seeding may help to reduce the production risk, iv) direct seeding can facilitate crop intensification, and v) irrigation water use can be reduced, if direct seeded rice can be established earlier by using premonsoon showers.

Although transplanting has been the major traditional method of rice establishment in Asia, economic factors and recent changes in rice production technology have improved the desirability of direct seeding methods. The rising labour cost and the need to intensify rice production through double and triple cropping provided the economic incentives for a switch to direct seeding.

2.2. Wet seeding through drum seeder

High cost of transplanting and nursery preparation as well as non availability of labour during peak planting periods can be mitigated by adopting direct wet seeding through drum seeder with proper management practices (Kenchaiyah *et al.*, 2000).

Wang and Sun (1990) observed that the vegetative growth period of machine sown direct seeded rice was shortened by 7 to 15 days and had more productive tillers and highly developed root system than manually transplanted rice.

Okazaki *et al.* (1990) achieved 63 to 73 per cent seed establishment when seeds were sown by using a machine comprising of furrow openers and seed drills and this was 10 per cent higher than the values obtained for direct sowing by broadcasting in submerged fields.

Deepa Thomas and James Martin (1999) evaluated the performance of drum seeder for sowing pre germinated seeds in lines of puddled soil. They concluded that two men could cover an area of 1 ha in a day. The advantages of using drum seeder include sowing in lines, optimum plant stand with required spacing, possibility of growing intercrop of green manure and dual crop of *Azolla* for incorporation, using rotary weeder for weed control and urea solution applicator and harvester.

The direct seeding with drum seeder not only helps in maintaining optimum plant population but also reduces the drudgery of human labour. The duration of wet seeded rice crop is reduced by seven days because of the absence of

transplanting shock and thus helps to avoid water stress at later growth stages (DRR, 1999). Number of tillers per unit area and leaf area index were also more in row sown rice than in broad cast and transplanted rice (Dingkuhn *et al.*, 1990; Bharathi, 1996). The use of drum seeder required 3.8 person-days per hectare, as compared to 57.2 person-days for transplanting (Angadi *et al.*, 2000).

According to Rachel Sophia Alexander and James Martin (1995), direct seeding gave the highest grain and straw yields and was comparable with the yield obtained under transplanted rice. Bhuvanewari (1998) reported that line sowing of rice by drum seeder gave higher grain yield for both *kharif* and *rabi* seasons.

The drum seeding method recorded the highest net return of Rs. 12240 with a benefit cost ratio of 1.23 followed by transplanting (0.97) and broadcasting (0.83); this indicates that the drum seeder method recorded 16 per cent more profit over transplanting and 55 per cent over broadcast method (Subbaiah *et al.*, 2000).

2.3. Effect of intercrop / dual crop on weed smothering

Green manure crop as intercrop has the ability to suppress weeds because of its rapid ground cover. Intercropping not only suppressed weeds, but also reduced weeding cost and gave additional yield (Rao and Shetty, 1976; Bhan and Sushil kumar, 1996). Intercrop / live mulch suppressed weeds more effectively and for longer time than mulches (Brandsaeter, 1996; Masiunas, 1998).

Many researchers in Philippines and India, observed that *Azolla* as a dual crop in rice effectively suppressed *Monochoria vaginalis*, *Echinochloa glaberescens*, *Cyperus difformis*, *Paspalum* sp. (Moody, 1984), *Marsilea* sp.

(Srinivasan and Pothiraj, 1988) suggesting the potential of inoculating *Azolla* for weed management in lowland rice (Satapathy, 1995). Gupta and Lamba (1978) observed that weed control effect of intercropping was ascribable to the smothering effect of the green manure crop.

According to Torres *et al.* (1995) leguminous N₂ fixing green manure intercrop partially shifted the rice weed flora from the common rice weeds. Possibility of growing green manure *Sesbania rostrata* as intercrop with direct seeded and transplanted crop with its incorporation improved yield attributes and enhanced rice yield (Jayachandran and Veerabadran, 1996a,b; Somasundaram, 1991; Sirajul Islam *et al.*, 1999).

2.4. Nitrogen management

Nitrogen is the kingpin of any fertilizer management programme, for it is the key to realise high yield potential of modern genotypes. Nitrogen accounts for 67 per cent of the total amount of fertilizers applied to rice and a balanced, rational use of green manures / biofertilizers with chemical fertilizers may increase the use efficiency.

2.4.1. Biological nitrogen nutrition in rice

Biological nitrogen fixation, which accounts for about 65 per cent of the total N currently being utilized in agriculture, is an important and promising area for practising sustainable agriculture (Goel *et al.*, 1999).

2.4.1.1. Biofertilizer *Azolla*

Azolla is a free floating water fern which fixes atmospheric nitrogen in association with the N₂ fixing cyanobacterium. *Azolla-Anabaena* symbiosis fixes considerable amounts of nitrogen in flooded rice fields ecological condition and contributes 40-60 kg N ha⁻¹ per rice crop (Kannaiyan, 1992).

The escalation of cost of inorganic fertilizers and scanty availability of organic manures attracted the attention of farming community to switch over to the application of biofertilizer for improving grain yield of rice as well as soil health. *Azolla* biofertilizer has gained popularity among the farming community because of its lower cost and lesser skill involved in mass multiplication (Samal, 2001).

The aquatic fern *Azolla* has potential as a green manure because of its high relative growth rate and symbiotic relationship with a nitrogen fixing endophytic cyanobacteria. It can be grown as intercrop with rice and the multiplied *Azolla* can be incorporated in the soil (Sukumar *et al.*, 1988). Besides fixing atmospheric nitrogen, *Azolla* by itself serves as a source of phosphorus and potassium and it enhances the supply of other nutrients (Liu, 1987).

The dual culture method of growing *Azolla* with rice is perhaps the most widespread practice because standing water is available in to the field during the growth of rice. Dual cropping of *Azolla* was found to be more practicable and economical (Singh, 1989). In the dual cropping system, *Azolla* inoculated at 1 t ha⁻¹ grew well under the rice canopy and covered the entire field in 20 days forming a thick mat (Gopaldaswamy *et al.*, 1994).

Cooler day and night temperatures, lower solar radiation, higher humidity and cloudy conditions that prevailed during *rabi* (*Thaladi*) season favoured the multiplication and total N fixation of *Azolla microphylla* to greater extent at Coimbatore (Kempuchetty, 1989), whereas, *Azolla microphylla*, a fast growing and higher nitrogen fixing type with tolerance to higher temperature and salinity could be used as biofertilizer for rice (Kannaiyan, 1992a). Maragatham *et al.* (2001) opined that the exploitation of *Azolla* as biofertilizer in flooded soil conditions, especially during *samba* season, favours the growth of *Azolla* and its multiplication. Kannaiyan (1992) reported that within 20-30 days *Azolla* could multiply and produce biomass ranging from 15 to 25 t ha⁻¹. Anthoniraj *et al.* (1994) reported that *Azolla microphylla* biomass production ranged from 42 to 164 g m⁻² day⁻¹ with a mean production of 91.8 g m⁻² day⁻¹ at Aduthurai.

For direct seeded rice, inoculating *Azolla* at 20 days after sowing (DAS) and incorporating 15 days thereafter and inoculating again at 50 DAS and incorporating at 70 DAS gave higher grain yield (Singh and Singh, 1989). Deepa Thomas (1996) concluded that inoculation of *Azolla microphylla* at 1 t ha⁻¹ 15 DAS and incorporating 15 days later in wet seeded rice recorded significantly higher yield over control at Coimbatore.

2.4.1.2. Nitrogen mineralization from *Azolla*

Decomposition of *Azolla* to ammonia, which is then available as an inorganic fertilizer, is the mode of nitrogen transfer to rice (Talley and Rains, 1980). Ito and Watanabe (1985) found that the organic forms of nitrogen in *Azolla* are less

easily decomposable and thus slowly release ammoniacal N throughout the crop growth leaving a substantial residue for the succeeding crop.

In Asian rice fields, the higher flood water ammoniacal N concentrations following N application, high temperatures common in the tropics, and elevated flood water pH resulting from photosynthetic activity create a favourable environment for ammonia loss (Fillery *et al.*, 1986; Vlek and Crasswell, 1981). So, the application of neem cake during incorporation of *Azolla* mutants could ensure gradual and continuous release of ammoniacal nitrogen during mineralisation which would be readily assimilated by rice crop during critical growth stage (Kumar and Kannaiyan, 1998).

The mineralisation of *Azolla* fresh biomass reached maximum between 2 to 3 weeks after incorporation and declined thereafter (Kannaiyan, 1995). Kumar and Kannaiyan (1993) reported that increased accumulation of ammoniacal N in the flood water was due to incorporation of *Azolla* mutants. Maximum accumulation of ammoniacal nitrogen in the flood water was observed on day 15 and maintained till day 20 after incorporation of *Azolla* hybrids (Gopaldaswamy and Kannaiyan, 1998).

2.4.1.3. Effect of *Azolla* on growth and yield components of rice

The entire nitrogen requirement of rice can not be met through *Azolla*, but its combined application with chemical N fertilizers ensures higher grain yield (Singh and Singh, 1986; Singh, 1989). However, beyond a certain level, application of N fertilizer inhibits the growth and N₂ fixation of *Azolla* (Ito and Watanabe, 1983).

The application of *Azolla* increased the number of tillers with increase in levels of nitrogen (40 to 60 kg N ha⁻¹), but with 90 and 120 kg N ha⁻¹, there were no further increase in the number of tillers. Similarly, *Azolla* inoculated plots showed significant increase in the number of filled grains per panicle over no *Azolla* plots (Sevichan and Madhusoodanan, 1998).

Surender Rao and Sitaramayya (1997) reported that growing of *Azolla* as a dual crop with rice resulted in significantly more tillers, longer panicles and more spikelets per panicle. The number of panicles m⁻², filled grains per panicle and grain and straw yields were higher with neem coated urea and *Azolla* as dual crop (Latha and Subramanian, 1986). The substitution of 25 kg N through *Azolla* increased the number of panicles m⁻², panicle length, panicle weight, filled grains per panicle and less sterility per cent (Kannan, 1982).

2.4.1.4. Effect of *Azolla* on yield of rice

Application of urea super granules alone at 100 kg N ha⁻¹ or in combination with *Azolla* in the ratio of 25:75 enhanced the growth and yield of rice (Chandrasekharan *et al.*, 1988) at Coimbatore. Jeyaraman (1991) reported that green manuring of *Azolla* along with 75 kg N ha⁻¹ could produce higher grain yield than control at Madurai. There was an average increase of 9-11 per cent in yield with the application of *Azolla* relative to the control (Sharma and Mitra, 1990).

Combination of *Azolla* at 1 t ha⁻¹ plus 60 kg N ha⁻¹ gave significantly higher grain yield than fertilizer alone at that level at New Delhi (Singh *et al.*, 1992). *Azolla* application significantly enhanced grain yield followed by *Gliricidia* over 100 per cent N as urea (Surender Rao and Sitaramayya, 1997).

Azolla microphylla was inoculated at 1 t ha⁻¹ at 10 days after transplanting and was found to augment the grain yield by 21 percent (Gopaldaswamy and Anthoniraj, 1997). In a research conducted at West Bengal, the highest grain yield along with uptake of N,P and K was recorded with the application of *Azolla* at 10 tonnes ha⁻¹ plus 30 kg N ha⁻¹ each at basal, active tillering and panicle initiation stages during dry season, while *Azolla* at 10 tonnes ha⁻¹ plus 15 kg N ha⁻¹ each at basal, active tillering and panicle initiation stages recorded the highest yield in wet season (Singh and Mandal, 1997).

Thamizh Vendan *et al.* (1999) reported that dual cropping of *Azolla microphylla* with rice enhanced soil available N status and grain yield at Aduthurai. Inoculation of *Azolla* at 10 t ha⁻¹ combined with the application of 60 kg N ha⁻¹ gave the highest grain yield of 4924 kg ha⁻¹ with an increase of 56 percent over that of an inoculated control (3152 kg ha⁻¹) at Orissa (Samal, 2001).

2.4.1.5. Effect of *Azolla* on nutrient uptake in rice

In lowland rice situations, *Azolla* N is slowly mineralised and the efficiency in a single crop season is about 70 percent of fertilizer N (Watanabe *et al.*, 1977). Though the decomposition of *Azolla* is rapid, the release of N is slow (Singh, 1978).

Sharma and Mahapatra (1990) revealed that N uptake (146.5 kg ha⁻¹) was higher at 120 kg N ha⁻¹ through urea super granules (60 kg N) + *Azolla* (60 kg N) and showed better supply of N to the rice through combinations of inorganic and organic sources of N than inorganic sources alone. Research conducted at Cuttack revealed that the intercropping of P enriched *Azolla caroliniana* at 1 t ha⁻¹ at different urea N levels (0-60 kg N ha⁻¹) gave significantly higher N uptake of rice

than that of unenriched *Azolla caroliniana* at 1 t ha⁻¹ (Singh, 1998). Singh and Mandal (1997) reported that N, P and K uptake by grain as well as straw was increased significantly over the control due to *Azolla* inoculation at 10 tonnes ha⁻¹ in West Bengal.

The review reveals that *Azolla* could be a renewable biofertilizer representing a self supporting biological system and this potential group of N₂ fixing *Azolla* could be effectively exploited under lowland conditions.

2.4.1.6. *Azolla* on nitrogen economy

Application of *Azolla* along with fertilizer nitrogen can scavenge fertilizer nitrogen, an advantage in intensive culture with large inputs of organic and inorganics (Lumpkin, 1987). *Azolla* as a single crop could contribute 50 kg N ha⁻¹ to rice and play a supplementary role in nitrogen supply (Singh, 1989). However, Esiobu *et al.* (1991) stated that two or three crops of *Azolla* raised along with rice produced yields equivalent to that of 90 kg ha⁻¹ of inorganic nitrogen application. Kolhe and Mitra (1990) found that incorporation of *Azolla* before planting at 10 t ha⁻¹ resulted in saving of 40 to 90 kg ha⁻¹ of fertilizer nitrogen. Under flooded ecosystem, individual inoculum of blue green algae and *Azolla* contributed 25-30 kg N and 40-60 kg N ha⁻¹ in rice respectively (Kannaiyan *et al.*, 1990). Manjappa *et al.* (1991) reported that the grain yield obtained with 30 kg N ha⁻¹ + *Azolla* at 10 t ha⁻¹ (3705 kg ha⁻¹) was equal to yield obtained with 60 kg N ha⁻¹ (3709 kg ha⁻¹).

Kannaiyan (1992) opined that biological nitrogen fixation through *Azolla-Anabaena* complex is considered to be a potential biological system by

contributing 40-60 kg N ha⁻¹ besides increasing rice yield at comparatively low cost in lowland rice cultivation. Combined application of *Azolla* and blue green algae can reduce the fertilizer requirement of the rice crop to the extent of 60 kg N ha⁻¹. Under the optimal condition, *Azolla* doubles its biomass in every 3-5 days and a single crop of rice can be expected to accumulate between 70 to 110 kg N ha⁻¹. Mandal *et al.* (1993) reported that grain yield response with the application of 10 t ha⁻¹ *Azolla* was found to be equivalent to an application of 60 kg N ha⁻¹ in dry season; Whereas in wet season, 5 to 10 t ha⁻¹ gave response equivalent to an application of 30 kg N ha⁻¹ as urea.

Gopaldaswamy and Anthoniraj (1997) stated that applying biofertilizer individually or in combination, a reduction of only 25 kg N ha⁻¹ over the recommended levels can be adopted without sacrificing the grain yield. *Azolla* accumulates the N₂ fixed by its symbiont *Anabaena Azollae* in its fronds during its growth and releases it to the crop after its decomposition contributing 30-60 kg N ha⁻¹ (Lakshmanan *et al.*, 1997). Skipping of the second top dressing of fertilizer N with 25 kg ha⁻¹ which coincided with *Azolla* trampling saved the fertilizer and labour for top dressing besides significantly increased the rice yield (Thamizh Vendan *et al.*, 1998). Joyanthi *et al.* (1998) reported that the effect of 10 t ha⁻¹ of *Azolla* alone was found to be equivalent to an application of 40 kg mineral N.

A clear understanding of biological N₂ fixation in the lowland rice soil ecosystem would lead to high rice yields through more efficient use of fertilizer N with simultaneous utilization of biofertilizer, thus achieving N economy.

2.4.2. Organic nitrogen nutrition in rice

The practice of intensive agriculture led to wide use of higher doses of chemical fertilizers, but insufficient use of organics led to decrease in soil fertility and soil structure (Palaniappan and Annadurai, 1999). Hence inclusion of organics in rice ecosystem will help sustain the yield and improve the soil fertility.

2.4.2.1. Green manures

Green manure refers to a plant material incorporated to the soil while green or soon after maturity for improving the soil (Soil Science Society of America, 1978). Green manure crops can be grown *in situ* or brought from outside.

The objectives of green manuring are to increase the organic matter content of soils, to maintain and improve soil structure, to reduce loss of nutrients particularly N, to provide a source of N for the succeeding crop and to reduce soil erosion and thereby increase the production of crop (Dyke *et al.*, 1976; Greenland *et al.*, 1979).

An ideal green manure crop for lowland rice should possess the following traits; early establishment and high seedling vigour, tolerance to flooding and drying, early onset of N₂ fixation and its efficient sustenance, fast growth with an ability to accumulate large biomass and N within 4 to 6 weeks of its growth, ease of incorporation, quick decomposability, and pest resistance (FAO, 1977; IRRI, 1988; Cosico, 1990).

At 30 days after direct seeding of rice, bulk density of surface layer was significantly lower and root growth was more vigorous under green manure system

than without green manure. Consequently at harvest, tillers and biomass and grain yield of rice under green manure system were significantly higher than that under without green manure system (Aggarwal *et al.*, 1997).

2.4.2.2. Use of *Sesbania rostrata* as green manure

For efficient rice farming, the cheaper, and higher quantity of biomass can be created through green manure crop like *Sesbania rostrata*. It is an introduced crop from Africa. It is preferred by the farmers because of its high biomass in shorter duration, high nodule numbers and easy decomposition. When this green manure is incorporated for rice before transplanting, about 50-80 kg of fertilizer N equivalent ha^{-1} could be achieved within 50-60 days at Coimbatore (Rangasamy *et al.*, 1997).

Sesbania rostrata, has been shown as promising green manure crop in rice farming systems due to its high N_2 fixing potential, fast growth and tolerance to flooding (Rinaudo *et al.*, 1983; Alazard *et al.*, 1987). Green manure species such as *Sesbania rostrata* and *Aeschynomene afraspera* can fix sufficient amount of nitrogen for optimum rice yields without any inorganic nitrogen input (Becker *et al.*, 1990; Meelu, *et al.*, 1992).

Becker *et al.* (1986) reported that stem nodulating ability of *Sesbania rostrata* provides an opportunity to fix nitrogen under water logging and high soil nitrogen conditions. *Sesbania rostrata* could add substantially higher amounts of nitrogen than is required by rice crop (Ladha *et al.*, 1988). Besides producing an economic seed yield, it is known to contribute significant amounts of soil nitrogen in rice fields (Buresh and De Datta, 1991). Balasubramani *et al.* (1992) have

reported that nitrogenase activity was significantly higher in stem nodules than in the root nodules of *Sesbania rostrata*.

Srinivasulu Reddy and Palaniappan (1987) reported that 30, 45 and 60 days old *Sesbania rostrata* can produce 19.0, 31.2 and 46.0 t ha⁻¹ biomass and accumulated 74, 132 and 186 kg N ha⁻¹ respectively. Under optimal conditions, 45 days old *Sesbania rostrata* produces 31.2 t ha⁻¹ biomass accumulating 132 kg N ha⁻¹ (Palaniappan and Srinivasulu Reddy, 1988). Compared to grain legumes like blackgram, soybean and cowpea, *Sesbania rostrata* produced the highest biomass (19.62 t ha⁻¹) and N accumulation (146.6 kg ha⁻¹) (Palniappan *et al.*, 1991). Manguiat *et al.* (1992) stated that a 56 day old green manure crop of *Sesbania rostrata* gave an average dry matter yield of 6.18 t ha⁻¹ with a nitrogen accumulation 159 kg ha⁻¹.

The above research reports indicate the potential of *Sesbania rostrata* as a green manure for rice under diversified rice agro-ecosystem.

2.4.2.3. Intercropping of *Sesbania rostrata* in rice

Though intercropping has been practiced from time immemorial, green manure intercropping in rice ecosystem is of recent origin. The main objective of intercropping green manure in rice is to achieve a substantial increase in rice yield with an additional yield of green manure for building up the soil fertility (Ramanathan, 1995). Separate land and season for its cultivation and bulkiness of the material for its transport stand in the way of adopting green manuring in rice cultivation. Hence, intercropping of *Sesbania rostrata* in rice field under waterlogged conditions is found to be an economically feasible and viable

proposition to reduce the requirement of inorganic fertilizer N for rice (Tsien *et al.*, 1983).

Sesbania rostrata interplanted at 10 x 200 cm and 10 x 150 cm produced 3 and 4 t of dry matter ha⁻¹ respectively and their decomposition released an average of 70 kg N ha⁻¹ (Mulongoy, 1986). Liu Chung Chu (1988) found that broadcasting of *sesbania* seeds in the wide intervals of double wide narrow spaced rice in the early season did not affect the yield of early rice at China.

Sirajul Islam *et al.* (1999) reported that the *Sesbania rostrata* did not compete with rice for moisture, as it was under wetland situation; for nutrients because of its deeper root and its self-nitrogen fixing ability; and for light because of wide spacing and thin canopy. Stem and root nodulating *Sesbania rostrata* was more superior than the root nodulating *Sesbania aculeata* and *Sesbania speciosa* in biomass production, nitrogen fixation and nitrogen content over a period of 60 days. Biomass producing capacity of *Sesbania rostrata* and *Azolla microphylla* was high when grown as dual crop in rice than as sole crop; harnessing of stem nodule nitrogen fixing system meets 25-50 percent of the nitrogen requirement of rice (Sundaravarathan and Kannaiyan, 2001).

2.4.2.4. Time of incorporation of green manures

The success of green manuring depends on the correct stage of trampling green matter into the soil and giving sufficient interval before sowing or planting the crop. In broadcast crop, usually the intercropped green manure is incorporated during the first weeding (Palaniappan and Annadurai, 1999).

Bhardwaj (1982) showed that higher rice yield could be obtained when rice was transplanted almost immediately after incorporating the green manure. At Coimbatore, incorporation of green manure at 45 days of growth and after a week of incorporation, rice could be raised with 100 kg N ha⁻¹ to obtain higher yield and to maintain soil productivity and soil fertility (Rajeswari, 1990).

Age of the green manure has a definite impact on its N content, with optimal levels reaching at 45 days (Yadvinder Singh *et al.*, 1991). Ramanathan (1995) reported that intercropping of *Sesbania rostrata* in rice and subsequent incorporation of whole plant at 45 days after transplanting produced higher biomass, while the pure stand of rice without green manure recorded the largest dry matter production.

Joseph (1998) reported that intercropping and incorporation of daincha at 35 DAS in standing rice field was beneficial for growth and yield of wet seeded rice. Anandhakrishnaveni *et al.* (2001) reported that when 25 days old seedlings of *Sesbania rostrata* were transplanted in the rogue spacing of rice at 1.5 m interval and incorporated at 45 DAT, the rice grain yield was improved.

2.4.2.5. Nitrogen mineralisation from green manure

For higher productivity, optimum nitrogen nutrition is essential to keep the soil ammonium concentration at higher level for utilization by the rice crop under lowland conditions (Sharma and Mahapatra, 1990). The magnitude of ammonium formation under submerged conditions is mainly dependent on the source and rate of applied N and organic matter content (Sahrawat, 1983).

In lowland rice ecosystem, high flood water ammoniacal N concentration following N application, high temperatures prevailing in the tropics and elevated flood water pH resulting from photosynthetic activity create a favourable environment for ammonia loss (Craswell and Vlek, 1979; Fillery *et al.*, 1986). Craswell and Vlek (1979) explained that aqueous ammonia content in flood water increased about 10 fold per unit increase in pH over the pH range 7.5 to 9.0. At constant total ammoniacal N concentration and pH, aqueous ammonia increased almost linearly with increasing temperature, resulting in nearly a four fold increase in the range from 10 to 40°C. Release of ammoniacal N from green manure was initially rapid, but slowed down markedly in a fairly short time (Bhardwaj and Dev, 1985).

Somasundaram (1991) reported that the concentration of ammoniacal N in the flood water increased upto five days after incorporation and thereafter the trend was inconsistent. Only traces could be obtained after 15th day of incorporation in green manure incorporated plots.

Thiyagarajan *et al.* (1994) indicated that the N demand during the initial stage of crop growth could be met from the N mineralised from soil organic matter itself. Nagarajah (1988) showed that ammonium N is rapidly released from incorporated *Sesbania* and *Azolla* in the tropical conditions. Nonetheless, if this release of ammonium N from green manure N does not meet the N requirements of rice or match the N uptake pattern of rice, supplemental applications of chemical N fertilizer will be needed for high yields.

Green manure at low levels of N (upto 40 kg ha⁻¹) reduced the volatilisation loss and the trend was reverse with increasing N levels (upto 120 kg N ha⁻¹) (Chakravorthy *et al.*, 1989). Sur *et al.* (1993) reported that the peak ammonium N accumulation occurred 15 days after green manure incorporation.

Rate of ammonification attained peak during 35 days after incorporation of green manure (Dey and Jain, 1996; Pramanik and Mahapatra, 1997). In general, mineralisation rates from applied green manure were higher during the first week of its incorporation (Dinesh and Dubey, 1998) and it extended till 20 days after transplanting (Alain Clement *et al.*, 1998) in all soils, thereafter the process got slowed down.

Beena Jacob *et al.* (1999) reported that the higher ammonium N level in soil was maintained only upto 15 DAT and then started declining. The mineralisation pattern of green manures showed that incorporation of 45, 55 and 65 day old plants resulted in the release of 112, 80 and 76 kg N ha⁻¹ respectively after 49 days of incubation (Kumar, 2001).

The ammoniacal N release from *Sesbania rostrata* was studied in flooded soil and it was found that more ammoniacal N was released from 60 day old than 48 day old *Sesbania rostrata*. Accumulation of soil ammonium from *Sesbania rostrata* was faster and larger than that from *Azolla microphylla* (Kumar, 2001).

Sundaravarathan and Kannaiyan (2001) opined that incorporation of N₂ fixing green manures *viz.*, *Sesbania rostrata* and *Azolla microphylla* with prilled urea recorded higher ammoniacal N release on seventh day after incorporation, while green manuring along with neem cake application resulted in gradual release

of ammoniacal N. Higher accumulation of ammoniacal N in flood water was observed on 14 and 21 days after incorporation of *Azolla microphylla* and *Sesbania rostrata* respectively.

2.4.2.6. Effect of *Sesbania rostrata* on growth and yield components of rice

Solaiappan *et al.* (1996) revealed that incorporation of *Sesbania rostrata* increased the plant height, leaf area index, dry matter production and total tiller production in semi dry rice.

Jayapaul *et al.* (1995) reported that intercropping of *Sesbania rostrata* seedlings at intra row spacing of 15 cm and incorporated at 45 DAT in the standing rice field positively increased the yield parameters such as panicle number, panicle length and filled grains per panicle, resulting in higher grain yield in wet seeded rice at Madurai.

Incorporation of *Sesbania rostrata* significantly increased the plant height, tiller numbers, grain and straw yield of rice over application of prilled urea alone and *Azolla microphylla* incorporation (Sundaravanthan and Kannaiyan, 2001).

2.4.2.7. Effect of *Sesbania rostrata* on yield of rice

Intercropping of *Sesbania rostrata* raised at 1.5 m interval in rice and ratooned along with the application of 50 and 100 kg N ha⁻¹ to rice gave 7 and 13 per cent more grain yield respectively than that of pure stand of rice (Balasubramanian, 1989). Halepyati and Sheelavantar (1990) indicated that grain and straw yields of rice significantly increased with the increase in the density of *Sesbania rostrata* incorporated in the soil.

Alagappan (1990) reported that transplanting of *Sesbania rostrata* seedlings 30 DAS as intercrop in rice with different levels of N resulted in considerable amount of N accumulation and recorded the highest rice yield. Becker *et al.* (1991) stated that when *Sesbania rostrata* was intercropped and incorporated during the dry season, rice yield averaged 6.27 t ha⁻¹ after *Sesbania rostrata*, whereas the yield was 5.79 t ha⁻¹ after 60 kg ha⁻¹ mineral N and 3.98 t ha⁻¹ without nitrogen input. Kalidurai and Kannaiyan (1992) observed an increase of rice yield by 127 per cent over control, when a biomass of 20 t ha⁻¹ of *Sesbania rostrata* was applied.

Raising *Sesbania rostrata* as intercrop in 2 rows all around rice plot at 2.5 m interval and incorporation at preflowering stage resulted in yield which was on par with basal incorporation of 12.5 t of *Sesbania rostrata* or *Sesbania speciosa* or *Cassia nigricans* (Alwar Arunachalam, 1996). Solaiappan and Veerabadran (1997) revealed that intercropping and incorporation of *Sesbania rostrata* significantly increased grain (4.6 t ha⁻¹) and straw (8.2 t ha⁻¹) yield which was 9.4 and 9.3 per cent higher than control.

2.4.2.8. Effect of green manuring on nutrient uptake in rice

Bhardwaj and Dev (1985) reported that N uptake between green manured and N fertilized crops did not vary and it ranged from 150 to 175 kg ha⁻¹. The N content of rice grain and straw with *Sesbania rostrata* intercropping was higher by 50 per cent over that of no green manure applied plots (Dreyfus *et al.*, 1985). Higher N uptake of rice was recorded when it was green manured than that of the application of urea alone. This indicated a better synchrony between green manure

N availability and rice N uptake (Manguiat *et al.*, 1997; Alain Clement *et al.*, 1998). Bhagat *et al.* (1988) reported that green manuring along with fertilizer N application in splits showed minimum leaching loss and more N uptake by rice.

According to Diekmann (1990), depletion of exchangeable ammoniacal N was primarily due to plant N uptake; Exchangeable ammoniacal N depletion was faster in direct seeded rice, presumably because of its higher growth rate during the vegetative stage and its more rapid N uptake. Because transplanted rice suffered from transplanting shock, its plant nitrogen uptake was lower than that of direct seeded rice during the first 20 days after application with delay in exchangeable ammoniacal N depletion by plant absorption.

Balasubramaniyan *et al.* (1993) reported that *Crotalaria juncea*, grown *in situ*, incorporated at 45 day of growth a week before transplanting significantly increased the N, P and K uptake over no green manure in lowland rice.

2.4.2.9. Green manure on nitrogen economy

Green manuring, which is of organic origin, offers the benefits of improving soil quality and fertility enhancement while meeting a part of nutrients need of crops (Vinod Kumar *et al.*, 1999). The use of green manures along with fertilizer N could help in nitrogen economy in lowland rice (Khind *et al.*, 1983). Application of green manure reduced denitrification, volatilisation and leaching losses of nitrogen and thus reducing the total N losses by 19 to 46 per cent (Mu and Qian, 1983).

Application of green manure along with inorganic nitrogen increased the mineralization of soil nitrogen, improved biological activity of the soil and reduced

nitrogen losses (Hesse, 1984). Green manuring is reported to increase the grain yield of rice substantially, contributing 30 to 60 kg N ha⁻¹ to the rice crop (IRRI, 1987; Goswami *et al.*, 1988; George and Prasad, 1989). Green manuring has been successfully adopted to improve the soil productivity, especially the soil available nitrogen. It can partially substitute the nitrogen fertilizer requirement of the subsequent crop (Meelu and Singh, 1991).

Matiwade and Sheelavantar (1994) found that 100 per cent of nitrogen required by rice crop could be substituted by green manuring with *Sesbania rostrata* alone. Integrated use of *Sesbania* and prilled urea saves more than 60 per cent of chemical N (Mahapatra and Sharma, 1996). Metha *et al.* (1996) found that green manuring may substitute upto 32 kg N ha⁻¹ (40 per cent of 80 kg N ha⁻¹).

The foregoing research evidence suggests that there is possibility of considerable fertilizer N economy in rice farming, if a suitable green manure of optimum age could be turned down in rice crop.

2.4.3. Inorganic nitrogen nutrition in rice

Of the three primary nutrients, nitrogen is the most deficient in Indian soils and it is also difficult to retain in soils due to various loss mechanisms, such as surface run off, ammonia volatilization, leaching and denitrification. Further more, nitrogen is the key nutrient to protein content of food grains and is thus removed in the largest amount (Rajendra Prasad, 2000). Nitrogen plays a predominant role in growth, development and yield of wet seeded rice (Malla Reddy and Bhaskar Reddy, 1999).

2.4.3.1. Nitrogen mineralisation from urea nitrogen

The transformation and availability of N in submerged soil are different from that of aerobic soil. Flooding the soil resulted in accumulation of ammoniacal N due to the instability of nitrate, coupled with low N released from organic matter decomposition (Savant and De Datta, 1982; Farroqui *et al.*, 1983).

The inorganic N fractions, more particularly NH_4^+ -N contribute an extremely dynamic N system in the soil and is the most influencing factor for rice production. Ammonification, the first step in mineralisation is the biological conversion of organic forms of N into inorganic N, *viz.*, NH_4^+ -N. It is essentially a catabolism of amino acids and presumably includes several types of deamination reactions.

The ammonification process is affected by several factors including soil temperature, physical treatments like puddling, moisture level, wetting and drying, quality of organic matter in the soil, clay content etc. (Ponnamperuma, 1972).

When N is applied as prilled urea by broadcast, it is quickly converted into ammonium form. In the aerobic layer of rice soil, it is converted to nitrate by *Nitrosomonas* and *Nitrobacter* and leached down to lower an aerobic zone. Where it is denitrified and lost as N_2 and N_2O gases into the atmosphere (Patrick and Mahapatra, 1968; Patrick and Tusneem, 1972).

The broadcast urea may persist largely in the urea form in the flood water 4 to 5 days after application and urea molecules are weakly adsorbed by soil colloids leading to loss of N through leaching (Craswell *et al.*, 1981).

Nitrification, biological oxidation of NH_4 to NH_3 , is common in rice soils, which leads to the loss of nitrogen. The nitrate formed in the oxidised layer diffused to anaerobic zone to undergo sequential reduction to NO_2 , NO_3 , N_2O and N_2 (Savant and De Datta, 1982; Mosier *et al.*, 1982).

The content of ammoniacal N in the soil was the highest at tillering stage and decreased thereafter to maturity, the reduction being more conspicuous after panicle initiation stage; control plots had the lowest NH_4^+ -N content (10 ppm) and it increased to double or more with the application of 84 and 112 kg N ha^{-1} (Bhardwaj and Singh, 1992). Talukdar *et al.* (1996) reported that concentration of NH_4^+ -N was higher at 30 days after transplanting (DAT) and then it gradually decreased at 60 and 90 DAT.

2.4.3.2. Time of N application on growth and yield of rice

Application of appropriate quantity of urea N at the right time is therefore one of the important agronomic techniques to increase yield and N uptake of the direct seeded rice crop (Bhattacharya and Singh, 1992).

In wet seeded rice, the seedlings take some time to establish and the nutrients in the seeds are sufficient to sustain 15 days of seedling growth and hence the basal N application can be reduced to a minimum (Maurya and Vaish, 1984). Studies on time of N application to direct seeded lowland rice indicated the advantages of delaying first dose of N upto first weeding or maximum tillering stage of 30 to 40 DAS (Mahapatra *et al.*, 1986).

Application of N in four splits at sowing, active tillering, late tillering and panicle initiation stages to a semi dwarf variety improved various crop growth parameters (Moorthy and Mitra, 1992). Root growth, tiller production and dry matter production were improved by split application of N at 15 DAS, active tillering and panicle initiation stages (Anbulatha, 1992).

Ahmed and Moody (1981) reported that delaying the first dose of N application from a week after germination to 30 DAS or till the maximum tillering stage, favourably influenced the yield components and yield of wet seeded rice. Anbulatha (1992) observed that grain yield of wet seeded rice could be improved by application of 50 per cent N at 15 DAS instead of N as basal at sowing. Application of N in four splits at 20,40,60 and 80 DAS recorded the highest grain yield in wet seeded rice (Rathnam, 1994).

Siji Susan George (1996) recommended application of N in four splits at 15,30,45 and 60 DAS for getting higher grain yield in direct seeded lowland rice. Top dressing of N at full heading stage enabled to increase the number of filled grain percentage and test grain weight (Tanaka, 1997). Venkatachalapathy (1997) observed that application of 120 kg N ha⁻¹ in four equal splits at 25 DAS, active tillering, panicle initiation and heading stage, increased the grain yield of wet seeded rice by 556 to 708 kg ha⁻¹ over the same level of N applied in 3 splits including one at sowing.

An additional split of N employed after active tillering, exactly a week later, which improved the N content of shoot, was under the process of dilution due to higher leaf and stem biomass production, a compensatory action as opined by

Thiyagarajan *et al.* (1994). This additional split was able to produce higher grain yield through increased filled grains per panicle. In wet seeded rice, top dressing of 120 kg N ha⁻¹ in four equal splits at seedling (21 days after seeding), active tillering, panicle initiation and flowering stages significantly increased the grain yield than the recommended practice of N application in three equal splits at seedling, active tillering and panicle initiation stages (Alagesan, 1997).

2.4.3.3. Effect of N levels on growth components in rice

Increase in plant height due to higher N application has been reported by many workers (Mandal *et al.*, 1991; Dahatonde, 1992; Alagesan, 1997; Kumari *et al.*, 2000). Increase in plant height with increase in N level upto 150 kg N ha⁻¹ was reported by Balasubramaniyan and Palaniyappan (1989) and Shiyas (1992). Higher dose of N at 250 kg ha⁻¹ produced significantly taller plants than those at other levels of N (200 and 150 kg N ha⁻¹) in medium duration hybrid rice CORH 2 at Madurai (Rajarithinam and Balasubramaniyan, 1999).

In direct seeded rice, application of N at 120 kg ha⁻¹ increased the number of tillers and leaf area index (LAI) and it was on par with 80 kg N ha⁻¹ (Pradeep Prasad *et al.*, 1994). Kandasamy and Ramasamy (1998) reported that use of higher dose of N at 200 kg ha⁻¹ significantly recorded the highest LAI over 150 and 100 kg N ha⁻¹. Each successive increment in nitrogen dose from 0 to 200 kg ha⁻¹ brought about significant increase in growth in terms of LAI and dry matter accumulation (Hari Om *et al.*, 1997). Valarmathi (1994) reported that the dry matter production was significantly superior at higher doses of N (200 kg ha⁻¹) at all the growth stages of rice variety ADT 36.

2.4.3.4. Effect of N levels on yield attributes and yield in rice

Application of N at 120 kg ha⁻¹ significantly recorded higher number panicles m⁻², filled grains per panicle and grain yield over those with 100 kg N ha⁻¹ (Sheik Dawood *et al.*, 1990). Dahatonde (1992) reported that panicle length, number of grains per panicle and thousand grain weight increased with higher level of N upto 150 kg N ha⁻¹. Use of N at 120 kg ha⁻¹ recorded higher grain yield, which was on par with 160 kg N ha⁻¹. (Shanmugasundaram and Selvakumari, 1993).

Singh *et al.* (1996) reported that yield attributes like length of panicle, number of grains per panicle and grain and straw yield were improved upto 90 kg N ha⁻¹ but there was no significant difference in 60 and 90 kg N ha⁻¹. Use of higher dose of N at 160 kg ha⁻¹ recorded the highest number of panicles m⁻², grains per panicle and panicle length and it was at par with 120 kg N ha⁻¹ (Singh, 1998).

Balasubramaniam and Palaniappan (1993) found that there was response to N even upto 200 kg N ha⁻¹; however 150 kg ha⁻¹ was found to be the economic optimum dose. Application of N at 90 kg ha⁻¹ significantly recorded more number of productive tillers m⁻², panicle weight, filled grains per panicle and grain yield of direct seeded rice (Dhurandher and Tripathy, 1999). In wet seeded rice, nitrogen level of 135 kg N ha⁻¹ for medium duration rice (Wells and Faw, 1978) and 120 kg ha⁻¹ for short duration rice (Satyanarayan and Sharma, 1976) were found to be optimum. Other studies indicated that wet seeded rice responded upto 150 kg N ha⁻¹ (Stutterhim *et al.*, 1994). Use of higher dose of N at 180 kg ha⁻¹ recorded the highest grain yield but there was no significant difference between 120 and 180 kg N ha⁻¹ (Nair and Gupta, 1999). Jaiswal and Singh (2001) reported that application

of 120 kg N ha⁻¹ significantly increased the yield attributes and yield compared to 60 kg N ha⁻¹ and the yield increase was 29.7 per cent over that of 60 kg N ha⁻¹.

2.4.3.5. Effect of fertilizer N on nutrient uptake in rice

The primary goal of improved N management practices should be to maximise N uptake at critical growth stages and to minimise N losses (De Datta, 1987). Both field and laboratory studies revealed that N is taken by the rice crop continuously from seedling stage to physiological maturity (Kharg and Singh, 1973). Nitrogen is absorbed rapidly during vegetative phase and the maximum rate of uptake is reached at flowering time (Mikkelsen, 1970; Chaplin, 1972). Uptake of fertilizer N by rice crop occurs mostly between 30 days after transplanting and panicle initiation stage. There is a rapid uptake of fertilizer N at these stages and slow uptake during the later period of growing season. Beyond panicle initiation, N uptake is rather low (Obcema *et al.*, 1984).

Application of N invariably increased the uptake of N (Krishnakumar, 1986; Shukla *et al.*, 1989) with a corresponding increase in the uptake of P and K (Balasubramanian, 1989; Alagappan, 1990; Siddeswaran, 1992). Schnier *et al.* (1990) suggested that row sown rice had a higher N demand and an inferior ability to convert high biomass production into grain yield when compared to transplanted rice. Yield response to applied N was significantly higher upto 60 kg N ha⁻¹ in transplanted rice and 90 kg ha⁻¹ in row sown rice. Balasubramaniyan and Palaniappan (1992) found that N uptake was enhanced by N application upto 150 kg ha⁻¹ beyond which the increase was insignificant. However, when the N uptake increased upto 225 kg N ha⁻¹, the recovery per cent decreased beyond 150 kg N ha⁻¹

(Krishnakumar and Subramonian, 1992). Application of higher dose of N at 180 kg ha⁻¹ recorded significantly higher total N and K uptake than 120 and 60 kg N ha⁻¹. However, the P uptake significantly differed with that recorded by 60 kg N ha⁻¹ and remained at par with 120 kg N ha⁻¹ (Nair and Gupta, 1999). Gangaiah and Rajendraprasad (1999) reported that uptake of N,P,K and Zn was significantly increased with each successive increment of N from 0 to 180 kg ha⁻¹.

2.4.3.6. Effect of fertilizer N on nitrogen use efficiency in rice

Nitrogen use efficiency of applied fertilizer N to lowland rice crop seldom exceeds 30 to 35 per cent. Even under better crop management practices, N use efficiency was not more than 60 per cent (De Datta, 1981). Though the N uptake showed linear increase with increasing N levels, the apparent recovery of applied N was correspondingly reduced (Reddy and Reddy, 1986). An apparent N recovery of 49-68 per cent was recorded when urea was applied in splits at three weeks after germination, mid tillering and panicle initiation stages (Panda *et al.*, 1988). Mongia (1992) observed that the apparent N recovery was the highest (32-67 per cent) when fertilizer N (120 kg ha⁻¹) was applied in three splits. Kandasamy (1997) reported that N recovery was more when initial 50 per cent of N was applied at 20 DAS in *Kuruvai* and *Samba* seasons and 10 DAS in *thaladi* season. Nitrogen uptake by rice increased progressively and significantly upto 80 kg N ha⁻¹, but the use efficiency was at the peak at 40 kg N ha⁻¹. However, the recovery of nitrogen was higher at 60 kg N ha⁻¹ which might be due to uptake of higher fraction of nitrogen from 60 kg than 80 kg ha⁻¹ (Pathi, 1999).

2.5. Integrated nitrogen management

Nitrogen is an important growth promoting factor for rice which largely determines the yield level. However, indiscriminate use of nitrogenous fertilizers would affect the soil quality. Considering the very low efficiency of applied nitrogenous fertilizer and the possibility of only a partial substitution in rice, it has become a necessity to integrate the use of biological, organic or inorganic sources of N for achieving higher N use efficiency, yield and sustained soil fertility (Kannaiyan *et al.*, 1990).

The optimum integrated N management strategy would be influenced by factor such as availability of native soil N, mineralization of the organic N source, timing of the chemical N source, losses of native and added N and interactive effects of the organic and chemical fertilizers on N availability and N loss (De Datta and Buresh, 1989).

2.5.1. Effect of INM on growth and yield of rice

Integrated use of *Sesbania rostrata* as green manure, *Azolla* and *Azospirillum* as biofertilizers and fertilizer urea at four graded levels increased the plant height, number of tillers hill⁻¹, LAI, dry matter accumulation, number of panicles m⁻², panicle length and number of filled grains per panicle and grain and straw yields (Sreedevi, 1988). Ramasamy *et al.* (1988) reported that the combined application of *sesbania aculeata* and *Azolla* was equal to 80 kg N ha⁻¹ and it produced higher yield than that obtained by applying 80 kg N ha⁻¹. Sharma and Mahapatra (1990) also obtained higher grain yield when 120 kg N ha⁻¹ was applied

in integrated inorganic-organic method in which 60 kg N ha⁻¹ was supplied through urea super granules and 60 kg N ha⁻¹ was through *Azolla*.

Babu (1995) reported that incorporation of green manure (*Sesbania aculeata*) at 12.5 t ha⁻¹ in addition to the recommended N level of 125 kg ha⁻¹ increased the number of panicles m⁻², number of filled grains and test grain weight and grain yield as compared to recommended N alone. Fifty per cent of recommended fertilizer N with addition of green manure produced comparable yields with that of 100 per cent nitrogen. Inclusion of biofertilizers viz., blue green algae and *Azolla* along with half of the fertilizer N dose was able to produce grain yields as that of 100 per cent N. Addition of biofertilizers along with green manures increased the yield of wet seeded rice at Coimbatore.

Incorporation of *Sesbania rostrata* at 6.25 t ha⁻¹ one week prior to sowing, inoculation of *Azolla* at 1.0 t ha⁻¹ 15 DAS and incorporation of multiplied *Azolla* 15 days later in combination with the application of prilled urea at 125 kg ha⁻¹ in 4 equal splits at tillering, panicle initiation, heading and flowering stages increased the growth and yield attributing characters viz., tillers m⁻², leaf area index, dry matter production, number of panicles m⁻², number of filled grains per panicle and grain yield of wet seeded rice at Coimbatore (Deepa Thomas, 1996).

Ramamoorthy *et al.* (1997) reported that the combination of organic source viz., *Sesbania rostrata* incorporation to supply 50 kg N ha⁻¹ and inorganic source with 150 kg N ha⁻¹ in 5 splits at 7 DAT, active tillering, panicle initiation, heading and flowering stages registered higher grain and straw yields with increased net returns in lowland transplanted rice. Application of recommended dose of

120 kg ha⁻¹ of N to rice combined with intercropping of *daincha* and incorporating it at 35 DAS increased the grain yield of wet seeded rice (Joseph, 1998). James Martin (1999) found that combined use of *Azospirillum*, *Sesbania rostrata* and *Azolla* along with 50 per cent of chemical N fertilizer resulted in comparable yield level with that of application of prilled urea at 100 kg N ha⁻¹. Application of 75 per cent of N (112.5 kg ha⁻¹) and intercropping of *daincha* and incorporating when the plants were at 45 cm height recorded higher grain yield of 8.09 t ha⁻¹ (Premsekhar, 2000).

The encouraging results of extensive studies indicate the potential of green manuring in increased rice production and green manuring could be a viable component of integrated nutrient package for rice.

2.5.2. Effect of INM on nutrient uptake and nitrogen use efficiency in rice

Saravanan *et al.* (1988) found that there was higher nitrogen use efficiency (21.5 kg grain per kg N) with conjunctive use of green manure and prilled urea than with prilled urea alone (17.1 kg grain per kg N).

Sreedevi and Thangamuthu (1991) reported that INM practices increased the N uptake significantly from 20 days after transplanting to harvest stage and P and K uptake was also higher, while biofertilizers increased N, P and K uptake marginally. Integrated use of organic and inorganic nitrogen sources significantly increased the N uptake in lowland rice (Pramanik and Mahapatra, 1997). Deepa Thomas and James Martin (1999) reported that integrated use of green manure *Sesbania rostrata* at 6.25 t ha⁻¹ and *Azolla* at 1.0 t ha⁻¹ along with application of

prilled urea at 125 kg N ha^{-1} increased the N,P,K uptake and apparent recovery per cent of nitrogen in wet seeded rice at Coimbatore.

2.6. Crop residue incorporation

Addition of organic matter to the soil through the return of crop residues improves soil structure, influences soil water, air and temperature relations, helps control runoff and erosion, and makes tillage easy (Kumar and Goh, 2000). Biological nitrogen fixation by leguminous crops and the recycling of fixed N when leguminous crop residues are returned to the soil can be significant source of N to the soil organic N pool as well for subsequent plant N uptake. The amount of N that recycles into agricultural fields through residues may add 25-100 kg N per year into agricultural soils (Mosier and Kroeze, 1998). Palaniappan and Annadurai (1999) opined that crop residues have potential for improving soil and water conservation and sustaining soil productivity. Nitrogen addition by crop residue was higher in cropping of rice-rice-greengram system (Jayapaul and Purushothaman, 1995).

2.6.1. Influence of Pulse straw on rice

Substantial amount of fertilizer N could be economised if straw of pulses after harvesting the grain are turned down into the soil (Srinivasulu Reddy, 1988). Rekhi and Meelu (1983) observed higher dry matter production of rice with the preceding greengram straw incorporation. Plant height, panicle number and yield of rice were significantly improved by greengram straw incorporation. Meelu and Rekhi (1983) obtained N economy of 60 kg N ha^{-1} for rice with the application of 60 kg N ha^{-1} along with greengram straw addition. Rajendra Prasad (1985) found that plant height, tillers, LAI, dry matter accumulation and grain yield of rice were

increased by incorporation of pulse crop residues. An yield advantage equivalent of 26 kg N ha⁻¹ was realised by incorporation of greengram haulms. Incorporation of greengram straw resulted in improved growth and yield attributes of rice, resulting in higher yield and nutrient uptake (Lekha Sreekanthan, 1987).

The results of various successful investigations amply indicate the scope of integrated use of different N sources not only to increase the rice yields but to economise on costly fertilizer N.

2.7. Rice based cropping systems

Rice-Rice is the most dominant cropping system under irrigated conditions in South and Eastern India, while rice-wheat, rice-groundnut, rice-legumes, rice-mustard and rice-potato are some of the predominant rice based cropping systems with 200 per cent cropping intensity in different North Indian states (AICARP, 1978). Various rice based cropping systems with 300 per cent cropping intensity have been reported from different parts of India, ranging from Rice-Rice-Rice (Palaniappan *et al.*, 1978) to rice followed by different cereals, pulses, oilseeds, vegetables and fibre crops (AICARP, 1978). Rice-Rice-Pulse (Greengram / black gram) is the predominant cropping system of major rice growing areas of Tamil Nadu.

2.7.1. Effect of green manure in rice based cropping systems

The possibility of including green manure in rice based cropping systems has been extensively studied by a number of workers (Lekha sreekanthan, 1987; Srinivasulu Reddy, 1988; Siddeswaran, 1992; Geethalakshmi, 1996). However, in all the above studies green manures were one of the component crops, either

preceding or succeeding rice, of three crop sequences. Intercropping of stem and root nodulating green manure crop (*Sesbania rostrata*) in wet seeded rice based cropping system has not been attempted.

Inclusion of leguminous green manures in the cropping system is known to improve the soil conditions for enhanced and sustained rice production during wet season (IRRI,1988). Kulkarni and Pandey (1987) reviewed the scope and feasibility of including green manure in rice based cropping system and concluded that either a green manure crop or dual purpose grain legume cum green manure could be successfully fitted into rice based cropping systems. Pradhan and Mondal (1997) reported that the recommended dose of N, P and K may safely be reduced by 25 per cent if green manure is provided to both the rice crops in sequence.

Inclusion of green manure in rice-rice system increased the productivity to 7.94 tonnes ha⁻¹ and it was further enhanced to 8.95 tonnes ha⁻¹ when cowpea was introduced in the system (Prabhakara Setty and Janardhana Gowda, 1997). Subbalakshmi Lokanathan *et al.* (1999) opined that incorporation of green manures like *Sesbania speciosa* and *Sesbania aculeata* increased the total grain yield and productivity of rice-rice cropping system at Madurai.

2.7.2. Influence of pulses in rice based cropping system

Inclusion of pulses during summer in a highly intensive rotation increased the yield of succeeding rice and wheat crops during *kharif* and *rabi* seasons respectively (Singh and Singh, 1975). Inclusion of pulses in the cropping systems, improved the soil N status thus, reduced N application to the succeeding crops in rice based cropping system (Sasidharan and Sadanandan, 1980). Meelu (1981)

revealed that introduction of legumes as summer crops proved beneficial to the succeeding crop in enhancing the yield. Further incorporation of summer greengram haulms in the soil as green manure after harvesting of pods resulted in substantial N economy in the succeeding rice.

De *et al.* (1983) reported that previous crop of greengram, cowpea and blackgram improved the grain and straw yields of subsequent crop of rice. With the overall view of maintaining soil fertility and economising fertilizer application, it is beneficial to include legumes as components of intensive cropping system (Palaniappan, 1985; Prasad and Palaniappan, 1987). Singh (1984) viewed that legumes grown in rotation with lowland rice can scavenge soil mineral N, which might otherwise be lost by denitrification or leaching after soil is flooded for rice production. Increased yields of rice was recorded when rice succeeded greengram (Mahapatra *et al.*, 1981; Rajendra Prasad, 1985).

Prasad and Palaniappan (1987) reported that inclusion of pulses in the cropping system for both grain and green manure would help reduce cost and maintain soil fertility. Balasubramanian and Palaniappan (1990) reported that yield and quality of greengram were not influenced by the green manuring treatment to preceding rice crop. However, marginal increase of about 7 per cent grain yield was recorded in green manured plots. Grain legumes provide proteins for human and animal nutrition as well as economic benefits to farmers because of the high market value for legume grain (Buresh and De Datta, 1991).

2.7.2.1. Influence of greengram in rice based cropping system

Greengram frequently finds a place in different rice based cropping systems of various regions in India. Some of the cropping systems involving greengram as a component are rice-wheat-greengram (Buck, 1972; Joshi and Khaire, 1972, Rekhi and Meelu, 1983); rice-rice-greengram (Pandey *et al.*, 1985; Palaniappan and Thangamuthu, 1987; Siddeswaran, 1992). The rice fallow pulses survive entirely on residual moisture and fertility left over by the preceding crop of rice. Under Tamil Nadu condition rice is being cultivated in nearly 18 lakh ha of which Cauvery and Tambiraparani command accounts 7 lakh ha which is ideally suited for rice fallow cultivation (Pandian, *et al.*, 2001).

Rice-rice-greengram is the traditional cropping system of major rice growing regions of Tamil Nadu. Satisfactory yields were obtained at Coimbatore by dibbling the seeds of greengram in February immediately after the harvest of rice without any land preparation (Palaniappan *et al.*, 1978). Pandian *et al.* (2001) reported that greengram seeds dibbled in rice stubbles immediately after harvest at a spacing of 30 x 10 cm produced higher grain yield of 593 kg ha⁻¹ which was 28 per cent more than relay sowing. At Coimbatore, wet seeded rice-greengram system resulted in higher rice grain equivalent yield and net return than that in transplanted rice-greengram system (Rachel Sophia Alexander and James Martin, 1995).

The practice of incorporating greengram haulms after harvesting the pods has been successfully tested in rice based cropping systems by many workers (Rekhi and Meelu, 1983; Rajendra Prasad, 1985; Lekha Sreekanthan, 1987) and the

results indicate the scope of economising substantial quantity of N to subsequent rice crop and improving the fertility status of the soil.

2.8. Effect of preceding crops on the performance of subsequent crops in the cropping system

Rice based cropping systems may include lowland rice and upland crops. In lowlands, where rice is transplanted in puddled soil, the physical properties of soil may be unfavourable to the succeeding upland crops (Melhuish *et al.*, 1976). The conditions in lowland rice fields are such that N and probably P could be limiting nutrients for the upland crops that follow rice in a sequence (Griffin and Brandon, 1983).

Ghosh (1981) reported that though green manuring could double the yields of succeeding cereals there was little benefit to legumes that followed cereals. Hamid *et al.* (1984) opined that at the higher rate of N fertilization, rice yield was greater when the crop was preceded by greengram. Rajendra Prasad (1985) and Lekha Sreekantan (1987) did not observe any depressing effect of the preceding rice crop on succeeding greengram.

Malathi (1989) concluded that there was no significant effect on grain and stover yield and uptake of nutrients by the residual greengram due to treatments of the first crop in a rice-rice-greengram cropping system. Balasubramaniyan and Palaniappan (1990) reported that yield and quality of greengram were not influenced by the green manuring treatment to preceding rice crop. However, marginal increase of about 7 per cent grain yield was recorded in green manured plots. Quayyum and Maniruzzaman (1996) found that the preceding legume

improved the yield attributing characters such as panicle length, number of panicles m^{-2} , number of grains per panicle and 1000 grain weight. The yield increase from the preceding legume was noted in rice crops receiving fertilizer upto 120 kg N ha^{-1} .

2.9. Nutrient management in cropping systems

Earlier, crop production research had been focussing attention on individual crops disregarding the fact that each crop was only a component of a cropping system. Hence the nutrient dosage for the individual crop was calculated based on the response of individual crop without considering the cropping system as a whole. This led to high and uneconomic recommendation of fertilizer dose. Hence fertilization should not be considered for individual crop but for the cropping system as a whole.

Biswas *et al.* (1987) observed that while developing a fertilizer schedule, it is necessary to take into account the residual effect of fertilizers applied to the previous crop and the influence of the preceding crop on the succeeding one.

Fertilizer use in high intensive cropping systems had been reviewed by Bhardwaj and Tandon (1981), Grewal and Sharma (1981), Mandal *et al.* (1981), Meelu and Rekhi (1981), Tandon (1983), Pillai *et al.* (1985) and Biswas *et al.* (1987). They opined that fertilizer prescription approach for the system as a whole was economical and more efficient.

2.9.1. Nitrogen requirement for rice based cropping systems

Purushothaman (1979) reported that each of the rice crops should be fertilized with recommended level of N for higher productivity and net return for the rice based multiple cropping systems at Coimbatore. Studies conducted at many locations in India with rice-rice system indicated that the response to N by the second crop of rice was uniformly wide spread, regardless of N dose to first crop of rice (AICARP, 1980).

In a rice-rice cropping system with a mean grain yield of 5 t ha⁻¹ in *khari*f and 5 to 6 t ha⁻¹ in *rabi*, N removal could be as high as 225 to 275 kg ha⁻¹. The N uptake data indicated a very high level of N removal which often exceeded the recommended application rates of N (Mahapatra *et al.*, 1981). They deduced the N requirement for a rice-rice cropping system as 120 kg ha⁻¹ for each crop of rice.

In rice based cropping systems, each crop of rice requires N application at the recommended rate. Even if a considerable proportion of N applied to a crop is present in the soil after harvest, its availability to the following crop is less than three per cent (Subbiah and Sachdev, 1983). Therefore, the strategy for increasing fertilizer use efficiency is to optimise the application of fertilizer N to each component rice crop in rice based cropping sequences.

The above results clearly indicate that N requirement of rice in a sequence could hardly be manipulated by relying on the residual N from the preceding crop.

2.9.2. Integrated nitrogen management in rice based cropping systems

Rice responds well to the mineral fertilizer applied but the efficiency of applied N is very low. Use of organic manures, biofertilizers and crop residues in rice based cropping systems not only could substitute a portion of the costly fertilizer N but also could help maintain fertility in intensively cultivated rice soils (Swaminathan, 1987). The practice of using green manures and biofertilizers and including pulses in the cropping system and incorporating their haulms, integrated with inorganic fertilizers received a great deal of attention for efficient and economic management of N for rice based cropping systems (Meelu and Morris, 1987).

Combined use of green manure with 60 kg N ha⁻¹ through mineral fertilizer gave rice yields comparable with 100 kg fertilizer N ha⁻¹ with negligible residual effect of green manuring on succeeding wheat crop (Mahapatra, *et al.*, 1981 and IRRI, 1984). In general, N contribution could be 10 to 25 kg ha⁻¹ from grain legumes and 30 to 40 kg ha⁻¹ from green manures which were raised preceding to rice in a rice based cropping system (Mahapatra *et al.*, 1985). Lekha Sreekanthan (1987) obtained higher rice yields with greengram stover incorporation in a rice-rice-greengram sequence at Coimbatore.

Integrated use of biofertilizers and inorganic fertilizers resulted in increased rice yields and N economy ranging from 25 to 30 kg ha⁻¹ with *Azolla* in different rice based crop sequences (Pillai *et al.*, 1980). Integrated N management studies with rice based cropping system at Coimbatore have revealed that application of blue green algae to first season rice (*kharif*) crop and *Azolla* to second season rice

(*rabi*) crop could substitute 25 kg N ha⁻¹ for each rice crop with a cumulative saving of 50 kg fertilizer N ha⁻¹ in rice-rice-pulse sequence in one cropping year (Palaniappan and Kempuchetty, 1986).

Several multilocation on-farm trials to study the management of fertilizers in a fixed single year rice-rice cropping system revealed that total productivity, net returns and cost-benefit ratio of the system as a whole were in favour of combined use of organic manures and/or biofertilizers with reduced dose of mineral fertilizer (Mahapatra *et al.*, 1985).

In order to integrate different N sources into a viable package for the cropping system as a whole, the potentialities and limitations of various components of plant nutrient system should be duly considered.

2.10. Soil fertility in rice based cropping systems

The influence of cropping system on the dynamics of soil fertility can not be appraised within a short period because of the contribution of native soil fertility, residual effect of previous crops and seasonal variations requiring a fairly longer period to assess.

Sustenance in productivity and fertility build up of soil is getting more and more important. In spite of increased cost of fertilizers and their adverse effect, particularly N fertilizers on soil and environment (Von Vexkull, 1993), the best alternative source for plant nutrients is to be found out. The green manures have immense scope in this respect. An integrated package of biofertilizers, N₂ fixing green manures, organic manures and inorganic fertilizers will be considered as a

holistic approach to maintain soil fertility and sustainability in rice based cropping system (Kannaiyan, 2001).

2.10.1. Nutrient status of the soil

Regardless of the quantity of fertilizer N applied, its residual value to succeeding crop hardly exceeds three per cent of original application (Reddy and Patrick, 1978). However, application of organic and biological sources of N and incorporation of crop residues enrich the soil. Viswanath *et al.* (1978) stated that, in general, roots accumulate significant amounts of major, secondary and micronutrients and under intensive cropping. If the stubbles were ploughed back into the soil, considerable quantities of nutrients would be returned to the soil, which gradually become available to the subsequent crops on decomposition.

Addition of substantial quantities of nutrients (N, P, K, Ca, Mg, S, Cu, Fe and Mn) to the soil after incorporation of green manure or crop residues, has been reported by several workers (Tiwari *et al.*, 1980; Meelu and Rekhi, 1981; Gotoh *et al.*, 1984; Ponnamperna, 1984; Titiloye *et al.*, 1985). Compared with the initial value, the N,P and K status of the soil after harvest of the ninth crop improved most in the rice-grass pea (green manure)-rice-sesbania sequence where both rainy and summer season rice were green manured before transplanting (Pradhan and Mondal, 1997). The available N,P and K status was enhanced due to continuous cropping of wet seeded rice-green gram sequence (Premsekhar, 2000).

2.10.2. Organic matter status of the soil

Tropical soils are normally low in organic matter, which contributes much to the productivity of soils through mineralisation of nutrients and improvement in

soil physical and biological conditions. The variation in the quantity of plant residues added and varying N content of different crops involved in the crop sequence affect the organic matter content in the soil.

Studies of Nair *et al.* (1973) on soil fertility under intensive multiple cropping in Northern India revealed that available N, P and organic matter slightly improved after leguminous crops. Thirumurugan (1989) found that the available nutrient status and organic carbon content of the post harvest soil gradually increased as a result of crop residue addition and inclusion of grain legume in rice based cropping system. Hedge (1996) opined that continuous rice-rice cropping led to increase in organic carbon status and decline in the P and K status. The availability of nutrients like P, K and Zn was depleted, whereas available N and organic carbon content increased compared with the initial status of the soil due to continuous cropping system in rice fallows (Subbaiah and Mahender kumar, 1997).

2.10.3. Residual effect of green manuring

Wilson *et al.* (1980) reported that only two to three per cent of green manure N would be used by the second crop. Wescott and Mikkelsen (1987) found that a mere 7.5 to 8.7 per cent of N found in green manure was available to the second crop of rice. Meelu *et al.* (1986) obtained significant residual effect of green manures on succeeding rice crop in rice-rice sequence.

Amount of residual N from one application of green manure is not likely to be large. However, continued use of green manure is likely to have measurable effect, because of the accumulation of modest quantities of organic N over years

(Bouldin *et al.*, 1984). Meelu and Morris (1987) observed that green manuring in intensive cropping system resulted in a saving of 60 to 80 kg N ha⁻¹ in rice.

Residual effect of green manures depends on their chemical decomposition and the rate of mineralization and also the frequency of application. Lower the C:N ratio of green manure, lower was the amount of residual N recovered in the soil organic fraction and higher was the amount of residue N mineralized. During decomposition of low N green manures, soil N may be transformed into highly stable and complex compounds rendering the soil N unavailable to the subsequent crop for a long time (Wagger, 1989).

Green manuring to supply more than 120 kg N ha⁻¹ resulted in occasional residual effects on second crop itself (Meelu and Morris, 1987; Morris *et al.*, 1989). Though residual effects of green manures are relatively small on short term application, the cumulative effects of annual application are expected to be appreciable (Bouldin, 1988). The residual effect of green manuring on succeeding rice yield ranged from 0.36 to 1.21 t ha⁻¹. Increase in yield of rice due to residual green manuring, on an average was 15.1 per cent. The response due to residual green manure in rice was with recommended level of fertilizer N (120 kg ha⁻¹) (Pasricha and Aulakh, 1995). Somasundaram *et al.* (1999) revealed that intercropping *Sesbania rostrata* and ratooning and incorporation at 45 DAT and at harvest in first season rice (*kuruvai*) had good residual effect on the succeeding rice (*Thaladi*) in rice-rice sequence at Coimbatore.

2.10.4. Nutrient uptake in rice based cropping system

It becomes essential to quantify the amount of nutrients removed by the individual crops in a system and the system as a whole in order to know the extent to which the crops in the systems and the system as such enrich or exhaust the soil available nutrients. This helps in formulating suitable fertilizer schedule. Further, the nutrient removal by a cropping system is an indication of the productivity level of that system (Kundu and Pillai, 1992). Quantification of nutrient removal by different cropping systems gains greater importance, particularly when newer cropping systems are evolved, in order to fix up the fertilizer schedule.

Deka and Singh (1984) reported that the uptake of N ranged from 289 to 370 kg ha⁻¹, P₂O₅ from 53-54 kg ha⁻¹ and K₂O from 246 to 263 kg ha⁻¹ in rice-wheat-maize-cowpea cropping system. Mongia and Gangwar (1991) observed that maximum nitrogen uptake was recorded in rice-sorghum+cowpea rotation followed by rice-maize, rice-greengram and rice-sorghum sequences.

Seetharaman (1989) found that nitrogen, phosphorus and potassium uptake was the highest in the four crop sequence of rice-groundnut-maize-blackgram at Pattukottai.

2.10.5. Soil nutrient balance in rice based cropping systems

Sharma and Saxena (1970) observed negative N balance in four cropping sequences without N and 35 kg N ha⁻¹ while the balance was positive with 70 kg N ha⁻¹. Sandanandan and Mahapatra (1973) observed a decrease in exchangeable K after every crop of rice in a monoculture system.



In rice based multiple cropping study conducted at Coimbatore, the nutrient balance was very much influenced by the fertility levels. There was a positive N balance when full N was applied while it was negative when half of N was applied. In the case of P, balance was positive for both full and half the quantity of application. Balance for K was negative with all the fertility levels (Purushothaman and Palaniappan, 1985).

Sharma (1987) found that different multiple crop sequences involving rice or wheat as the base crop resulted in positive P and K balance in soil. Results from a number of longterm fertilizer experiments showed that under optimum rates of potassium application, crop uptake of potassium exceeded the addition of K resulting in negative potassium balance (Tandon and Sekhon, 1988). Panda and Sahoo (1989) reported that with the higher nutrient levels, there was increasing positive balance of both N and P. However, the K balance was negative at the levels between 0-90 kg N ha⁻¹ applied to each crop of rice in the cropping system. Positive balance of N and P and negative balance on K were recorded, when chemical fertilizers plus FYM and BGA were applied together for a rice-wheat sequence. The negative balance of K was attributed to the K addition which was much less than the amount removed by the crop (Prasad and Rokima, 1991).

Saravanan and Manickam (1993) found that N balance after the two successive rice crops was positive indicating an increase in the native N, which is of much significance for crop productivity. Singh and Prasad (1994) reported that maximum nitrogen balance (128 kg N ha⁻¹) was recorded under rice-gram-greengram cropping sequence, whereas potassium balance was negative under rice-

maize-blackgram (184 kg N ha^{-1}). High negative balance of phosphorus was recorded under rice-potato-greengram ($-214 \text{ kg P ha}^{-1}$) sequence. Continuous rice-rice cropping sequence recorded the positive N and P balance and negative K balance with the recommended levels of nutrient application (Hedge, 1996).

2.11. Economics of rice based cropping system

Sharma (1987) reported that the higher net profit per hectare was obtained in a three crop sequence of rice-wheat-mungbean. Maximum gross return (Rs. 59400 ha^{-1}) was obtained with rice-potato-transplanted winter maize at Ludhiana in Punjab.

Under wetland conditions of Aliyarnagar in Tamil Nadu, rice-rice-sunnhemp system recorded higher net return of Rs. 8511 ha^{-1} with a per day net return of Rs. 28.85 ha^{-1} (Narayanan and Sivaprakasam, 1975). Calendacron and De Datta (1987) reported that potato-rice-rice was the most remunerative system for irrigated conditions and rice-rice-ratoon, and rice-greengram for rainfed lowland conditions of Philippines.

Nallaiiah Durairaj (1990) revealed that the rice (short duration) in *Kar* season-green manure-rice (short duration) in pishanam-summer (blackgram) or (gingelly) fetched a higher net return of Rs. 46373 and 46535 ha^{-1} with B:C ratio of 3.71 over other cropping sequences. Ramasamy *et al.* (1991) found that four crop sequence *viz.*, rice-blackgram-gingelly-greengram gave consistently the highest net annual return Rs. 18500 to 21450 ha^{-1} with high benefit cost ratio of 3.26 - 3.61. Rice-rice-sequence recorded significantly higher net return of Rs. $33699 \text{ ha}^{-1} \text{ year}^{-1}$ and rice-wheat (Rs. $26528 \text{ ha}^{-1} \text{ year}^{-1}$) (Naglikar *et al.*, 1999).

From the foregoing review, it could be inferred that voluminous research work has been carried out on the influence of various sources of N on rice with varying levels of response. Possibility of integrating different N sources for successful and profitable rice production is well established. Fertilizer N economy of varying extents could be achieved in rice culture by proper and judicious use of alternative N sources. There is a lacuna in the current state of knowledge regarding the integrated use of different N sources, through combined application of *Azolla microphylla* and *Sesbania rostrata*, and soil fertility dynamics in wet seeded rice based cropping system as a whole. It is in this context the present investigation was conducted to study the integrated N management in wet seeded rice - rice-greengram system.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Field investigations were conducted during *kharif*, *rabi* and summer seasons of 2000-'01 and 2001-'02 at the Wetland Farm of Tamil Nadu Agricultural University, Coimbatore to develop integrated nitrogen management for wet seeded rice based cropping system. The details of the experiment materials used and methodology adopted are presented hereunder.

3.1. MATERIALS

3.1.1. Field location

The experiments were conducted in field No. D₁ of Wetland Farm of Tamil Nadu Agricultural University, Coimbatore. The experimental site is situated in North Western agroclimatic zone of Tamil Nadu at 11⁰ North latitude, 77⁰ East longitude at an altitude of 426.7m above mean sea level.

3.1.2. Weather and Climate

The mean annual rainfall of Coimbatore is 657 mm (mean of 83 years) distributed over 47 rainy days. The annual mean maximum and minimum temperatures are 31.5 and 21.4°C respectively. The relative humidity ranges from 61 to 91 per cent in the forenoon and from 14 to 68 per cent in the afternoon. The mean bright sunshine hours per day is 7.4 hours with a mean solar radiation of 429 cal cm⁻² min⁻¹.

The weather condition that prevailed during the cropping period (2000-'01 and 2001-'02) are furnished in Table 1. The weekly weather parameters are presented in Appendix 1 and depicted in Fig.1 and 2.

Table 1. Weather condition prevailed during cropping period

Weather parameters	First cropping cycle (2000-'01)			Second cropping cycle (2001-'02)		
	<i>Kharif</i> 2000	<i>Rabi</i> (2000-'01)	Summer 2001	<i>Kharif</i> 2001	<i>Rabi</i> (2001-'02)	Summer 2002
Total Rainfall (mm)	403.1	124.4	-	177.9	437.4	32.0
Total rainy days	21	12	-	16	18	2
Mean max. temperature (°C)	31.3	30.1	34.9	31.6	29.7	32.9
Mean min. temperature (°C)	22.4	19.7	21.8	22.4	20.1	20.2
Relative humidity morning (Percentage)	82.4	88.8	82.7	82.8	90.4	85.0
Relative humidity evening (Percentage)	56.0	48.4	34.9	52.4	57.3	37.4
Mean solar radiation (Cal. cm ⁻² min ⁻¹)	359.1	384.9	418.9	368.8	375.9	410.4
Mean sunshine hours day ⁻¹	5.4	6.6	8.6	5.8	6.4	7.9

3.1.3. Field and Soil

The soil of the experimental field was moderately drained, deep clay loam classified taxonomically as *Typic haplustalf*. Composite soil samples were collected prior to the experiment and were analysed for physico-chemical characteristics. The soil nutrients status was low, medium and high for available nitrogen, phosphorus and potassium respectively. The soil was nearly neutral in

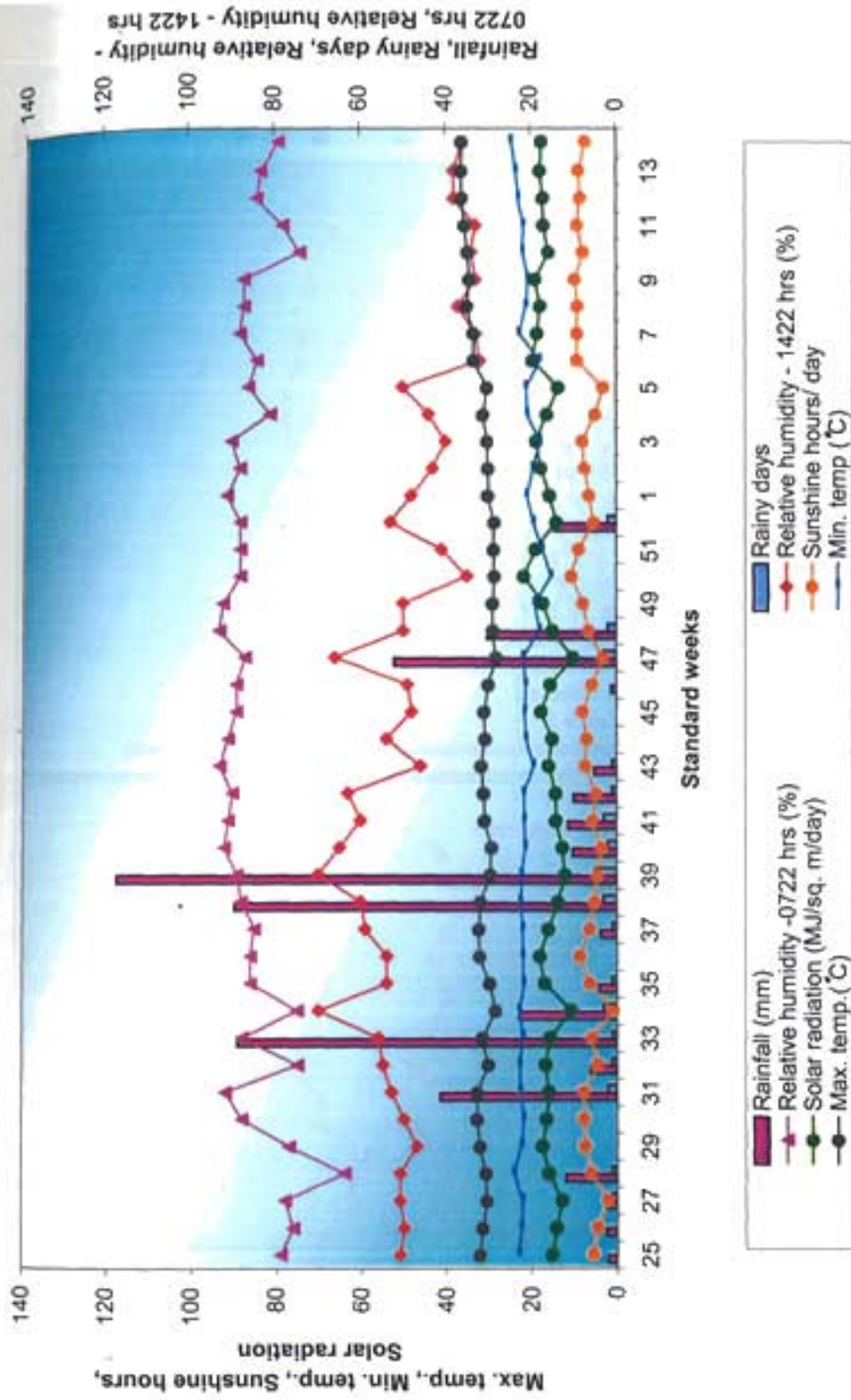


Fig. 1. Weekly weather parameters prevailed during first cropping cycle (2000-01)

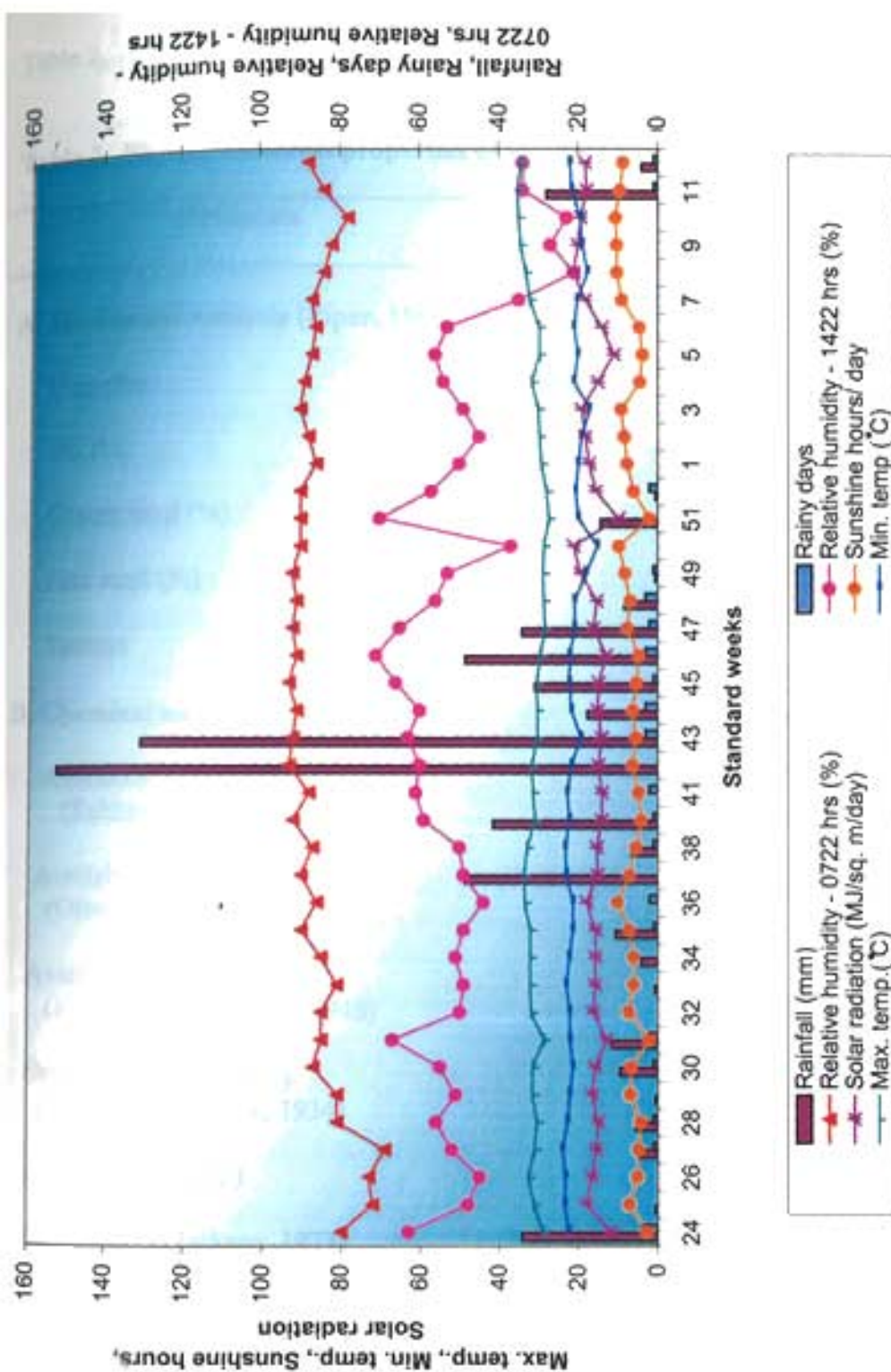


Fig. 2. Weekly weather parameters prevailed during second cropping cycle (2001-02)

reaction. The detailed physico-chemical characteristics of the soil are furnished in Table 2.

Table 2. Physico-chemical properties of soil of the experimental field

Particulars	Composition
A. Mechanical analysis (Piper, 1966)	
Clay (%)	43.2
Silt (%)	18.6
Coarse sand (%)	12.5
Fine sand (%)	25.7
Texture	Clay loam
B. Chemical analysis	
Available N (kg ha ⁻¹) (Subbiah and Asija, 1956)	276.0
Available P (kg ha ⁻¹) (Olsen <i>et al.</i> , 1954)	16.2
Available K (kg ha ⁻¹) (Stanford and English, 1949)	554
Organic carbon (g kg ⁻¹) (Walkley and Black, 1934)	6.9
pH (Jackson, 1973)	7.6
EC (d Sm ⁻¹) (Jackson, 1973)	0.4

3.1.4. Crop, Variety and Seasons

Short duration rice ADT 36 and medium duration rice ADT 39 cultivars were grown during *kharif* (June–October) and *rabi* (October–February) seasons,

respectively while greengram variety, Pusa Bold was used as rice fallow pulse during summer in both the years (2000-'01 and 2001-'02) of study. The details of crop varieties used are given in Table 3.

Table 3. Characteristics of varieties used

Character	Rice ADT 36	Rice ADT 39	Greengram Pusa Bold
1. Parentage	Triveni x IR 20	IR 8 x IR 20	Pure line selection from NM-92
2. Duration (days)	110	120-125	55-58 days
3. 1000 / 100 grain weight (g)	20.9	18.0	7.3
4. Yield (kg ha ⁻¹)	5050	5600	450-500
5. Habit	Semi dwarf, compact	Semi dwarf, erect	Short duration with high yield
6. Panicle	Long, dense and compact	Medium, moderately dense	—
7. Released by	Tamil Nadu Rice Research Institute, Aduthurai	Tamil Nadu Rice Research Institute, Aduthurai	Indian Agricultural Research Institute, New Delhi

3.1.4.1. Green manure

Sesbania rostrata, a leguminous green manure crop (variety Co 1) was grown as intercrop as per treatments. *Sesbania rostrata* is indigenous to Senegal, West Africa. It produces effective aerial rhizobial nodules throughout the stem besides the roots. It is a quick growing succulent green manure crop capable of producing 30 to 35 t ha⁻¹ of biomass accumulating 120 to 140 kg N ha⁻¹ within 55 to 60 days. It is tolerant to flooding and waterlogging and is quickly decomposable upon incorporation.

3.1.5. Manures and Fertilizers

The nutrient contents of various manures and fertilizers used in different seasons during the study are presented in Table 4.

Table 4. Nutrient content of manures and fertilizers used

Material	*Nutrient content (%)		
	N	P	K
A. Organic manures			
1. Green manure (<i>Sesbania rostrata</i>)			
<i>Kharif</i> 2000	3.70	0.23	2.13
<i>Rabi</i> 2000 -'01	3.75	0.28	2.22
<i>Kharif</i> 2001	3.77	0.24	2.21
<i>Rabi</i> 2001-'02	3.79	0.29	2.28
2. <i>Azolla</i> (<i>Azolla microphylla</i>)			
<i>Kharif</i> 2000	2.80	0.69	2.88
<i>Rabi</i> 2000 -'01	2.83	0.75	2.86
<i>Kharif</i> 2001	2.81	0.68	2.85
<i>Rabi</i> 2001-'02	2.84	0.73	2.86
3. Greengram haulms			
Summer 2001	1.54	0.24	1.86
Summer 2002	1.56	0.25	1.88
4. Rice stubbles			
<i>Kharif</i> 2000	0.58	0.13	1.45
<i>Rabi</i> 2000 -'01	0.53	0.10	1.41
<i>Kharif</i> 2001	0.59	0.15	1.46
<i>Rabi</i> 2001-'02	0.54	0.12	1.42
B. Chemical fertilizers			
Prilled urea	46.00	-	-
Single super phosphate	-	16.00	-
Muriate of potash	-	-	60.00

* On dry weight basis of organic manures

3.2. Methods

3.2.1. Experimental techniques

The experiments were laid out in a split plot design with three replications. The lay out plans of the experiments are depicted in Fig. 3. The experimental lay out was kept undisturbed throughout the period of investigation.

The details of the treatments used are given below:

3.2.2. Treatment details

Main plot treatments

Organic sources in rice based system

<i>Kharif</i>	<i>Rabi</i>	Summer
S ₁ : Rice	– Rice	– Greengram
S ₂ * : Rice + <i>Azolla</i> **	– Rice + <i>Sesbania rostrata</i> *	– Greengram
S ₃ : Rice + <i>Sesbania rostrata</i> *	– Rice + <i>Azolla</i> **	– Greengram
S ₄ : Rice + <i>Sesbania rostrata</i> * + <i>Azolla</i> **	– Rice + <i>Azolla</i> **	– Greengram
S ₅ : Rice + <i>Sesbania rostrata</i> * + <i>Azolla</i> **	– Rice + <i>Sesbania rostrata</i> *	– Greengram
S ₆ : Rice + <i>Sesbania rostrata</i> * + <i>Azolla</i> **	– Rice + <i>Sesbania rostrata</i> * + <i>Azolla</i> **	– Greengram

* Intercrop

** Dualcrop

Sub plot treatments

Nitrogen levels

N₀ : Control

N₁ : 50% Recommended N

N₂ : 75% Recommended N

N₃ : 100% Recommended N

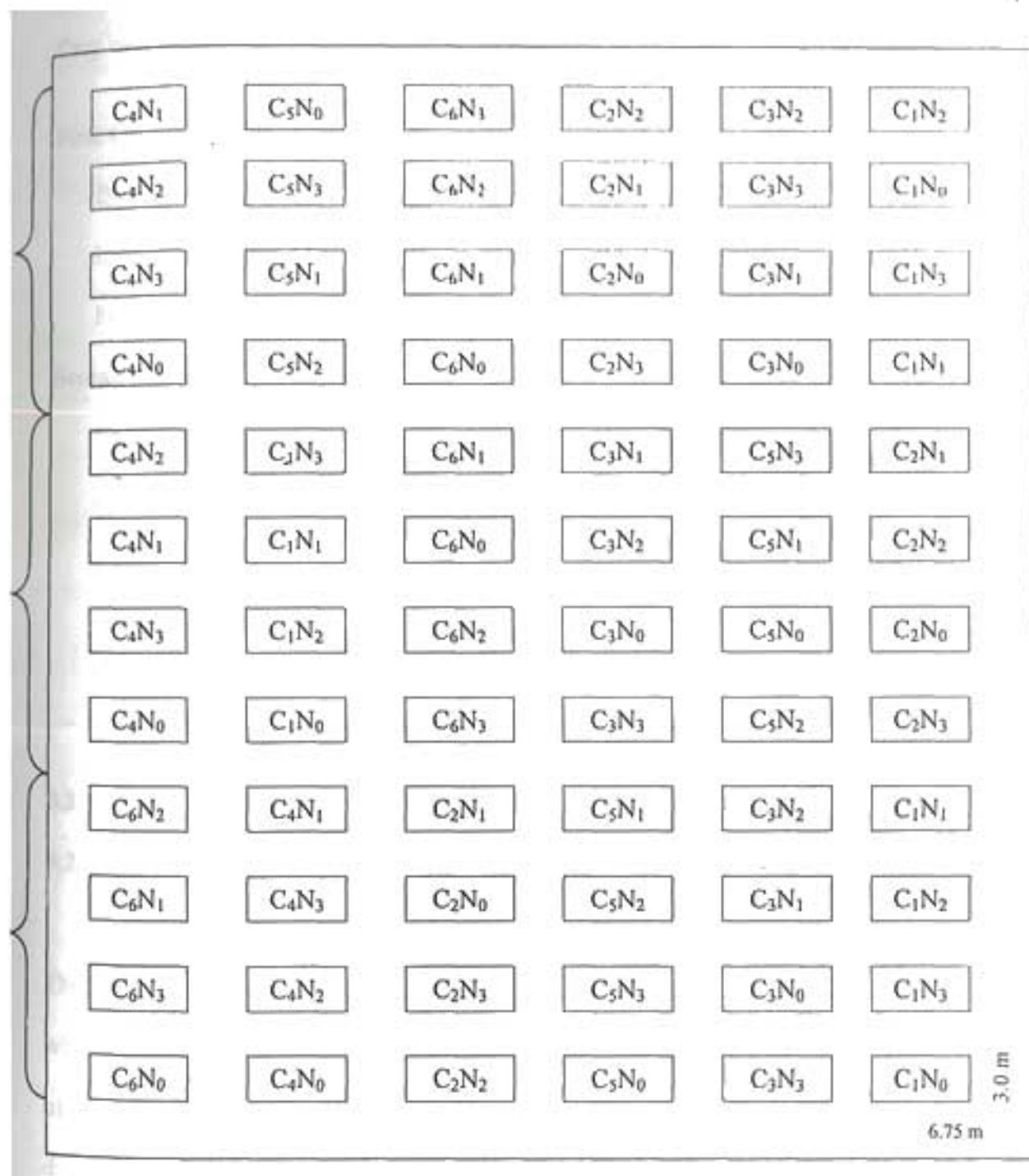


Fig. 3. Layout of the experimental field

3.2.3. Details of plot size, dates of sowing and harvest

Particulars	<i>Kharif</i>	<i>Rabi</i>	Summer
Field No.	D ₁	D ₁	D ₁
Crop and variety	Rice ADT 36	Rice ADT 39	Greengram Pusa Bold
First Cropping Cycle (2000-01)			
Date of sowing	20.6.2000	12.10.2000	7.2.2001
Date of Harvest	2.10.2000	6.2.2001	3.4.2001
Field duration (days)	104	117	56
Second Cropping Cycle (2001-02)			
Date of sowing	15.6.2001	8.10.2001	25.1.2002
Date of Harvest	29.9.2001	24.1.2002	23.3.2002
Field duration (days)	106	118	57
Gross plot size	6.75 x 3.0 m	6.75 x 3.0 m	6.75 x 3.0 m
Net plot size	5.25 x 1.5 m	5.25 x 1.5 m	6.15 x 2.4 m

3.2.4 Crop husbandary

3.2.4.1. Field preparation

The experimental field was dry ploughed with tractor drawn disc harrow. The field was puddled with country plough and than with tractor drawn cage wheel and levelled with bullock drawn wooden levelling plank before the lay out of experiment. The main plots and sub plots were laid out with irrigation and drainage channels all around.

3.2.4.2. Wet seeding by using drum seeder

The “Rice cum green manure seeder” manually drawn developed in Tamil Nadu Agricultural University, Coimbatore was used in the study (Plate 1). The seeder has single wheel and two floats and designed to sow rice and green manure (*Sesbania rostrata*) seeds in alternate rows of 12.5 cm apart and sowing of six rows at a time. The seeder width was 0.75 m. Two men labour can cover an area of 0.54 ha day⁻¹ with a walking speed of around 1.5 km hr⁻¹.

The rice seeds were soaked in water overnight and incubated for 24 hours and the pregerminated seeds were drum seeded at a rate of 75 kg ha⁻¹. The intercrop, *Sesbania rostrata* seeds treated with concentrated sulphuric acid (100 ml kg⁻¹ of seeds) for 10 minutes, washed repeatedly with clean water 4 times, were shade dried and drum seeded at a rate of 25 kg ha⁻¹.

Rice and *Sesbania rostrata* seeds were sown in alternate rows of 12.5 cm in Rice + *Sesbania rostrata* treatment, while sole rice was sown at a row spacing of 25 cm, with the seed holes for *Sesbania rostrata* closed.

The greengram seeds were hand dibbled in rice stubbles immediately after harvest of rice crop at a spacing of 30 x 10 cm using a seed rate of 25 kg ha⁻¹.

3.2.4.3. Inoculation and incorporation of *Azolla*

Azolla was raised by dual cropping technique. Fresh *Azolla microphylla* was inoculated 15 days after sowing (DAS) of rice at 1.0 t ha⁻¹ in the respective treatment plots and water was maintained at three to five cm depth. At 35 DAS,

the *Azolla* multiplied in each treated plot was incorporated into the soil by using conoweeder developed by Tamil Nadu Agricultural University, Coimbatore.

3.2.4.4. Incorporation of green manure

The intercrop of *Sesbania rostrata* was allowed to grow upto 35 DAS and it was trampled in the soil by using the conoweeder. In Rice + *Sesbania rostrata* + *Azolla* treatment plot, the *Sesbania rostrata* was trampled along with *Azolla* by using the same conoweeder at 35 DAS.

3.2.4.5. Water management

A saturated soil was maintained at the time of drum seeding. Light irrigation and drainage of water were alternated for about 10 days to facilitate aeration and adequate moisture for germination of seeds and establishment of seedlings. Thereafter the crop was irrigated to a depth of 5 cm on the day of disappearance of ponded water. Irrigation was withheld 10 days before harvest. For greengram, irrigation was given immediately after sowing and at flowering and pod formation stages.

3.2.4.6. Fertilizer application

Recommended doses of 120:38:38 kg ha⁻¹ and 150:50:50 kg ha⁻¹ of nitrogen, phosphorus and potassium in the form of urea (46% N), single super phosphate (16% P₂O₅) and muriate of potash (60% K₂ O) were applied to the rice crops during *kharif* and *rabi* season respectively. Nitrogen was applied as per the treatments, in four equal splits at seedling, active tillering, panicle initiation and flowering stages. The entire dose of phosphorus was applied basally before sowing. Potassium was applied along with nitrogen in four equal splits

at seedling, active tillering, panicle initiation and flowering stages. Just prior to sowing, a uniform dose of zinc sulphate at 25 kg ha⁻¹ was applied to the rice crop in the both the years of study. Only rice crops were fertilized and greengram was grown as a residual crop without fertilizer application.

3.2.4.7. Weed management

The emulsifiable form of pretilochlor plus (pretilochlor prepacked with fenclorim safener-sofit 30% EC) at 0.3 kg ai ha⁻¹ mixed with 50 kg of sand was applied uniformly at 3 DAS. The field was maintained with a thin film of standing water, when the herbicide was applied. At 35 DAS, conoweeder was used to incorporate *Azolla* or *Sesbania rostrata* or both as per the treatment and while incorporating these, the weeds present in between the crop rows were also incorporated. The left out weeds especially within the crop rows were manually removed. Conoweeder combined with manual weeding was also followed for the sole crop of rice.

3.2.4.8. Plant protection

Adequate prophylactic plant protection measures were taken as per the recommendation of the Crop Production Guide of Tamil Nadu Agricultural University for all rice crops as well as for greengram (CPG, 1999).

3.2.4.9. Harvesting and threshing

For the rice crops, the plants in the border rows (0.75 m) all around the plots were harvested first and then the plants from the net plots were harvested and threshed. Grain and straw yields were recorded separately. Grain yields were adjusted to 14 per cent moisture. Straw was sun dried thoroughly and yield was

recorded. In the case of greengram, pods were picked twice at 7 days interval from the net plot area, threshed and grain yields were recorded at 8 per cent moisture. The haulms were incorporated after estimating the quantity.

3.3. Biometric observations

Plant samples were collected from the predesignated sample area of 0.25m^2 in the second and third rows on either side of the plot excluding one border row. Data on growth components were recorded at different stages. The data on yield attributes were recorded at maturity.

3.3.1. Plant population

Plant population was counted in marked area of one m^2 by using a quadrat at 15 DAS.

3.3.2. Growth components

3.3.2.1. Plant height

Plant height was measured from ground level to the tip of the topmost leaf and expressed in cm for rice and greengram at harvest.

3.3.2.2. Number of tillers

In each experimental plot, four quadrats of 0.25 m^2 each were selected at random and total tillers were counted and expressed as number m^{-2} at flowering stage in rice.

3.3.2.3. Leaf area index

The leaf area index (LAI) of rice and greengram was worked out at flowering stage as per the method suggested by Palaniswamy and Gomez (1974)

for rice and Puttasamy *et al.* (1976) for greengram by using the formula given below.

$$\text{LAI} = \frac{(\text{L} \times \text{W}) \text{K} \times \text{Number of leaves}}{\text{Area occupied by the plant}}$$

Where,

L = Length of the leaf (cm) (For rice third leaf from the top; For greengram fourth trifoliate leaf from tip of the main stem)

W = Maximum width of same leaf (cm)

K = Constant factor (0.75 for *kharif* season rice, 0.73 for *rabi* season rice and 0.6306 for greengram)

The LAI was computed by taking into account the area of the quadrat (50 cm x 50 cm) and total number of leaves in those plants within a quadrat for rice. In greengram, the area occupied by the plant was 30 cm x 10 cm.

3.3.2.4. Dry matter production

Rice plant samples were drawn at active tillering, panicle initiation, flowering and at maturity stages at two locations (0.25 m² each from the sample area (second and third row). In greengram, five plants were removed from sample rows at harvest. These samples were first air dried in the shade and then oven dried at 70°C to a constant weight and DMP was recorded and expressed in kg ha⁻¹.

3.3.3. Yield attributes

3.3.3.1. Yield attributes of rice

3.3.3.1.1. Panicles m⁻²

Four quadrat areas of 0.25 m² were selected at random in each plot and the panicle bearing tillers alone were counted and expressed as panicles m⁻².

3.3.3.1.2. Panicle length

Five panicles were collected randomly in each experimental plot. The length of the panicle was measured from the point of scar to the tip of the panicle and mean length was expressed in cm.

3.3.3.1.3. Filled grains per panicle

Number of filled grains in 5 panicles were counted and mean values were expressed as filled grains per panicle.

3.3.3.1.4. Thousand grain weight

One thousand grains were counted from each plot, weighed and expressed in grams.

3.3.3.2. Growth and yield attributes of greengram

The following growth and yield attributes were measured from the tagged plants.

- | | |
|-----------------------------------|-------------------------------|
| i) Plant height | v) Length of pod (cm) |
| ii) Leaf area index | vi) Number of seeds per pod |
| iii) Number of clusters per plant | vii) Hundred grain weight (g) |
| iv) Number of pods per plant | |

3.3.4. Yield

3.3.4.1. Grain yield

Rice and greengram grain yield were recorded from net plot and expressed in kg ha⁻¹.

3.3.4.2. Straw yield

Dry weight of straw per net plot was recorded after sun-drying and expressed in kg ha⁻¹.

3.3.4.3. Harvest index

Harvest index (HI) was calculated for rice by using the formula suggested by Donald and Humblin (1976).

$$\text{HI (\%)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Grain yield + straw yield (kg ha}^{-1}\text{)}} \times 100$$

3.3.5. Observation on intercrop

3.3.5.1. *Sesbania rostrata* population

The population stand was counted at two locations (0.25m² each in the sample area) in each plot at the time of incorporation (35 DAS) and expressed as number of plants m⁻².

3.3.5.2. Biomass and dry matter production

Sesbania rostrata plants were collected from the sampling area at two locations (0.25 m² each) from the sample area in each plot at the time of incorporation (35 DAS). The biomass was air dried and then oven dried at 70°C to constant weight. The DMP was estimated and expressed in kg ha⁻¹.

3.3.6. Observation on dual crop (*Azolla*)

3.3.6.1. Biomass production

The multiplied *Azolla* was collected at two locations (0.25 m² each) from the sample area in each plot at the time of incorporation (35 DAS).

The samples were weighed to estimate fresh biomass and expressed in kg ha⁻¹. They were air dried and then oven dried at 70°C to constant weight and DMP was recorded. From this, dry matter production was worked out and expressed in kg ha⁻¹.

3.3.7. Residues added

For the estimation of the amount of residues added after each crop, the soil was dug out upto 30 cm depth in an area of quadrat (0.25m²) in each plot. The stubble with the soil was taken out and washed in a drum with continuous flow of water as per the procedure suggested by Long (1951). The residues were separated, dried and weighed. Residues added to each plot were calculated and expressed in kg ha⁻¹. The dried residues were powdered in a Willey Mill and the powder was used to estimate the N content by Microjeldhal method (Humphries, 1956). The nutrient content was multiplied by the weight of dried residues to assess the quantity of nitrogen added to the soil.

3.4. Chemical analysis of soil

Composite soil samples were drawn before the start of the experiment. After harvest of each crop, soil samples were collected from each plot at 0-15 cm depth, dried under shade and sieved through 2mm sieve and analysed for the organic carbon, N, P and K.

3.4.1. Organic carbon

Organic carbon was estimated by chromic acid wet digestion method as suggested by Walkley and Black (1934) and expressed in g kg^{-1} .

3.4.2. Available Nitrogen

The soil available Nitrogen was estimated by alkaline permanganate method of Subbiah and Asija (1956) and expressed in kg ha^{-1} .

3.4.3. Available Phosphorus

The soil available phosphorus was estimated by the method of Olsen *et al.* (1954) and expressed in kg ha^{-1} .

3.4.4. Available Potassium

Available potassium was estimated by using neutral normal ammonium acetate extraction and flame photometry developed by Stanford and English (1949) and expressed in kg ha^{-1} .

3.5. Plant analysis

The plant samples used for dry matter estimation were ground into fine powder in a Willey Mill and used for chemical analysis to determine the content of major nutrients.

3.5.1. Nitrogen

The N content of plant samples was estimated by microkjeldhal method (Humphries, 1956) and uptake was determined at active tillering, panicle initiation, flowering and at harvest stages by multiplying the nutrient content with yield of dry matter and expressed in kg ha^{-1} .

3.5.2. Phosphorus

The P content in plant samples was estimated by colorimetric method (Jackson, 1973) and uptake was computed and expressed in kg ha^{-1} .

3.5.3. Potassium

The plant samples were analysed for K content by using flame photometer (Jackson, 1973) and uptake was computed and expressed in kg ha^{-1} .

3.6. Estimation of ammonia

Flood water samples were collected at 0,5,10, 15,20,25 and 30 days after *Azolla* and *Sesbania rostrata* incorporation as per the treatments. The flood water samples were used for ammonia estimation by colorimetric method (Solorzano, 1969) and expressed in ppm of NH_4^+ -N in the flood water.

3.7. Nitrogen use efficiency

The parameters to study the use efficiency of N are as follows:

3.7.1. Agronomic efficiency (AE)

The agronomic efficiency i.e., additional yield per unit of input as indicated by kg of grain per kg of applied N was computed by the following formula (Yoshida, 1981).

$$\text{AE} = \frac{\text{Grain yield in fertilized plot (kg ha}^{-1}) - \text{Grain yield in unfertilized plot (kg ha}^{-1})}{\text{Quantity of fertilizer N applied (kg ha}^{-1})}$$

3.7.2. Physiological efficiency (PE)

The physiological efficiency, also known as efficiency of utilization, as indicated by kg of grain per kg absorbed N (Yoshida, 1981) was computed as follows:

$$PE = \frac{\text{Grain yield in fertilized plot (kg ha}^{-1}\text{)} - \text{Grain yield in unfertilized plot (kg ha}^{-1}\text{)}}{\text{N uptake in fertilized plot (kg ha}^{-1}\text{)} - \text{N uptake in unfertilized plot (kg ha}^{-1}\text{)}}$$

3.7.3. Apparent recovery

Apparent recovery, also known as 'recovery fraction' was computed as per the formula suggested by Pillai and Vamadevan (1978).

$$\text{Apparent recovery of N(\%)} = \frac{Y_t - Y_o}{N_t} \times 100$$

Where,

Y_t = uptake of N in particular treatment (kg ha⁻¹)

Y_o = uptake of N in unfertilized plot (kg ha⁻¹)

N_t = quantity of N applied for the treatment (kg ha⁻¹)

3.7.4. Nitrogen harvest index (NHI)

The nitrogen harvest index was computed as per the formula suggested by Spiretz (1977).

$$NHI (\%) = \frac{\text{N uptake in economic yield}}{\text{N uptake in biological yield}} \times 100$$

All the above parameters of N use efficiency were worked out for rice crop only.

3.8. Nitrogen balance in the cropping system

Soil available N balance in the cropping system (annual cropping cycle) was computed for different treatments as per the procedure suggested by Sadanandan and Mahapatra (1973).

3.9. Statistical analysis

The data on various characters studied during the course of investigation were statistically analysed as suggested by Gomez and Gomez (1984). Wherever the treatment differences were found to be significant ('F' test), critical differences were worked out at five per cent probability level and the values furnished. Treatment differences that were non-significant, were denoted as 'NS'.

3.10. Economic analysis

Gross and net returns were computed for the cropping system as a whole, considering the cost of inputs and outputs as prevalent at Tamil Nadu Agricultural University Farm, Coimbatore during the period of experiment. Benefit-cost ratio was worked out for different treatments, by dividing the gross returns by total cost of cultivation.

3.10.1. Partial budgeting

Partial budgeting is one of the planning economic tools used to assess the viability of a proposed component technology. Based on this tool, as suggested by Gonzales and Van Der Veen (1986), the economic advantages of different treatments were worked out and the derived benefits or losses are expressed in Rs. ha⁻¹.

RESULTS

CHAPTER IV

RESULTS

The results of the field experiments conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif*, *rabi* and summer seasons of 2000-'01 and 2001-'02 to study the effect of organic and inorganic nitrogen application on growth, yield, nutrient uptake, N use efficiency and soil fertility in wet seeded rice-rice-green gram cropping system are presented in this chapter.

4.1. Growth characters of *Sesbania rostrata*

4.1.1. Plant population (Table 5)

Sesbania rostrata population at 15 DAS was comparable under the organic N sources and inorganic N levels. The population was 134.3, 134.0, 136.5 and 137.0 m⁻² in *kharif* 2000, *rabi* 2000-'01, *kharif* 2001 and *rabi* 2001-'02 seasons respectively.

4.1.2. Biomass production (Table 6)

Fresh biomass production of green manure at the time of incorporation (35 DAS) was not influenced by the organic sources and inorganic N levels. The biomass was 7.15, 8.06, 7.42 and 8.26 t ha⁻¹ during *kharif* 2000, *rabi* 2000-'01, *kharif* 2001 and *rabi* 2001-'02 seasons respectively.

4.1.3. N accumulation (Table 7)

Nitrogen accumulation in *Sesbania rostrata* was almost similar under the organic and inorganic N levels. The N accumulation was 52.9, 60.4, 55.9

Table 5. Effect of organic N sources and inorganic N levels on plant population of *Sesbania rostrata* at 15 DAS

Treatments	Plant population m ⁻² at 15 DAS			
	<i>Kharif</i> 2000	<i>Rabi</i> 2000-'01	<i>Kharif</i> 2001	<i>Rabi</i> 2001-'02
Organic sources				
S ₁	-	-	-	-
S ₂	-	133	-	135
S ₃	132	-	134	-
S ₄	134	-	136	-
S ₅	135	134	137	137
S ₆	136	135	138	138
N levels				
N ₀	130	131	133	134
N ₁	134	134	136	137
N ₂	136	135	138	138
N ₃	137	136	139	139
Mean	134.3	134.0	136.5	137.0

Data not statistically analysed

Table 6. Effect of organic N sources and inorganic N levels on biomass production of *Sesbania rostrata* at 35 DAS

Treatments	Biomass production (t ha ⁻¹) at 35 DAS			
	<i>Kharif</i> 2000	<i>Rabi</i> 2000-'01	<i>Kharif</i> 2001	<i>Rabi</i> 2001-'02
Organic sources				
S ₁	-	-	-	-
S ₂	-	7.98	-	8.14
S ₃	7.01	-	7.29	-
S ₄	7.12	-	7.37	-
S ₅	7.20	8.07	7.47	8.27
S ₆	7.26	8.13	7.53	8.37
N levels				
N ₀	6.98	7.95	7.27	8.16
N ₁	7.09	8.02	7.39	8.22
N ₂	7.22	8.10	7.47	8.28
N ₃	7.29	8.16	7.53	8.39
Mean	7.15	8.06	7.42	8.26

Data not statistically analysed

Table 7. Effect of organic N sources and inorganic N levels on N accumulation of *Sesbania rostrata* at 35 DAS

Treatments	N accumulation (kg ha ⁻¹) at 35 DAS			
	<i>Khariif</i> 2000	<i>Rabi</i> 2000-'01	<i>Khariif</i> 2001	<i>Rabi</i> 2001-'02
Organic sources				
S ₁	-	-	-	-
S ₂	-	59.8	-	61.7
S ₃	51.8	-	55.0	-
S ₄	52.7	-	55.5	-
S ₅	53.2	60.5	56.3	62.7
S ₆	53.7	61.0	56.8	63.4
N levels				
N ₀	51.6	59.6	54.8	61.8
N ₁	52.4	60.1	55.7	62.3
N ₂	53.5	60.8	56.3	62.7
N ₃	53.9	61.2	56.8	63.6
Mean	52.9	60.4	55.9	62.6

Data not statistically analysed

and 62.6 kg ha⁻¹ in *kharif* 2000, *rabi* 2000-'01, *kharif* 2001 and *rabi* 2001-'02 seasons respectively.

4.2. Growth characters of *Azolla*

4.2.1. Biomass production (Table 8)

The biomass production of *Azolla* at the time of incorporation (35 DAS) was not influenced by the organic sources and inorganic N levels. The biomass was 8.18, 9.78, 8.49 and 9.83 t ha⁻¹ in *kharif* 2000, *rabi* 2000-'01, *kharif* 2001 and *rabi* 2001-'02 seasons respectively.

4.2.2. N accumulation (Table 9)

Nitrogen accumulation by *Azolla* was almost similar under the organic sources and inorganic N levels. The N accumulation was 45.8, 54.0, 47.8 and 55.8 kg ha⁻¹ during *kharif* 2000, *rabi* 2000-'01, *kharif* 2001 and *rabi* 2001-'02 seasons respectively.

4.3. Weed population at 35 DAS (Table 10 and 11)

Intercropping of green manure, dual cropping of *Azolla* and combinations of green manure intercropping and *Azolla* dual cropping significantly reduced the weed population density in all the seasons.

Dual cropping of *Azolla* considerably suppressed the grass weeds and sedges at all the seasons. However, broad leaved weeds were suppressed only to a limited extent.

Intercropping of *Sesbania rostrata* markedly suppressed the grass weeds, sedges and broad leaved weeds at all the seasons. Combination of intercropping of

Table 8. Effect of organic N sources and inorganic N levels on biomass production of *Azolla* at 35 DAS

Treatments	Biomass production (t ha ⁻¹) at 35 DAS			
	<i>Kharif</i> 2000	<i>Rabi</i> 2000-'01	<i>Kharif</i> 2001	<i>Rabi</i> 2001-'02
Organic sources				
S ₁	-	-	-	-
S ₂	7.64	-	8.00	-
S ₃	-	9.05	-	9.29
S ₄	8.25	9.50	8.58	9.99
S ₅	8.38	-	8.67	-
S ₆	8.46	10.79	8.72	10.39
N levels				
N ₀	7.30	8.86	7.75	9.11
N ₁	8.06	9.43	8.34	9.76
N ₂	8.50	9.78	8.77	10.11
N ₃	8.86	11.05	9.12	10.32
Mean	8.18	9.78	8.49	9.83

Data not statistically analysed

Table 9. Effect of organic N sources and inorganic N levels on N accumulation by *Azolla* at 35 DAS

Treatments	N accumulation (kg ha ⁻¹) at 35 DAS			
	<i>Kharif</i> 2000	<i>Rabi</i> 2000-'01	<i>Kharif</i> 2001	<i>Rabi</i> 2001-'02
Organic sources				
S ₁	-	-	-	-
S ₂	42.8	-	44.9	-
S ₃	-	51.3	-	52.7
S ₄	46.2	53.8	48.3	55.6
S ₅	46.9	-	48.8	-
S ₆	47.4	57.0	49.0	59.0
N levels				
N ₀	40.9	50.2	43.6	51.7
N ₁	45.2	53.4	46.8	55.4
N ₂	47.6	55.4	49.3	57.4
N ₃	49.6	57.2	51.3	58.6
Mean	45.8	54.0	47.8	55.8

Data not statistically analysed

Table 10. Effect of organic N sources and inorganic N levels on weed population at 35 DAS - Kharif 2000 and 2001

Treatments	Weed population m ⁻² at 35 DAS					
	Kharif 2000			Kharif 2001		
	Grass weeds	Sedges	Broad leaved weeds	Grass weeds	Sedges	Broad leaved weeds
Organic sources						
S ₁	1.99 (101.0)	1.77 (59.4)	1.44 (27.7)	1.94 (88.2)	1.72 (53.1)	1.38 (24.7)
S ₂	1.73 (53.2)	1.60 (40.3)	1.26 (18.6)	1.66 (45.6)	1.55 (35.8)	1.19 (16.1)
S ₃	1.49 (31.6)	1.49 (31.8)	1.13 (13.9)	1.43 (26.7)	1.44 (27.9)	1.08 (12.3)
S ₄	1.33 (21.8)	1.21 (16.3)	0.78 (6.1)	1.27 (18.5)	1.16 (14.6)	0.71 (5.2)
S ₅	1.33 (21.7)	1.20 (16.2)	0.77 (6.0)	1.26 (18.4)	1.15 (14.4)	0.70 (5.1)
S ₆	1.33 (21.7)	1.20 (16.2)	0.76 (5.9)	1.26 (18.2)	1.15 (14.3)	0.69 (5.0)
SEd	0.053	0.067	0.103	0.049	0.058	0.107
CD (P=0.05)	0.118	0.149	0.229	0.109	0.129	0.238
N levels						
N ₀	1.47 (35.5)	1.33 (24.2)	0.87 (8.2)	1.43 (31.8)	1.28 (21.6)	0.80 (7.6)
N ₁	1.53 (40.9)	1.41 (29.3)	1.02 (12.6)	1.46 (35.1)	1.36 (26.1)	0.96 (11.2)
N ₂	1.56 (44.5)	1.45 (32.5)	1.08 (14.8)	1.49 (37.8)	1.40 (28.8)	1.02 (12.8)
N ₃	1.58 (46.5)	1.47 (34.2)	1.11 (15.9)	1.50 (38.9)	1.42 (30.2)	1.04 (13.9)
SEd	0.064	0.078	0.123	0.059	0.083	0.133
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Interaction : Not significant

The figures in paranthesis indicate the original values

Table 11. Effect of organic N sources and inorganic N levels on weed population at 35 DAS - Rabi 2000-'01 and 2001-'02

Treatments	Weed population m ⁻² at 35 DAS					
	<i>Rabi 2000-'01</i>			<i>Rabi 2001-'02</i>		
	Grass weeds	Sedges	Broad leaved weeds	Grass weeds	Sedges	Broad leaved weeds
Organic sources						
S ₁	1.97 (94.7)	1.74 (56.1)	1.39 (25.5)	1.93 (86.1)	1.70 (50.8)	1.31 (21.3)
S ₂	1.45 (28.3)	1.46 (29.1)	1.08 (12.6)	1.39 (25.2)	1.41 (26.0)	1.01 (10.3)
S ₃	1.69 (48.6)	1.57 (37.8)	1.21 (16.6)	1.64 (43.5)	1.54 (34.6)	1.13 (13.6)
S ₄	1.67 (47.9)	1.56 (37.6)	1.21 (16.5)	1.62 (42.6)	1.52 (33.5)	1.10 (13.1)
S ₅	1.44 (27.8)	1.45 (28.9)	0.84 (12.5)	1.38 (24.5)	1.39 (25.2)	1.00 (10.3)
S ₆	1.29 (19.6)	1.18 (15.4)	0.72 (5.4)	1.23 (17.0)	1.12 (13.4)	0.63 (4.4)
SEd	0.409	0.067	0.116	0.054	0.058	0.112
CD (P=0.05)	0.110	0.149	0.259	0.120	0.129	0.249
N levels						
N ₀	1.52 (37.9)	1.40 (27.4)	0.97 (10.2)	1.49 (35.4)	1.37 (25.6)	0.88 (8.3)
N ₁	1.58 (43.6)	1.49 (33.3)	1.12 (14.5)	1.53 (39.4)	1.44 (29.8)	1.02 (11.7)
N ₂	1.61 (47.4)	1.54 (37.1)	1.18 (16.6)	1.55 (41.5)	1.47 (32.5)	1.08 (13.6)
N ₃	1.63 (49.2)	1.56 (38.8)	1.21 (18.1)	1.57 (42.9)	1.50 (34.3)	1.13 (15.0)
SEd	0.064	0.083	0.138	0.069	0.074	0.133
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Interaction : Not significant

The figures in paranthesis indicate the original values

green manure and dual cropping of *Azolla* controlled the grass weeds, sedges and broad leaved weeds irrespective of the season. The inorganic N levels did not vary in the weed suppression in all the seasons.

4.4. Flood water ammoniacal N (Table 12 to 15)

The flood water ammoniacal nitrogen was at its peak 15 days after incorporation of *Azolla* and green manure in all the seasons.

Intercropping of *Sesbania rostrata* and dual cropping of *Azolla* recorded markedly higher ammoniacal nitrogen than that from sole rice. However, these treatments were on par. Combination of intercropping of green manure and dual cropping of *Azolla* had higher ammoniacal nitrogen than those from individual application of *Azolla* or green manure. Sole rice recorded less ammoniacal nitrogen.

Among the N levels, application of 100 per cent recommended N recorded higher ammoniacal N than other levels. The ammoniacal N in the flood water was the lowest in the control.

4.5. Effect of organic and inorganic N application on rice

4.5.1. Growth components

4.5.1.1. Plant population of rice (Table 16)

Rice plant population count was recorded on 15 DAS. Organic N sources and inorganic N levels did not alter the plant population m^{-2} in all the seasons. The population was 377.5, 386.0, 381.5 and 387.5 m^{-2} in *kharif* 2000, *rabi* 2000-'01, *kharif* 2001 and *rabi* 2001-'02 seasons respectively.

Table 12. Effect of organic N sources and inorganic N levels on ammoniacal nitrogen in the flood water of rice – *Kharif* 2000

Treatments	Ammoniacal N (ppm)						
	(Days after incorporation)						
	0	5	10	15	20	25	30
Organic sources							
S ₁	4.82	5.79	6.86	7.23	2.58	1.47	0.53
S ₂	6.29	7.30	9.27	9.82	3.36	1.86	0.64
S ₃	6.42	7.42	9.39	9.95	3.45	1.97	0.67
S ₄	9.07	10.06	12.83	13.68	4.85	2.83	0.98
S ₅	9.08	10.07	12.84	13.69	4.85	2.84	0.99
S ₆	9.09	10.07	12.84	13.69	4.86	2.84	0.99
SEd	0.251	0.264	0.363	0.381	0.157	0.085	0.026
CD (P=0.05)	0.561	0.590	0.812	0.851	0.350	0.192	0.061
N levels							
N ₀	3.60	4.10	5.01	5.45	2.13	1.37	0.52
N ₁	6.97	7.86	9.87	10.50	3.75	2.18	0.77
N ₂	9.16	10.46	13.12	13.90	4.81	2.71	0.92
N ₃	10.12	11.45	14.68	15.53	5.29	2.94	0.99
SEd	0.290	0.315	0.414	0.438	0.182	0.103	0.034
CD (P=0.05)	0.592	0.642	0.841	0.890	0.372	0.213	0.072

Interaction : Not significant

Table 13. Effect of organic N sources and inorganic N levels on ammoniacal nitrogen in the flood water of rice – Rabi 2000-'01

Treatments	Ammoniacal N (ppm)						
	(Days after incorporation)						
	0	5	10	15	20	25	30
Organic sources							
S ₁	5.60	6.36	7.74	8.08	4.16	1.81	0.62
S ₂	7.15	8.18	10.46	11.02	5.30	2.75	0.75
S ₃	7.32	8.36	10.64	11.21	5.34	2.81	0.78
S ₄	7.53	8.77	12.07	12.63	5.72	3.21	0.89
S ₅	7.70	9.06	12.38	12.93	5.77	4.27	0.97
S ₆	10.42	11.95	15.98	16.82	7.39	4.83	1.32
SEd	0.260	0.269	0.372	0.390	0.175	0.094	0.035
CD (P=0.05)	0.581	0.601	0.831	0.872	0.392	0.212	0.081
N levels							
N ₀	3.72	4.32	5.93	6.31	2.87	1.76	0.56
N ₁	7.12	8.13	10.73	11.24	4.86	2.62	0.89
N ₂	9.33	10.85	14.11	14.76	6.81	3.89	1.01
N ₃	10.32	11.86	15.41	16.15	7.95	4.84	1.08
SEd	0.300	0.320	0.424	0.443	0.202	0.113	0.044
CD (P=0.05)	0.612	0.652	0.862	0.902	0.413	0.232	0.092

Interaction: Not significant

Table 14. Effect of organic N sources and inorganic N levels on ammoniacal nitrogen in the flood water of rice – Kharif 2001

Treatments	Ammoniacal N (ppm)						
	(Days after incorporation)						
	0	5	10	15	20	25	30
Organic sources							
S ₁	4.98	5.92	7.48	8.02	3.26	1.58	0.59
S ₂	6.35	7.24	9.60	10.36	3.74	1.89	0.72
S ₃	6.57	7.55	9.92	10.67	4.04	1.99	0.76
S ₄	8.86	9.86	12.20	13.01	6.24	3.09	0.93
S ₅	9.07	10.07	12.40	13.22	6.43	3.20	0.97
S ₆	9.87	10.98	13.31	14.18	6.91	3.46	1.18
SEd	0.255	0.273	0.368	0.385	0.166	0.089	0.031
CD (P=0.05)	0.570	0.612	0.822	0.861	0.372	0.201	0.072
N levels							
N ₀	3.92	4.28	5.26	5.77	2.82	1.39	0.55
N ₁	7.25	8.03	10.02	10.75	4.77	2.37	0.87
N ₂	9.19	10.55	13.19	14.06	6.08	3.03	0.98
N ₃	10.14	11.56	14.78	15.72	6.73	3.35	1.06
SEd	0.295	0.320	0.419	0.433	0.192	0.113	0.044
CD (P=0.05)	0.601	0.650	0.851	0.882	0.391	0.233	0.093

Interaction : Not significant

Table 15. Effect of organic N sources and inorganic N levels on ammoniacal nitrogen in the flood water of rice – Rabi 2001-'02

Treatments	Ammoniacal N (ppm)						
	(Days after incorporation)						
	0	5	10	15	20	25	30
<i>Organic sources</i>							
S ₁	5.69	6.47	7.82	8.26	4.23	1.85	0.67
S ₂	7.27	8.32	10.56	11.20	5.37	3.49	0.78
S ₃	7.48	8.54	10.76	11.43	5.41	2.84	0.83
S ₄	7.71	8.98	12.23	12.87	5.84	3.32	0.94
S ₅	7.90	9.29	12.53	13.18	5.88	4.36	0.99
S ₆	10.69	12.25	16.22	17.15	7.50	5.01	1.38
SEd	0.278	0.300	0.390	0.412	0.184	0.103	0.035
CD (P=0.05)	0.621	0.670	0.871	0.921	0.412	0.233	0.081
<i>N levels</i>							
N ₀	3.82	4.45	5.98	6.43	2.97	1.95	0.61
N ₁	7.24	8.28	10.75	11.36	4.94	2.78	0.94
N ₂	9.50	11.04	14.25	14.93	6.97	4.14	1.07
N ₃	10.60	12.18	15.76	16.60	8.04	5.02	1.12
SEd	0.320	0.350	0.443	0.478	0.216	0.13	0.044
CD (P=0.05)	0.652	0.712	0.902	0.973	0.443	0.253	0.092

Interaction : Not significant

Table 16. Effect of organic N sources and inorganic N levels on plant population of rice at 15 DAS

Treatments	Plant population m ⁻² at 15 DAS			
	<i>Kharif</i> 2000	<i>Rabi</i> 2000-'01	<i>Kharif</i> 2001	<i>Rabi</i> 2001-'02
Organic sources				
S ₁	373	380	377	381
S ₂	374	384	380	384
S ₃	378	385	381	386
S ₄	380	387	383	390
S ₅	381	389	385	392
S ₆	383	390	386	393
SEd	5.8	6.7	6.3	7.2
CD (P=0.05)	NS	NS	NS	NS
N levels				
N ₀	375	383	378	383
N ₁	377	386	381	387
N ₂	378	387	383	389
N ₃	380	388	384	391
SEd	4.4	4.9	3.9	5.8
CD (P=0.05)	NS	NS	NS	NS
Mean	377.5	386.0	381.5	387.5

Interaction : Not significant

4.5.1.2. Plant height (table 17 and 18)

The plant height was recorded at maturity. Rice, which was intercropped with green manure and dual cropped with *Azolla*, had taller plants. Sole rice registered the lowest plant height. The plant height increased with increase in N application upto 100 per cent recommended level. The control recorded the lowest plant height.

The interaction between organic N sources and inorganic N levels was significant. Rice + green manure + *Azolla* coupled with 100 per cent recommended N had the tallest plants of rice. Influence of inorganic N in rice + green manure + *Azolla* was conspicuous only upto 50 per cent recommended level.

4.5.1.3. Number of tillers (Table 19 and 20)

Tiller production was favourably influenced by organic N sources as well as inorganic N levels. Rice + green manure + *Azolla* recorded higher tiller production per unit area. The sole rice recorded the lowest number of tillers.

Among the N levels, 100 per cent recommend N recorded higher tiller number. The lowest tiller production was observed in the control.

The interaction between organic sources and inorganic N levels was significant. The response in tiller production was observed in sole rice upto 100 per cent recommend N. But, when either *Azolla* or green manuring was included, the response was upto 75 per cent recommended level. When both *Azolla* and

Table 17. Effect of organic N sources and inorganic N levels on plant height (cm) of rice at maturity - *Kharif* 2000 and 2001

Treatments	<i>Kharif</i> 2000						<i>Kharif</i> 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	60.2	67.9	73.9	78.7	70.2	67.5	74.8	80.5	84.9	76.9	67.5	74.8	80.5	84.9	76.9
S ₂	65.4	73.5	79.7	84.2	75.7	72.7	80.2	86.1	90.2	82.3	72.7	80.2	86.1	90.2	82.3
S ₃	65.9	74.3	80.6	84.9	76.4	73.1	80.8	86.8	90.7	82.8	73.1	80.8	86.8	90.7	82.8
S ₄	72.9	81.6	84.8	86.0	81.3	79.9	87.8	90.2	91.6	87.4	79.9	87.8	90.2	91.6	87.4
S ₅	73.3	82.1	85.2	86.2	81.7	80.5	88.5	91.0	91.9	88.0	80.5	88.5	91.0	91.9	88.0
S ₆	73.5	82.3	85.4	86.3	81.8	83.9	92.1	94.0	94.7	91.2	83.9	92.1	94.0	94.7	91.2
Mean	68.5	76.9	81.6	84.4		76.3	84.0	88.1	90.6		76.3	84.0	88.1	90.6	
	SEd		CD (P = 0.05)			SEd		CD (P = 0.05)			SEd		CD (P = 0.05)		
S	1.04		2.31			0.95		2.11			0.95		2.11		
N	1.29		2.63			1.19		2.43			1.19		2.43		
	2.01		4.12			1.57		3.22			1.57		3.22		
			4.63			2.14		4.35			2.14		4.35		

Table 18. Effect of organic N sources and inorganic N levels on Plant height (cm) of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01					Rabi 2001-'02				
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	53.1	61.3	67.9	73.2	63.8	57.2	65.6	72.4	77.8	68.2
S ₂	58.3	66.8	73.6	78.6	69.3	62.9	71.5	78.5	83.6	74.1
S ₃	58.8	67.5	74.5	79.2	70.0	64.0	72.7	79.8	84.8	75.3
S ₄	60.2	69.0	76.1	80.7	71.5	65.3	74.2	81.4	86.3	76.8
S ₅	61.3	70.2	77.4	81.9	72.7	66.5	75.5	82.8	87.6	78.1
S ₆	68.3	77.7	79.6	82.7	77.1	73.3	82.7	85.5	87.8	82.3
Mean	60.0	68.7	74.9	79.4	71.1	64.8	73.7	80.0	84.7	75.3
		SEd	CD (P = 0.05)			SEd	CD (P = 0.05)			
S		1.62	3.62			1.53	3.42			
N		2.07	4.21			1.92	3.91			
S at N		2.34	4.83			2.19	4.53			
		2.56	5.22			2.61	5.32			

Table 19. Effect of organic N sources and inorganic N levels on tiller number m⁻² of rice at flowering - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	382	454	512	561	477	395	464	520	566	486	395	464	520	566	486
S ₂	420	502	568	608	525	435	509	569	611	531	435	509	569	611	531
S ₃	432	518	587	626	540	445	523	587	627	546	445	523	587	627	546
S ₄	504	596	626	638	591	530	617	647	662	614	530	617	647	662	614
S ₅	508	600	629	641	594	537	625	653	668	620	537	625	653	668	620
S ₆	511	603	631	643	597	582	673	686	696	659	582	673	686	696	659
Mean	459	546	592	620		487	568	610	638		487	568	610	638	
	SEd						SEd						CD (P = 0.05)		
S	9.6						9.9						22.1		
N	12.4						12.9						26.3		
S at N	17.8						18.6						38.2		
N at S	22.2						24.3						49.3		
	CD (P = 0.05)						CD (P = 0.05)						CD (P = 0.05)		
	21.3						21.3						22.1		
	25.2						25.2						26.3		
	36.4						36.4						38.2		
	45.1						45.1						49.3		

Table 20. Effect of organic N sources and inorganic N levels on tiller number m⁻² of rice at flowering - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	406	482	537	583	502	420	499	556	605	520	420	499	556	605	520
S ₂	448	529	587	627	548	467	551	611	654	571	467	551	611	654	571
S ₃	456	541	602	641	560	477	565	627	667	584	477	565	627	667	584
S ₄	468	556	618	656	574	501	593	657	696	612	501	593	657	696	612
S ₅	474	566	630	666	584	513	607	672	709	625	513	607	672	709	625
S ₆	538	632	657	672	625	579	674	697	718	667	579	674	697	718	667
Mean	465	551	605	641		493	581	636	675		493	581	636	675	
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		13.5	30.2				14.4	32.1				14.4	32.1		
N		17.4	35.3				17.8	36.2				17.8	36.2		
		19.2	39.4				20.7	42.4				20.7	42.4		
			43.2				23.3	47.3				23.3	47.3		

green manuring were combined, the response could be observed only upto 50 per cent recommended level.

4.5.1.4. Leaf area index (Table 21 and 22)

Organic and inorganic N supply had positive influence on the LAI at flowering in all the seasons. Among the organic N sources, rice + green manure + *Azolla* resulted in substantially higher LAI than that in other treatments. Sole rice registered lower LAI.

There was improvement in LAI with increase in N level. The highest LAI was recorded in 100 per cent N.

There was considerable increase in LAI in sole rice with increase in inorganic N upto 100 per cent. But the LAI was comparable with 75 per cent and 100 per cent levels in case of rice either intercropped with green manure or dual cropped with *Azolla*. There was no further increase in LAI in rice after 50 per cent level which had both intercrop of green manure and dual crop of *Azolla*.

4.5.1.5. Dry matter production (DMP) (Table 23 to 30 and Fig. 4 to 7)

Organic and inorganic N fertilization exerted marked influence on the DMP at all the four stages of observation viz., active tillering, panicle initiation, flowering and at maturity.

Among the organic N sources, rice + green manure + *Azolla* recorded significantly higher DMP. Sole rice registered lower DMP than other treatments.

Table 21. Effect of organic N sources and inorganic N levels on LAI of rice at flowering - *Khairif* 2000 and 2001

Treatments	<i>Khairif</i> 2000						<i>Khairif</i> 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	2.76	4.16	4.99	5.51	4.36	2.97	4.28	5.09	5.59	4.48	2.97	4.28	5.09	5.59	4.48
S ₂	3.30	4.75	5.62	6.09	4.94	3.56	4.90	5.72	6.16	5.08	3.56	4.90	5.72	6.16	5.08
S ₃	3.65	5.13	6.02	6.45	5.31	3.73	5.09	5.95	6.36	5.28	3.73	5.09	5.95	6.36	5.28
S ₄	4.65	6.14	6.46	6.62	5.97	4.73	6.12	6.37	6.57	5.95	4.73	6.12	6.37	6.57	5.95
S ₅	4.68	6.16	6.48	6.64	5.99	4.83	6.22	6.46	6.63	6.03	4.83	6.22	6.46	6.63	6.03
S ₆	4.69	6.18	6.49	6.66	6.00	5.24	6.64	6.66	6.68	6.30	5.24	6.64	6.66	6.68	6.30
Mean	3.95	5.42	6.01	6.32	6.00	4.18	5.54	6.04	6.33	6.00	4.18	5.54	6.04	6.33	6.00
		SEd	CD (P = 0.05)	SEd	CD (P = 0.05)		SEd	CD (P = 0.05)	SEd	CD (P = 0.05)		SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
S		0.116	0.261				0.113	0.252				0.113	0.252		
N		0.143	0.292				0.134	0.273				0.134	0.273		
S at N		0.206	0.421				0.195	0.402				0.195	0.402		
N at S		0.248	0.503				0.236	0.471				0.236	0.471		

Table 22. Effect of organic N sources and inorganic N levels on LAI of rice at flowering - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	3.07	4.67	5.52	6.10	4.84	3.32	4.82	5.66	6.19	4.99	3.32	4.82	5.66	6.19	4.99
S ₂	3.61	5.25	6.11	6.65	5.40	3.91	5.44	6.29	6.79	5.60	3.91	5.44	6.29	6.79	5.60
S ₃	3.71	5.45	6.21	6.75	5.53	3.94	5.48	6.31	6.80	5.63	3.94	5.48	6.31	6.80	5.63
S ₄	3.91	5.75	6.51	6.85	5.76	4.14	5.78	6.36	6.84	5.78	4.14	5.78	6.36	6.84	5.78
S ₅	4.01	5.95	6.61	6.95	5.88	4.20	5.86	6.43	6.90	5.85	4.20	5.86	6.43	6.90	5.85
S ₆	4.46	6.43	6.75	6.97	6.15	4.82	6.48	6.78	6.98	6.26	4.82	6.48	6.78	6.98	6.26
Mean	3.80	5.58	6.28	6.71	6.15	4.06	5.64	6.30	6.75	6.15	4.06	5.64	6.30	6.75	6.15
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		0.113		0.251			0.175		0.390			0.175		0.390	
N		0.158		0.332			0.212		0.431			0.212		0.431	
S at N		0.245		0.503			0.235		0.483			0.235		0.483	
N at S		0.227		0.562			0.257		0.522			0.257		0.522	

Table 23. Effect of organic N sources and inorganic N levels on DMP (kg ha^{-1}) of rice at active tillering - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001									
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	
S ₁	872	1264	1498	1654	1322	898	1305	1548	1708	1365						
S ₂	1056	1453	1690	1840	1510	1076	1489	1736	1890	1548						
S ₃	1084	1485	1724	1873	1541	1106	1524	1774	1926	1582						
S ₄	1373	1776	1856	1926	1733	1484	1906	1994	2061	1861						
S ₅	1377	1780	1859	1930	1736	1510	1936	2026	2090	1890						
S ₆	1380	1784	1861	1932	1739	1666	2096	2131	2161	2013						
Mean	1190	1590	1748	1859		1290	1709	1868	1973							
	SEd	CD (P = 0.05)				SEd	CD (P = 0.05)									
S	44.0	98.2				42.8	95.3									
N	51.9	105.4				48.9	99.2									
S at N	63.2	129.3				69.6	142.4									
N at S	76.0	154.2				78.0	158.2									

Table 24. Effect of organic N sources and inorganic N levels on DMP (kg ha⁻¹) of rice at active tillering - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	966	1384	1634	1796	1445	986	1412	1676	1844	1480	986	1412	1676	1844	1480
S ₂	1158	1582	1837	1992	1642	1184	1618	1885	2048	1684	1184	1618	1885	2048	1684
S ₃	1189	1617	1875	2028	1677	1218	1655	1924	2084	1720	1218	1655	1924	2084	1720
S ₄	1299	1731	1991	2140	1790	1334	1774	2046	2204	1839	1334	1774	2046	2204	1839
S ₅	1325	1760	2021	2169	1819	1364	1808	2082	2239	1873	1364	1808	2082	2239	1873
S ₆	1619	2056	2138	2212	2006	1665	2117	2202	2277	2065	1665	2117	2202	2277	2065
Mean	1259	1688	1916	2056		1292	1730	1569	2116		1292	1730	1569	2116	
	SEd	SEd	CD (P = 0.05)	CD (P = 0.05)		SEd	SEd	CD (P = 0.05)	CD (P = 0.05)		SEd	SEd	CD (P = 0.05)	CD (P = 0.05)	
S	58.0	58.0	129.3	129.3		61.1	61.1	136.2	136.2		61.1	61.1	136.2	136.2	
N	66.3	66.3	134.5	134.5		70.3	70.3	142.5	142.5		70.3	70.3	142.5	142.5	
S at N	72.0	72.0	147.4	147.4		77.4	77.4	158.4	158.4		77.4	77.4	158.4	158.4	
N at S	78.5	78.5	159.2	159.2		81.6	81.6	165.6	165.6		81.6	81.6	165.6	165.6	

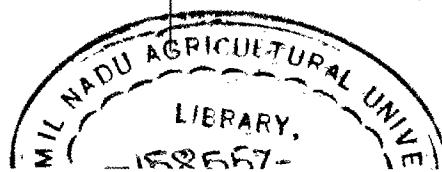


Table 25. Effect of organic N sources and inorganic N levels on DMP (kg ha⁻¹) of rice at panicle initiation - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	1852	2540	2962	3226	2645	1908	2600	3028	3298	2708	1908	2600	3028	3298	2708
S ₂	2102	2798	3226	3484	2902	2173	2871	3302	3562	2977	2173	2871	3302	3562	2977
S ₃	2134	2833	3263	3519	2937	2208	2909	3342	3599	3014	2208	2909	3342	3599	3014
S ₄	2679	3383	3518	3637	3304	2752	3457	3594	3719	3380	2752	3457	3594	3719	3380
S ₅	2686	3388	3524	3641	3310	2782	3490	3629	3751	3413	2782	3490	3629	3751	3413
S ₆	2690	3392	3527	3645	3314	3044	3755	3809	3860	3617	3044	3755	3809	3860	3617
Mean	2357	3056	3336	3527	3314	2478	3180	3450	3632	3314	2478	3180	3450	3632	3314
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		77.3	172.3				75.1	167.4				75.1	167.4		
N		91.4	185.4				88.4	179.3				88.4	179.3		
S at N		121.3	248.5				126.3	258.5				126.3	258.5		
N at S		128.3	260.2				132.0	267.3				132.0	267.3		

Table 26. Effect of organic N sources and inorganic N levels on DMP (kg ha^{-1}) of rice at panicle initiation - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02									
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	
S ₁	1958	2660	3093	3362	2768	2032	2740	3177	3452	2850						
S ₂	2278	2985	3421	3685	3092	2360	3072	3512	3712	3182						
S ₃	2306	3018	3457	3719	3125	2390	3106	3548	3815	3215						
S ₄	2422	3137	3577	3836	3243	2512	3231	3675	3940	3339						
S ₅	2451	3169	3610	3868	3275	2546	3269	3715	3976	3376						
S ₆	2904	3625	3762	3890	3545	3004	3731	3873	3996	3651						
Mean	2386	3099	3487	3726		2474	3192	3583	3827							
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)								
S		103.7	231.2				105.6	235.4								
N		116.0	235.4				120.5	244.3								
S at N		125.2	256.3				127.1	260.2								
N at S		131.9	267.5				134.8	273.5								

Table 27. Effect of organic N sources and inorganic N levels on DMP (kg ha⁻¹) of rice at flowering - *Kharif* 2000 and 2001

Treatments	<i>Kharif</i> 2000						<i>Kharif</i> 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	4637	7252	8994	9962	7711	4702	7334	9083	10059	7794	4702	7334	9083	10059	7794
S ₂	5629	7352	9998	10958	8484	5722	8360	10112	11081	8819	5722	8360	10112	11081	8819
S ₃	5667	7394	10043	11000	8526	5762	8405	10160	11126	8863	5762	8405	10160	11126	8863
S ₄	7882	10612	11102	11570	10292	8007	10654	11144	11622	10357	8007	10654	11144	11622	10357
S ₅	7886	10615	11107	11575	10296	8049	10700	11192	11667	10402	8049	10700	11192	11667	10402
S ₆	7889	10618	11109	11578	10298	9018	11672	12094	12344	11282	9018	11672	12094	12344	11282
Mean	6598	8974	10392	11107		6877	9520	10631	11316		6877	9520	10631	11316	
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		309.4	689.4				296.4	660.3				296.4	660.3		
N		344.3	698.3				335.0	679.4				335.0	679.4		
S at N		465.3	952.5				467.3	956.5				467.3	956.5		
N at S		475.9	965.2				480.0	973.6				480.0	973.6		

Table 28. Effect of organic N sources and inorganic N levels on DMP (kg ha⁻¹) of rice at flowering - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	4765	7412	9170	10154	7875	4792	7454	9225	10219	7923					
S ₂	6085	8738	10500	11478	9200	6120	8788	10565	11551	9256					
S ₃	6127	8783	10547	11523	9245	6182	8854	10633	11617	9321					
S ₄	6877	9537	11303	12277	9998	6950	9626	11408	12389	10093					
S ₅	6919	9583	11352	12323	10044	7006	9686	11472	12449	10153					
S ₆	9095	11763	12256	12741	11464	9202	11883	12378	12870	11583					
Mean	6645	9303	10854	11749		6708	9382	10946	11849						
	SEd	SEd	CD (P = 0.05)	CD (P = 0.05)		SEd	SEd	CD (P = 0.05)	CD (P = 0.05)						
S	388.4		865.4			349.2		778.2							
N	437.5		887.2			441.9		896.3							
S at N	473.1		968.5			475.0		972.5							
N at S	483.3		980.2			488.4		990.4							

Table 29. Effect of organic N sources and inorganic N levels on DMP (kg ha⁻¹) of rice at maturity - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	6986	9760	11701	12707	10289	7112	9920	11845	12866	10436	7112	9920	11845	12866	10436
S ₂	8960	11142	12942	13806	11712	9089	11338	13102	14019	11887	9089	11338	13102	14019	11887
S ₃	9693	11628	13240	14017	12145	9702	11838	13452	14285	12319	9702	11838	13452	14285	12319
S ₄	11156	13295	13728	14140	13080	11470	13485	13972	14435	13340	11470	13485	13972	14435	13340
S ₅	11305	13414	13847	14267	13208	11682	13878	14368	14829	13689	11682	13878	14368	14829	13689
S ₆	11405	13497	13940	14328	13293	12696	14852	15150	15436	14534	12696	14852	15150	15436	14534
Mean	9918	12123	13233	13878		10292	12552	13648	14311		10292	12552	13648	14311	
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		268.6	598.4				279.3	622.3				279.3	622.3		
N		312.7	634.2				319.2	647.2				319.2	647.2		
S at N		431.2	882.5				446.8	914.7				446.8	914.7		
N at S		461.7	936.3				481.5	976.5				481.5	976.5		

Table 30. Effect of organic N sources and inorganic N levels on DMP (kg ha⁻¹) of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	7366	10224	12168	13195	10738	7624	10647	12413	13437	11030					
S ₂	9416	11852	13544	14470	12320	9673	12152	13798	14738	12590					
S ₃	10042	12354	13876	14725	12749	10256	12602	14145	15009	13003					
S ₄	10740	12904	14157	14994	13198	10927	13136	14430	15248	13435					
S ₅	11184	13112	14346	15142	13446	11142	13345	14633	15442	13640					
S ₆	12260	14492	14962	15420	14284	12312	14728	15520	15700	14565					
Mean	10168	12490	13842	14658		10322	12768	14157	14929						
	SEd			CD (P = 0.05)			SEd			CD (P = 0.05)					
S	344.8			768.3			325.9			726.3					
N	395.7			802.6			373.8			758.4					
S at N	451.5			924.3			458.5			938.6					
N at S	474.6			962.5			485.3			984.3					

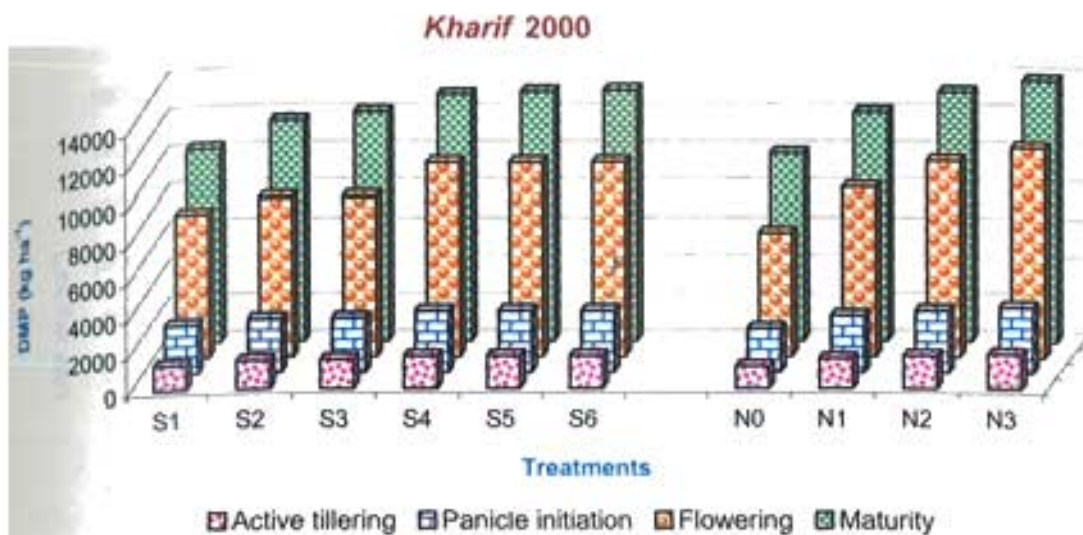


Fig.4. Effect of organics and inorganic N on DMP of rice.

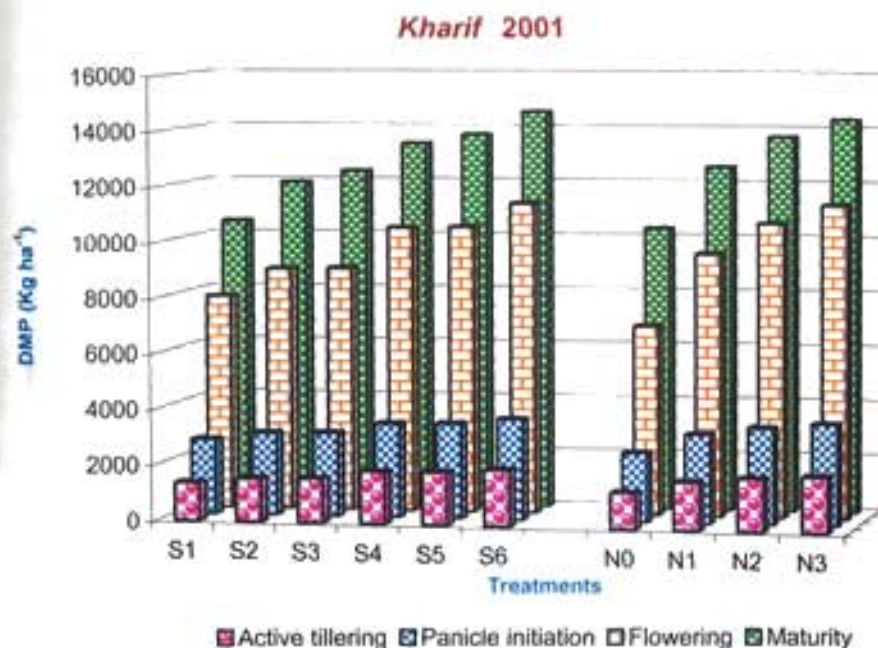


Fig.5. Effect of organics and inorganic N on DMP of rice.

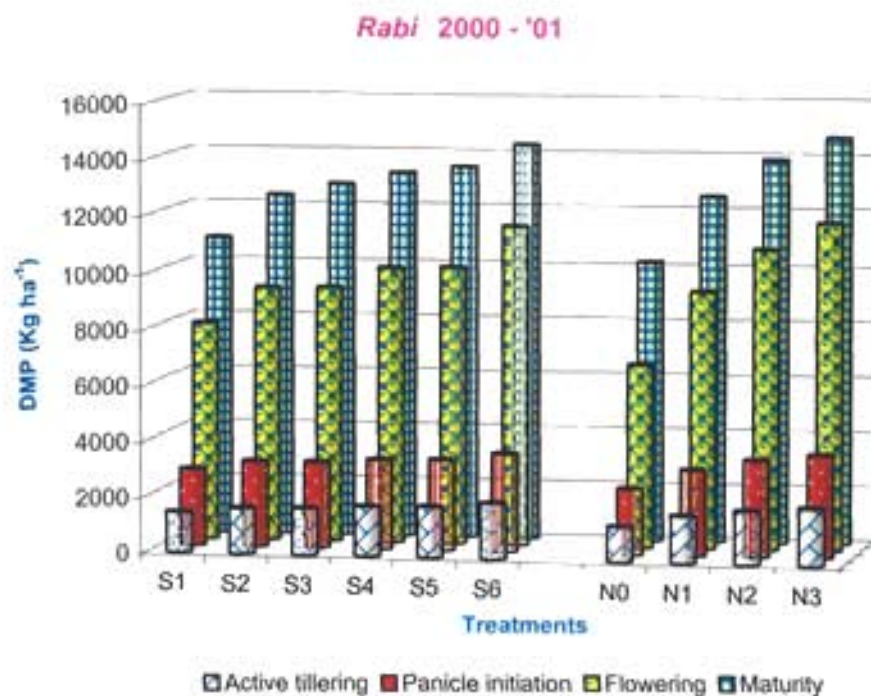


Fig.6. Effect of organics and inorganic N on DMP of rice.

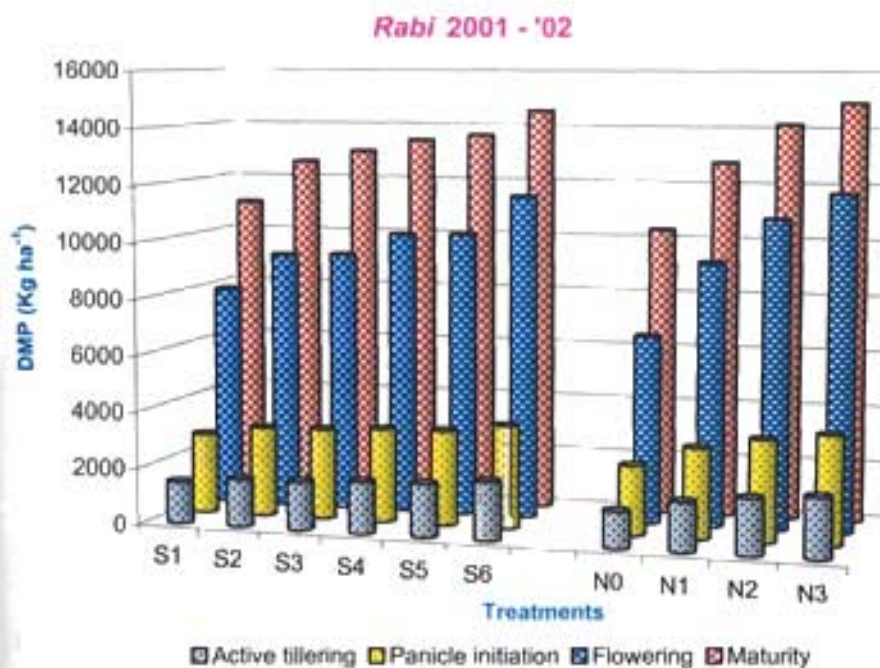


Fig. 7 . Effect of organics and inorganic N on DMP of rice.

Application of 100 per cent recommended N resulted in significantly higher DMP than other levels of N fertilization. Lower DMP was observed in the control.

Interaction between organic and inorganic N application was significant. In the absence of organic and inorganic N supply, DMP was the lowest in sole rice. Influence of inorganic N in the presence of rice + green manure + *Azolla* was pronounced upto 50 per cent N application.

The data on DMP indicates that the effect of different treatments and treatment combinations was similar at all the four stages of observation.

4.5.2. Yield attributes

4.5.2.1. Panicles m⁻² (Table 31 and 32)

The influence of organic N sources and inorganic N levels was considerable on the production of ear bearing tillers per unit area in all the seasons.

Among the organic sources green manuring and *Azolla* dual cropping combination produced significantly higher number of panicles. Sole rice produced less number of panicles.

Application of 100 per cent N registered significantly more number of panicles. Less number of panicles was observed in the control.

Interaction between organic N sources and inorganic N levels was significant. The least number of panicles m⁻² was observed in sole rice without N

Table 31. Effect of organic N sources and inorganic N levels on panicles m⁻² of rice at maturity - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	375	445	499	544	466	386	451	505	547	472	451	493	552	589	514
S ₂	415	490	548	586	509	424	493	552	589	514	493	552	589	589	514
S ₃	423	503	564	600	522	433	505	567	602	527	505	597	623	634	592
S ₄	490	576	606	614	572	516	597	623	634	592	604	628	655	664	633
S ₅	493	579	608	616	574	522	604	628	639	598	649	655	664	664	633
S ₆	495	581	610	617	576	564	649	655	664	633	649	655	664	664	633
Mean	448	529	573	596		474	550	588	612		474	550	588	612	
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		7.6	17.2				8.2	18.3				8.2	18.3		
N		9.8	20.1				10.8	22.5				10.8	22.5		
S at N		18.7	38.3				16.6	34.3				16.6	34.3		
N at S		20.2	41.5				19.2	39.2				19.2	39.2		

Table 32. Effect of organic N sources and inorganic N levels on panicles m⁻² of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	398	470	522	564	489	412	487	542	585	506	487	536	609	643	567
S ₂	439	518	576	613	536	457	536	594	631	554	466	548	637	668	591
S ₃	445	526	586	621	544	487	574	637	680	604	497	587	673	687	642
S ₄	456	540	601	635	558	487	574	637	668	591	480	564	617	649	604
S ₅	461	549	612	644	567	497	587	651	680	604	559	650	673	687	642
S ₆	523	614	637	649	606	559	650	673	687	642	480	564	617	649	604
Mean	454	536	589	621	606	480	564	617	649	606	480	564	617	649	606
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		11.3	25.3				9.5	21.2				9.5	21.2		
N		13.9	28.2				13.0	26.5				13.0	26.5		
S at N		17.8	36.5				15.9	32.6				15.9	32.6		
N at S		20.0	40.6				19.4	39.4				19.4	39.4		

supply through any source. Influence of inorganic N in the presence of rice + green manure + *Azolla* was observed only upto 50 per cent recommended N level.

4.5.2.2. Panicle length (Table 33 and 34)

Rice intercropped with green manuring and dual cropped with *Azolla* had longer panicles. Sole rice recorded shorter panicles.

Application of 100 per cent recommended N produced significantly longer panicles. Shorter panicles were observed in the control.

Interaction between organic and inorganic N application was significant. Rice + green manure + *Azolla* with 100 per cent recommended N application produced the longer panicles, while non supply of N through any source resulted in shorter panicles. The impact of inorganic N in the presence of rice + green manure + *Azolla* was pronounced only upto 50 per cent recommended N level.

4.5.2.3. Filled grains per panicle (Table 35 and 36)

Filled grains per panicle was greatly influenced by organic and inorganic N application in all the seasons. Rice + green manure + *Azolla* resulted in significantly more number of filled grains per panicle. Less number of filled grains per panicle was registered in sole rice.

Among the N levels, fertilization of 100 per cent recommended N recorded significantly more number of filled grains per panicle. The control recorded less number of filled grains per panicle.

Table 33. Effect of organic N sources and inorganic N levels on panicle length (cm) of rice at maturity - *Kharif* 2000 and 2001

Treatments	<i>Kharif</i> 2000						<i>Kharif</i> 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	18.2	20.4	21.4	22.2	20.6	19.4	21.5	22.8	23.5	21.8	19.4	21.5	22.8	23.5	21.8
S ₂	19.3	21.6	22.6	23.2	21.7	20.5	22.7	23.9	24.3	22.9	20.5	22.7	23.9	24.3	22.9
S ₃	19.6	21.8	22.8	23.3	21.8	20.7	22.9	24.0	24.4	23.0	20.7	22.9	24.0	24.4	23.0
S ₄	20.9	23.2	23.4	23.6	22.7	21.9	24.2	24.6	24.8	23.8	21.9	24.2	24.6	24.8	23.8
S ₅	21.0	23.3	23.4	23.7	22.8	22.1	24.4	24.7	24.9	24.0	22.1	24.4	24.7	24.9	24.0
S ₆	21.1	23.4	23.5	23.8	22.9	22.7	25.1	25.3	25.4	24.6	22.7	25.1	25.3	25.4	24.6
Mean	20.0	22.3	22.9	23.3		21.2	23.5	24.2	24.6		21.2	23.5	24.2	24.6	
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		0.09		0.21		0.08			0.22		0.08			0.22	
N		0.15		0.32		0.14			0.31		0.14			0.31	
S at N		0.26		0.53		0.26			0.53		0.26			0.53	
N at S		0.36		0.72		0.45			0.92		0.45			0.92	

Table 34. Effect of organic N sources and inorganic N levels on panicle length (cm) of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	16.3	18.7	20.2	21.2	19.0	17.5	19.7	21.1	21.8	20.0	17.5	19.7	21.1	21.8	20.0
S ₂	17.5	20.0	21.4	22.1	20.3	18.6	20.9	22.2	22.5	21.0	18.6	20.9	22.2	22.5	21.0
S ₃	17.7	20.2	21.5	22.2	20.4	18.7	21.1	22.3	22.6	21.2	18.7	21.1	22.3	22.6	21.2
S ₄	18.8	21.4	22.6	23.2	21.5	19.8	22.3	23.4	23.6	22.3	19.8	22.3	23.4	23.6	22.3
S ₅	18.9	21.6	22.7	23.3	21.6	19.9	22.5	23.6	23.8	22.4	19.9	22.5	23.6	23.8	22.4
S ₆	20.0	22.8	23.2	23.5	22.4	20.7	23.4	23.7	23.9	22.9	20.7	23.4	23.7	23.9	22.9
Mean	18.2	20.8	21.9	22.5	22.4	19.2	21.6	22.7	23.0	22.4	19.2	21.6	22.7	23.0	22.4
	SEd		CD (P = 0.05)			SEd		CD (P = 0.05)			SEd		CD (P = 0.05)		
S	0.14		0.32			0.09		0.21			0.09		0.21		
N	0.20		0.42			0.11		0.22			0.11		0.22		
S at N	0.29		0.61			0.21		0.43			0.21		0.43		
N at S	0.39		0.83			0.30		0.62			0.30		0.62		

Table 36. Effect of organic N sources and inorganic N levels on filled grains panicle⁻¹ of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02									
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	
S ₁	72.3	80.9	87.1	91.1	82.9	75.2	83.0	88.7	92.5	84.8						
S ₂	77.1	86.1	92.5	96.2	87.9	79.8	87.8	93.6	97.1	89.6						
S ₃	78.9	88.1	94.6	98.2	89.9	81.7	89.9	95.8	99.2	91.6						
S ₄	80.9	90.3	96.9	100.4	92.1	83.9	92.0	97.8	101.1	93.7						
S ₅	82.1	91.4	97.9	101.4	93.2	85.2	93.2	98.8	102.0	94.8						
S ₆	89.5	98.7	100.7	102.3	97.8	92.0	99.7	101.7	103.1	99.1						
Mean	80.1	89.2	94.9	98.3		82.9	90.9	96.0	99.2							
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)								
S		1.26	2.82				1.16	2.62								
N		1.48	3.01				1.42	2.93								
S at N		1.56	3.23				1.56	3.25								
N at S		1.88	3.82				1.83	3.72								

Interaction effect due to organic N sources and inorganic N levels was significant. In sole rice, there was progressive improvement in panicle number upto 100 per cent recommended N. In rice + *Azolla* or rice + green manure, improvement in panicle number was considerable upto 75 per cent N level. In the case of rice + *Azolla* + green manure in both the *kharif* and *rabi* seasons, the response in terms of panicle number was upto 50 per cent N only.

4.5.2.4. Thousand grain weight (Table 37)

Thousand grain weight did not differ significantly due to different organic N sources as well as N levels in any of the seasons. The interaction effect between organic N sources and inorganic N levels was also not significant.

4.5.3. Nutrient uptake by rice

4.5.3.1. Nitrogen uptake (Table 38 to 45 and Fig. 8 to 11)

Organic N sources and inorganic N levels substantially influenced the N uptake in all the four stages of observation, viz., active tillering, panicle initiation, flowering and maturity.

Rice + green manure + *Azolla* resulted in significantly higher N uptake, while sole rice recorded lower N uptake.

Increased levels of N progressively improved the N uptake upto the 100 per cent recommended N. Control resulted in lower N uptake.

Interaction effect due to organic and inorganic N application was significant. The largest N removal was observed in rice + green manure + *Azolla* with

Table 37. Effect of organic N sources and inorganic N levels on thousand grain weight of rice at maturity

Treatments	Thousand grain weight (g)			
	<i>Kharif</i> 2000	<i>Kharif</i> 2001	<i>Rabi</i> 2000-'01	<i>Rabi</i> 2001-'02
Organic sources				
S ₁	19.0	19.4	16.4	16.7
S ₂	19.5	20.0	17.1	17.2
S ₃	19.6	20.1	17.3	17.4
S ₄	20.1	20.3	17.4	17.5
S ₅	20.2	20.5	17.5	17.7
S ₆	20.2	20.9	18.0	18.2
SEd	0.58	0.76	0.85	0.72
CD (P=0.05)	NS	NS	NS	NS
N levels				
N ₀	18.7	19.1	16.1	16.2
N ₁	19.8	20.3	17.2	17.3
N ₂	20.2	20.6	17.8	18.0
N ₃	20.4	20.8	18.0	18.3
SEd	0.94	0.89	0.98	0.99
CD (P=0.05)	NS	NS	NS	NS

Interaction : Not significant

Table 38. Effect of organic N sources and inorganic N levels on N uptake (kg ha^{-1}) of rice at active tillering - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	12.2	24.8	32.9	38.6	27.1	14.5	27.4	35.8	41.9	29.9	14.5	27.4	35.8	41.9	29.9
S ₂	18.7	31.6	39.9	45.2	33.9	21.3	34.4	42.9	48.5	36.8	21.3	34.4	42.9	48.5	36.8
S ₃	19.2	32.3	40.7	45.9	34.5	22.0	35.2	43.8	49.2	37.5	22.0	35.2	43.8	49.2	37.5
S ₄	29.0	41.9	46.0	47.1	41.0	32.2	45.1	48.6	50.6	44.1	32.2	45.1	48.6	50.6	44.1
S ₅	29.2	42.1	46.2	47.2	41.2	33.1	45.8	49.2	51.2	44.8	33.1	45.8	49.2	51.2	44.8
S ₆	29.2	42.2	46.3	47.3	41.2	38.9	51.4	53.7	55.6	49.9	38.9	51.4	53.7	55.6	49.9
Mean	22.9	35.8	42.0	45.2	41.2	27.0	39.9	45.6	49.5	41.2	27.0	39.9	45.6	49.5	41.2
	SEd		CD (P = 0.05)			SEd		CD (P = 0.05)			SEd		CD (P = 0.05)		
S	1.26		2.81			1.43		3.21			1.43		3.21		
N	1.48		3.02			1.77		3.63			1.77		3.63		
S at N	2.54		5.23			2.59		5.32			2.59		5.32		
N at S	2.71		5.52			2.86		5.83			2.86		5.83		

Table 39. Effect of organic N sources and inorganic N levels N uptake (kg ha⁻¹) of rice at active tillering - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	16.6	29.8	38.9	45.2	32.6	17.9	31.8	41.2	47.8	34.7	17.9	31.8	41.2	47.8	34.7
S ₂	23.8	37.2	46.4	52.2	39.9	25.3	39.5	48.9	54.9	42.1	25.3	39.5	48.9	54.9	42.1
S ₃	24.6	38.2	47.5	53.1	40.8	26.6	40.6	50.1	55.8	43.3	26.6	40.6	50.1	55.8	43.3
S ₄	28.2	41.6	50.7	56.1	44.1	30.7	44.5	53.9	59.5	47.1	30.7	44.5	53.9	59.5	47.1
S ₅	29.1	42.6	51.6	57.0	45.0	31.1	45.1	54.4	59.9	47.6	31.1	45.1	54.4	59.9	47.6
S ₆	38.7	51.7	55.3	57.4	50.8	40.9	54.6	57.8	60.3	53.4	40.9	54.6	57.8	60.3	53.4
Mean	26.8	40.2	48.4	53.5	50.8	28.7	42.7	51.0	56.4	50.8	28.7	42.7	51.0	56.4	50.8
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		1.75	3.92				1.92	4.31				1.92	4.31		
N		2.07	4.21				2.32	4.72				2.32	4.72		
S at N		2.74	5.62				2.83	5.80				2.83	5.80		
		2.97	6.03				3.12	6.32				3.12	6.32		

Table 40. Effect of organic N sources and inorganic N levels on N uptake (kg ha^{-1}) of rice at panicle initiation - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001									
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	
S ₁	18.6	35.4	46.1	52.8	38.2	20.4	37.4	48.3	55.2	40.3	20.4	37.4	48.3	55.2	40.3	
S ₂	27.2	44.3	55.2	61.2	47.0	29.2	46.3	57.5	63.3	49.0	29.2	46.3	57.5	63.3	49.0	
S ₃	28.1	45.4	56.4	62.2	48.0	30.3	47.5	58.8	64.5	50.3	30.3	47.5	58.8	64.5	50.3	
S ₄	40.3	57.7	62.4	63.9	56.0	43.7	60.6	64.0	66.4	58.7	43.7	60.6	64.0	66.4	58.7	
S ₅	40.5	57.9	62.5	64.0	56.2	45.0	61.7	65.1	67.4	59.8	45.0	61.7	65.1	67.4	59.8	
S ₆	40.6	58.0	62.6	64.1	56.3	51.5	67.8	71.1	73.2	65.9	51.5	67.8	71.1	73.2	65.9	
Mean	32.6	49.8	57.5	61.3		36.7	53.5	60.8	65.0		36.7	53.5	60.8	65.0		
	SEd						SEd						CD (P = 0.05)			
S	1.39						1.62						3.61			
N	1.72						1.92						3.92			
S at N	2.84						2.79						5.73			
N at S	3.15						3.01						6.14			
	CD (P = 0.05)						CD (P = 0.05)						CD (P = 0.05)			
	3.12						3.12						3.61			
	3.51						3.92						3.92			
	5.82						5.73						5.73			
	6.40						6.14						6.14			

Table 41. Effect of organic N sources and inorganic N uptake (kg ha^{-1}) of rice at panicle initiation - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	23.2	40.3	51.2	58.0	43.2	25.9	43.2	54.3	61.2	46.2	25.9	43.2	54.3	61.2	46.2
S ₂	32.1	49.4	60.4	66.5	52.1	34.9	52.5	63.7	70.1	55.3	34.9	52.5	63.7	70.1	55.3
S ₃	33.3	50.7	61.8	67.8	53.4	36.2	53.9	65.2	71.5	56.7	36.2	53.9	65.2	71.5	56.7
S ₄	38.1	55.3	66.0	71.8	57.8	41.4	58.8	69.8	75.9	61.4	41.4	58.8	69.8	75.9	61.4
S ₅	40.3	57.7	68.2	73.9	60.0	42.5	60.0	70.9	76.9	62.6	42.5	60.0	70.9	76.9	62.6
S ₆	55.9	68.6	71.6	74.4	67.6	54.3	71.4	74.7	77.6	69.5	54.3	71.4	74.7	77.6	69.5
Mean	37.2	53.7	63.2	68.7		39.2	56.6	66.4	72.2		39.2	56.6	66.4	72.2	
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		2.15	4.80				2.33	5.21				2.33	5.21		
N		2.51	5.12				2.76	5.62				2.76	5.62		
S at N		2.78	5.71				2.98	6.14				2.98	6.14		
N at S		3.12	6.34				3.25	6.63				3.25	6.63		

Table 42. Effect of organic N sources and inorganic N levels on N uptake (kg ha^{-1}) of rice at flowering - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	36.2	62.4	79.2	89.7	66.9	38.4	65.2	83.4	94.2	70.3					
S ₂	50.0	76.6	93.6	103.6	81.0	52.6	79.6	97.7	108.1	84.5					
S ₃	52.2	78.9	96.0	105.9	83.2	55.0	82.1	100.2	110.4	86.9					
S ₄	74.3	98.8	105.9	108.6	96.9	75.7	103.2	108.7	113.0	100.1					
S ₅	74.5	98.9	106.1	108.7	97.0	76.9	104.4	109.8	114.1	101.3					
S ₆	74.6	99.0	106.2	108.8	97.2	85.9	113.7	117.1	119.9	109.2					
Mean	60.3	85.7	97.8	104.2		64.0	91.4	102.8	109.9						
	SEd		CD (P = 0.05)			SEd		CD (P = 0.05)							
S	2.60		5.81			2.91		6.50							
N	3.00		6.12			3.40		6.92							
S at N	4.64		9.50			4.25		8.73							
N at S	5.03		10.21			5.23		10.60							

Table 43. Effect of organic N sources and inorganic N levels on N uptake (kg ha⁻¹) of rice at flowering - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02									
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	
S ₁	41.3	68.7	86.3	97.2	73.4	43.5	71.1	89.0	100.1	75.9						
S ₂	56.5	84.3	102.1	112.4	88.8	59.3	87.2	105.3	115.8	91.9						
S ₃	58.9	86.9	104.8	115.0	91.4	61.8	89.8	107.8	118.1	94.4						
S ₄	64.1	91.8	109.6	119.7	96.3	67.2	94.9	112.7	122.9	99.4						
S ₅	66.4	93.9	111.6	121.6	98.4	69.6	97.2	114.8	124.9	101.6						
S ₆	85.5	112.6	117.8	122.8	109.6	89.0	116.2	121.2	126.0	113.1						
Mean	62.1	89.7	105.4	114.8		65.0	92.7	108.5	117.9							
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)								
S		3.91		8.72			3.27		7.32							
N		4.48		9.11			4.04		8.24							
S at N		4.98		10.20			5.03		10.35							
		5.22		10.62			5.37		10.92							

Table 44. Effect of organic N sources and inorganic N levels on N uptake (kg ha⁻¹) of rice at maturity - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	43.8	72.3	92.5	107.7	79.0	45.2	74.4	95.6	112.4	81.9	45.2	74.4	95.6	112.4	81.9
S ₂	59.9	88.9	109.4	122.9	95.3	61.5	91.3	112.7	128.9	98.6	61.5	91.3	112.7	128.9	98.6
S ₃	62.7	92.1	112.9	126.0	98.4	64.4	94.6	116.3	132.1	101.8	64.4	94.6	116.3	132.1	101.8
S ₄	88.9	115.4	122.6	129.2	114.0	92.5	118.8	127.0	134.6	118.2	92.5	118.8	127.0	134.6	118.2
S ₅	90.0	115.6	122.7	129.3	114.4	95.3	121.3	129.0	135.9	120.4	95.3	121.3	129.0	135.9	120.4
S ₆	90.2	115.7	122.9	129.4	114.6	114.7	137.5	141.4	144.9	134.6	114.7	137.5	141.4	144.9	134.6
Mean	72.6	100.0	113.8	124.0		78.9	106.3	120.3	131.4		78.9	106.3	120.3	131.4	
	SEd		CD (P = 0.05)			SEd		CD (P = 0.05)			SEd		CD (P = 0.05)		
S	4.26		9.52			4.67		10.41			4.67		10.41		
N	4.78		9.73			5.37		10.92			5.37		10.92		
S at N	6.45		13.24			7.72		15.80			7.72		15.80		
S × N	6.93		14.05			8.14		16.52			8.14		16.52		

Table 45. Effect of organic N sources and inorganic N levels on N uptake (kg ha⁻¹) of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	47.9	77.1	98.5	114.9	84.6	48.5	77.9	99.7	116.5	85.7	48.5	77.9	99.7	116.5	85.7
S ₂	65.1	94.7	116.3	132.1	102.0	65.9	95.8	117.7	133.9	103.3	65.9	95.8	117.7	133.9	103.3
S ₃	68.0	98.0	119.8	135.5	105.3	68.9	99.2	121.3	137.4	106.7	68.9	99.2	121.3	137.4	106.7
S ₄	71.0	100.5	122.0	137.6	107.8	72.1	102.0	123.6	139.6	109.3	72.1	102.0	123.6	139.6	109.3
S ₅	73.8	103.0	124.4	139.9	110.3	75.3	104.9	126.2	142.1	112.1	75.3	104.9	126.2	142.1	112.1
S ₆	98.0	125.8	133.8	141.2	124.7	101.5	129.5	136.9	143.7	127.9	101.5	129.5	136.9	143.7	127.9
Mean	70.6	99.8	119.1	133.5		72.0	101.6	120.9	135.5		72.0	101.6	120.9	135.5	
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		5.92	13.21				6.05	13.51				6.05	13.51		
N		6.80	13.82				6.85	13.90				6.85	13.90		
S at N		7.42	15.24				7.72	15.82				7.72	15.82		
N at S		7.94	16.13				8.18	16.63				8.18	16.63		

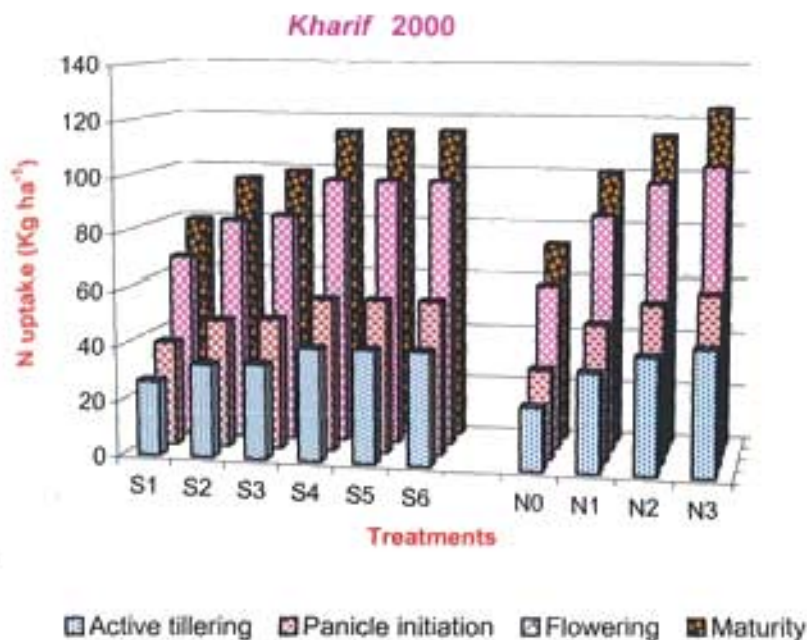


Fig. 8. Effect of organics and inorganic N on N uptake (Kg ha⁻¹) of rice

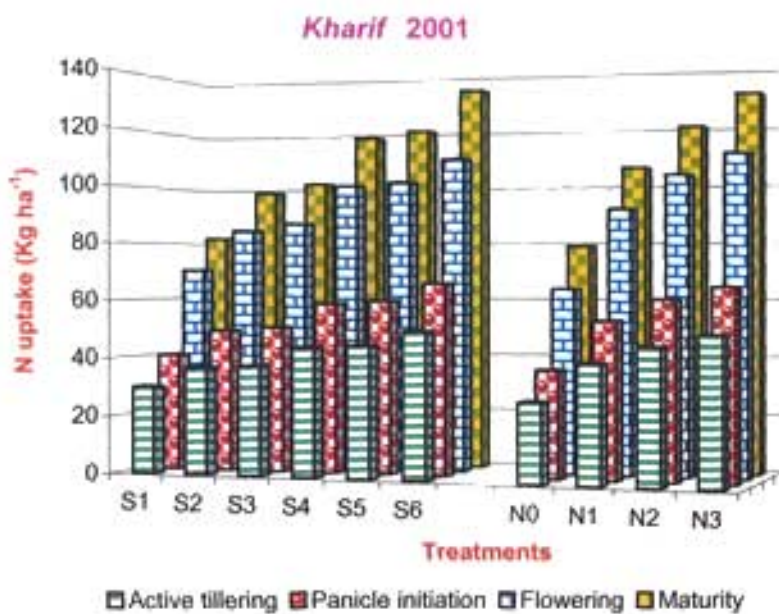


Fig. 9. Effect of organics and inorganic N on N uptake (Kg ha⁻¹) of rice.

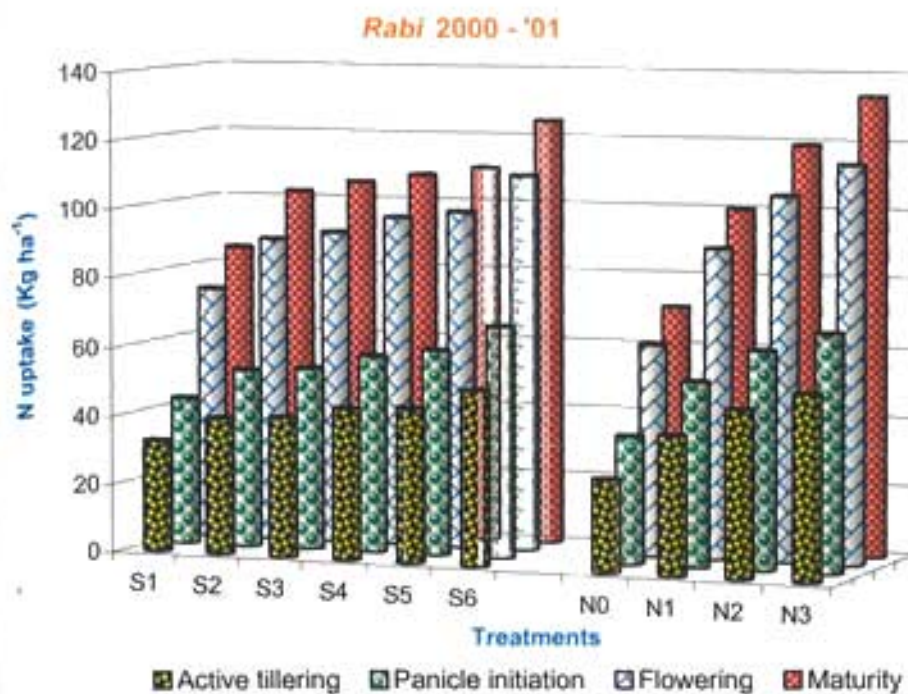


Fig. 10 Effect of organics and inorganic N on N uptake (Kg ha⁻¹) of rice.

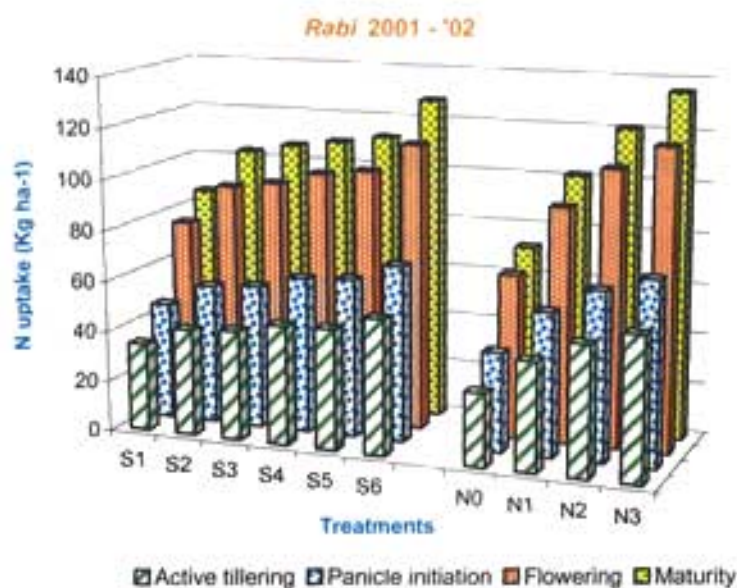


Fig. 11. Effect of organics and inorganic N on N uptake (Kg ha⁻¹) of rice.

100 per cent N application, while the N uptake was the lowest in the absence of N supply through any source. The impact of fertilizer N in the presence of rice + green manure + *Azolla* was only upto 50 per cent recommended N application.

Nitrogen uptake between active tillering and panicle initiation was slower while it increased considerably from panicle initiation to flowering. Thereafter, it was steady with a moderate rate of increase upto maturity.

The influence of various treatments and treatment combinations on the uptake of N was similar at all the four stages of observation.

4.5.3.2. Phosphorus uptake (Table 46 and 47)

Phosphorus uptake at maturity was influenced by organic N sources and inorganic N levels. Organic sources promoted the uptake of phosphorus, which tended to increase progressively with N supply upto 100 per cent recommended N levels. Sole rice registered lower P uptake than other treatments.

Interaction effect between organic and inorganic N application was considerable. The largest quantity of P removal was recorded with 100 per cent recommended N in presence of rice + green manure + *Azolla*, while the smallest P removal was in the control.

4.5.3.3. Potassium uptake (Table 48 and 49)

Potassium uptake at maturity was affected by organic N sources and fertilizer N levels in all the seasons. Among the organic sources, rice + green manure + *Azolla* resulted in significantly higher K uptake, while sole rice registered

Table 46. Effect of organic N sources and inorganic N levels on P uptake (kg ha^{-1}) of rice at maturity - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	17.6	25.8	31.0	34.5	27.2	18.4	26.7	32.0	35.6	28.1	18.4	26.7	32.0	35.6	28.1
S ₂	21.9	30.3	35.6	38.4	31.6	22.7	31.2	36.6	39.7	32.6	22.7	31.2	36.6	39.7	32.6
S ₃	22.8	31.1	36.3	39.0	32.3	23.6	32.0	37.3	40.4	33.3	23.6	32.0	37.3	40.4	33.3
S ₄	29.3	37.3	38.9	40.2	36.4	30.4	38.5	40.1	41.6	37.6	30.4	38.5	40.1	41.6	37.6
S ₅	29.4	37.5	39.0	40.3	36.5	31.3	39.3	40.8	42.2	38.4	31.3	39.3	40.8	42.2	38.4
S ₆	29.6	37.6	39.1	40.4	36.7	34.8	42.5	43.7	45.4	41.6	34.8	42.5	43.7	45.4	41.6
Mean	25.1	33.2	36.7	38.8	36.7	26.7	35.0	38.4	40.8	36.7	26.7	35.0	38.4	40.8	36.7
	SEd		CD (P = 0.05)			SEd		CD (P = 0.05)			SEd		CD (P = 0.05)		
S	0.82		1.82			0.99		2.21			0.99		2.21		
N	0.94		1.91			1.13		2.30			1.13		2.30		
S at N	1.43		2.93			1.46		3.02			1.46		3.02		
N at S	1.59		3.24			1.64		3.34			1.64		3.34		

Table 47. Effect of organic N sources and inorganic N levels on P uptake (kg ha^{-1}) of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02									
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	
S ₁	19.8	28.1	33.5	37.2	29.6	19.9	29.0	34.8	38.4	30.6						
S ₂	24.2	32.6	37.9	41.2	34.0	24.7	33.9	39.6	43.1	35.3						
S ₃	25.0	33.3	38.4	41.7	34.6	25.6	34.7	40.2	43.6	36.0						
S ₄	26.2	34.5	39.5	42.7	35.7	27.0	36.0	41.3	44.6	37.2						
S ₅	27.3	35.5	40.5	43.6	36.7	28.2	37.7	42.4	45.6	38.5						
S ₆	33.6	41.5	43.2	44.8	40.8	35.2	44.4	45.7	46.9	43.0						
Mean	26.0	34.2	38.8	41.9		26.7	35.9	40.7	43.7							
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)								
S		1.16	2.61				1.22	2.72								
N		1.38	2.80				1.38	2.82								
S at N		1.51	3.12				1.66	3.40								
N at S		1.74	3.54				1.83	3.72								

Table 48. Effect of organic N sources and inorganic N levels on K uptake (kg ha^{-1}) of rice at maturity - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	46.2	84.6	112.0	127.6	92.6	47.3	85.9	112.3	128.0	93.4					
S ₂	66.0	103.0	129.8	143.8	110.6	67.2	104.2	130.1	144.0	111.3					
S ₃	69.2	105.9	132.5	146.3	113.5	70.5	107.1	132.9	146.6	114.2					
S ₄	105.6	140.1	147.3	154.3	136.8	103.3	139.6	147.3	153.0	135.8					
S ₅	105.8	142.1	149.2	156.2	138.3	104.5	140.7	148.3	154.0	136.9					
S ₆	106.0	143.3	150.2	157.4	139.2	119.1	155.1	158.9	161.8	148.7					
Mean	83.1	119.8	136.8	147.6		85.3	122.1	138.3	147.9						
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)							
S		4.53	10.12				3.99	8.92							
N		5.18	10.52				4.58	9.33							
S at N		6.94	14.21				6.93	14.21							
N at S		7.34	14.90				7.24	14.72							

Table 49. Effect of organic N sources and inorganic N levels on K uptake (kg ha^{-1}) of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01					Rabi 2001-'02				
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	49.8	89.0	116.2	132.2	96.8	51.2	90.6	118.0	134.1	98.5
S ₂	69.9	107.4	134.5	148.4	115.0	72.4	108.8	136.1	150.4	116.9
S ₃	73.4	110.6	137.5	151.2	118.2	76.1	112.1	139.2	153.3	120.1
S ₄	77.6	114.5	141.0	154.4	121.9	80.4	116.2	142.8	156.6	124.0
S ₅	80.8	117.4	143.7	156.8	124.6	83.6	119.2	145.6	159.1	126.9
S ₆	112.9	145.2	152.4	158.6	141.8	113.7	147.4	154.7	161.2	144.2
Mean	77.4	114.0	137.5	150.3		79.6	115.7	139.4	152.4	
	SEd	SEd	CD (P = 0.05)	CD (P = 0.05)	SEd	SEd	CD (P = 0.05)	CD (P = 0.05)	SEd	SEd
S	5.34	5.34	11.91	11.91	5.43	5.43	12.12	12.12	5.43	5.43
N	6.01	6.01	12.20	12.20	6.16	6.16	12.53	12.53	6.16	6.16
S at N	6.74	6.74	13.82	13.82	6.93	6.93	14.20	14.20	6.93	6.93
N at S	7.06	7.06	14.34	14.34	7.35	7.35	14.92	14.92	7.35	7.35

lower K uptake. Application of 100 per cent recommended N level recorded significantly higher K uptake. Lower K uptake was noticed in the control.

Interaction between organic N sources and inorganic N levels was significant. The largest quantity of K removal was recorded with the application of 100 per cent recommended N in rice + green manure + *Azolla*. Skipping of application of organic and inorganic N resulted in the lowest K uptake. Rice + green manure + *Azolla* exerted marked improvement at K uptake upto the N level of 50 per cent recommended N.

4.5.4. Grain yield (Table 50 and 51 and Fig. 12 and 13)

There was perceptible difference in rice grain yield due to the organic N sources and inorganic N levels in all the seasons.

Rice+green manure+*Azolla* resulted in substantially higher grain yield, while sole rice registered lower grain yield.

Fertilization of 100 per cent recommended N recorded markedly higher grain yield. Control resulted in lower grain yield.

The interaction effect due to organic N sources and inorganic N levels was significant. There was considerable improvement in grain yield upto 100 per cent N level in sole rice, while in rice + green manure or rice + *Azolla*, marked increase in grain yield was observed only upto 75 per cent N. In the case of rice+*Azolla*+green manure, substantial response in grain yield was upto 50 per cent recommended level in both *kharif* and *rabi* seasons.

Table 50. Effect of organic N sources and inorganic N levels Grain yield (kg ha⁻¹) of rice - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	2964	4326	5238	5692	4555	3052	4425	5342	5804	4655	3052	4425	5342	5804	4655
S ₂	3926	4982	5796	6215	5230	4035	5097	5912	6338	5346	4035	5097	5912	6338	5346
S ₃	4238	5249	5992	6379	5465	4359	5368	6112	6504	5586	4359	5368	6112	6504	5586
S ₄	5027	6014	6233	6442	5929	5152	6136	6358	6572	6054	5152	6136	6358	6572	6054
S ₅	5092	6075	6290	6485	5986	5246	6198	6410	6619	6118	5246	6198	6410	6619	6118
S ₆	5135	6114	6325	6514	6022	5682	6630	6754	6870	6484	5682	6630	6754	6870	6484
Mean	4397	5460	5979	6288		4587	5642	6148	6451		4587	5642	6148	6451	
	SEd	SEd	CD (P = 0.05)	CD (P = 0.05)		SEd	SEd	CD (P = 0.05)	CD (P = 0.05)		SEd	SEd	CD (P = 0.05)	CD (P = 0.05)	
S	123.1	123.1	274.3	274.3		120.1	120.1	268.2	268.2		120.1	120.1	268.2	268.2	
N	147.2	147.2	298.4	298.4		144.2	144.2	292.4	292.4		144.2	144.2	292.4	292.4	
S at N	201.5	201.5	412.5	412.5		209.4	209.4	428.7	428.7		209.4	209.4	428.7	428.7	
N at S	215.0	215.0	436.2	436.2		223.0	223.0	452.3	452.3		223.0	223.0	452.3	452.3	

Table 51. Effect of organic N sources and inorganic N levels on grain yield (kg ha⁻¹) of rice - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02									
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	
S ₁	3186	4572	5498	5966	4806	3295	4687	5619	6092	4923						
S ₂	4202	5346	6124	6563	5559	4319	5466	6249	6694	5682						
S ₃	4518	5619	6324	6730	5798	4617	5734	6445	6859	5914						
S ₄	4865	5904	6456	6858	6021	4956	6014	6581	6984	6134						
S ₅	4997	6028	6571	6952	6137	5082	6133	6694	7082	6247						
S ₆	5562	6568	6796	7116	6511	5654	6678	6908	7230	6618						
Mean	4555	5673	6295	6698		4653	5785	6416	6824							
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)								
S		146.9	327.5				151.9	338.4								
N		181.6	368.2				189.4	384.2								
S at N		203.4	416.3				212.6	435.3								
N at S		223.2	452.7				228.0	462.5								

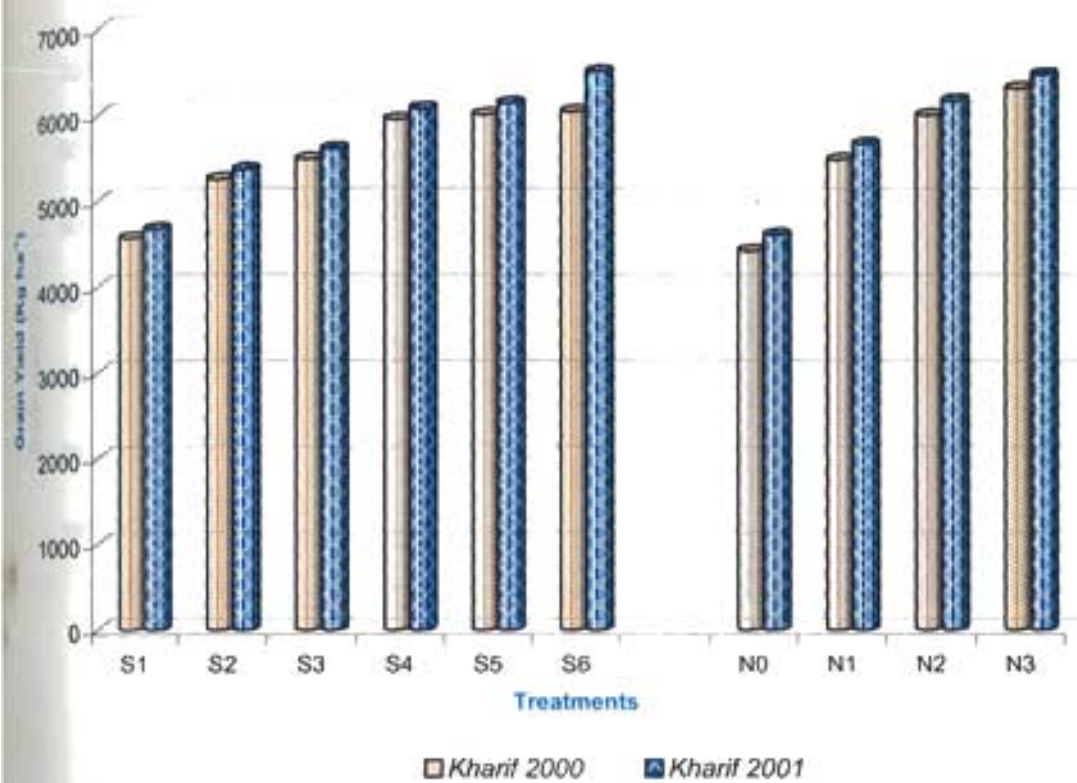


Fig. 12. Effect of organics and inorganic N on grain yield (Kg ha⁻¹) of rice.

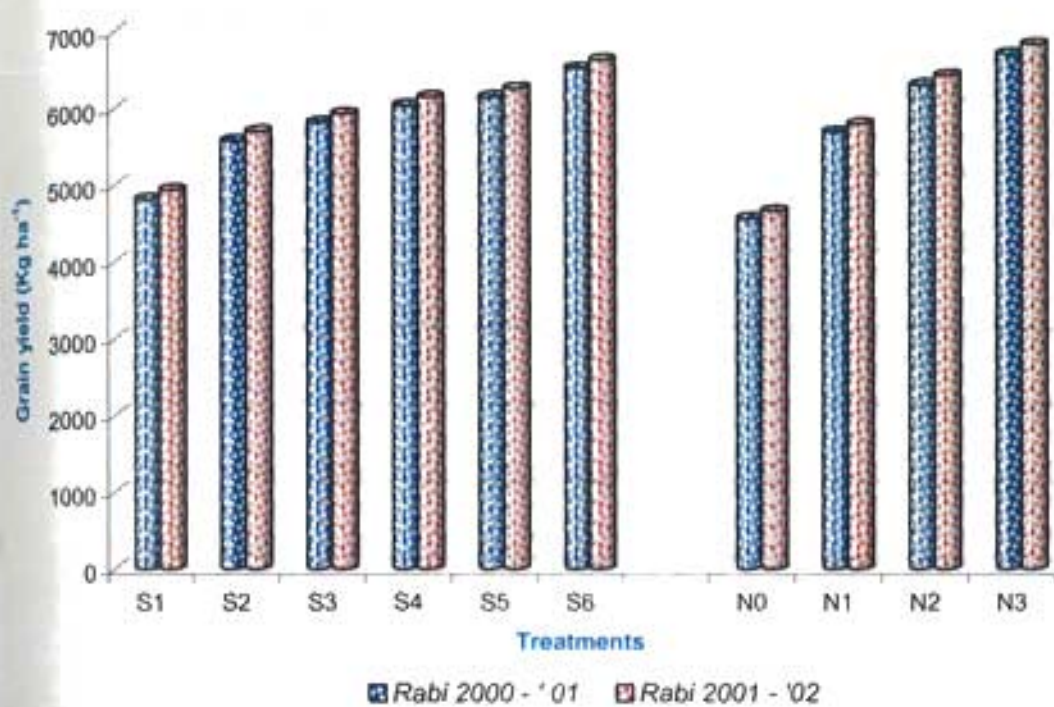


Fig. 13. Effect of organics and inorganic N on grain yield (Kg ha⁻¹) of rice.

4.5.5. Straw yield (Table 52 and 53)

Organic N sources and inorganic N levels exerted favourable influence on rice straw yield in *kharif* as well as *rabi* seasons.

Straw production was augmented by organic N application. Nitrogen supply enhanced the straw yield considerably upto 100 per cent recommended level of N, through the rate of increase tended to diminishing trend with the increased N supply.

Interaction between organic and inorganic N supply was significant. The influence of inorganic N in the presence of rice + green manure + *Azolla* was conspicuous only upto 50 per cent recommended level of N, whereas rice + green manure or rice + *Azolla* recorded response in straw production upto 75 per cent level. In case of sole rice, the response was upto 100 per cent level.

4.5.6. Harvest index (Table 54 and 55)

The mean data on harvest index (%) indicated that rice+green manure + *Azolla* resulted in higher harvest index, while the sole rice registered lower harvest index. Increasing N levels increased harvest index upto 100 per cent recommended level of N, though the rate of increase tended to diminish.

4.5.7. Nitrogen use efficiency

4.5.7.1. Agronomic efficiency (Table 56 and 57)

Organic N sources and inorganic N levels influenced the agronomic efficiency (AE). Organic N sources resulted in lower AE values. Increased levels of

Table 52. Effect of organic N sources and inorganic N levels on straw yield (kg ha⁻¹) of rice - Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	3896	5302	6315	6859	5593	3942	5380	6391	6958	5668					
S ₂	4896	6016	6990	7459	6340	4930	6122	7076	7573	6425					
S ₃	5215	6254	7134	7516	6530	5213	6347	7221	7669	6613					
S ₄	5966	7082	7336	7574	6990	6184	7222	7490	7746	7160					
S ₅	6045	7163	7405	7657	7068	6301	7502	7775	8031	7402					
S ₆	6099	7201	7449	7692	7110	6872	8045	8180	8305	7850					
Mean	5352	6503	7105	7459											
		SEd	CD (P = 0.05)			SEd	CD (P = 0.05)								
S		142.9	318.4			137.5	306.4								
N		168.8	342.5			164.9	334.6								
S at N		232.2	475.3			255.8	523.7								
N at S		252.7	512.6			269.8	547.3								

Table 53. Effect of organic N sources and inorganic N levels on Straw yield (kg ha⁻¹) of rice at maturity - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01				Rabi 2001-'02					
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	4068	5532	6543	7097	5810	4204	5662	6679	7235	5945
S ₂	5090	6373	7282	7779	6631	5222	6558	7425	7925	6783
S ₃	5390	6607	7430	7878	6826	5501	6734	7569	8023	6957
S ₄	5727	6864	7573	8015	7045	5827	6984	7713	8156	7170
S ₅	6053	6955	7667	8089	7191	5906	7070	7801	8230	7252
S ₆	6554	7677	7931	8173	7584	6500	7899	8157	8407	7740
Mean	5480	6668	7404	7839		5527	6818	7557	7996	
	SEd	SEd	CD (P = 0.05)	CD (P = 0.05)		SEd	SEd	CD (P = 0.05)	CD (P = 0.05)	
S	173.3	173.3	386.2	386.2		176.2	176.2	392.6	392.6	
N	203.4	203.4	412.5	412.5		208.3	208.3	422.5	422.5	
S at N	235.8	235.8	482.7	482.7		238.0	238.0	487.2	487.2	
N at S	255.7	255.7	518.6	518.6		257.8	257.8	524.3	524.3	

Table 54. Effect of organic N sources and inorganic N levels on harvest index (%) of rice - *Kharif* 2000 and 2001

Treatments	<i>Kharif</i> 2000						<i>Kharif</i> 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	43.21	44.93	45.34	45.35	44.71	43.64	45.13	45.53	45.48	44.95	43.64	45.13	45.53	45.48	44.95
S ₂	44.50	45.30	45.33	45.45	45.15	45.01	45.43	45.42	45.46	45.33	45.01	45.43	45.42	45.46	45.33
S ₃	44.83	45.63	45.65	45.81	45.48	45.54	45.82	45.84	45.89	45.77	45.54	45.82	45.84	45.89	45.77
S ₄	45.73	45.92	45.94	45.96	45.89	45.45	45.93	45.91	45.90	45.80	45.45	45.93	45.91	45.90	45.80
S ₅	45.72	45.89	45.92	45.86	45.85	45.43	45.24	45.19	45.18	45.26	45.43	45.24	45.19	45.18	45.26
S ₆	45.71	46.14	45.92	45.85	45.91	45.26	45.17	45.22	45.27	45.23	45.26	45.17	45.22	45.27	45.23
Mean	44.95	45.64	45.68	45.71	45.91	45.06	45.45	45.52	45.53	45.23	45.06	45.45	45.52	45.53	45.23

Data not statistically analysed

Table 55. Effect of organic N sources and inorganic N levels on harvest index (%) of rice - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	43.92	45.25	45.66	45.67	45.13	43.94	45.29	45.69	45.71	45.16	43.94	45.29	45.69	45.71	45.16
S ₂	45.22	45.62	45.28	45.76	45.47	45.27	45.66	45.70	45.79	45.61	45.27	45.66	45.70	45.79	45.61
S ₃	45.60	45.96	45.98	46.06	45.90	45.63	45.99	45.99	46.09	45.93	45.63	45.99	45.99	46.09	45.93
S ₄	45.93	46.24	46.02	46.11	46.08	45.96	46.27	46.04	46.13	46.10	45.96	46.27	46.04	46.13	46.10
S ₅	45.22	46.43	46.15	46.22	46.01	46.25	46.45	46.18	46.25	46.28	46.25	46.45	46.18	46.25	46.28
S ₆	45.90	46.10	46.14	46.54	46.17	46.52	45.81	45.85	46.23	46.10	46.52	45.81	45.85	46.23	46.10
Mean	45.30	45.93	45.87	46.06		45.60	45.91	45.91	46.03		45.60	45.91	45.91	46.03	

Data not statistically analysed

Table 56. Effect of organic N sources and inorganic N levels on agronomic efficiency (kg grain / kg N) of rice-Kharif 2000 and 2001

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	-	22.7	25.3	22.7	23.6	-	22.9	25.4	22.9	23.7	-	22.9	25.4	22.9	23.7
S ₂	-	17.6	20.8	19.0	19.1	-	17.7	20.8	19.2	19.2	-	17.7	20.8	19.2	19.2
S ₃	-	16.9	19.5	17.8	18.0	-	16.8	19.5	17.9	18.0	-	16.8	19.5	17.9	18.0
S ₄	-	16.5	13.4	11.8	13.9	-	16.4	13.4	11.8	13.9	-	16.4	13.4	11.8	13.9
S ₅	-	16.4	13.3	11.6	13.8	-	15.9	12.9	11.4	13.4	-	15.9	12.9	11.4	13.4
S ₆	-	16.3	13.2	11.5	13.6	-	15.8	11.9	9.9	12.3	-	15.8	11.9	9.9	12.3
Mean	-	17.7	17.6	15.7		-	17.6	17.3	15.5		-	17.6	17.3	15.5	

Data not statistically analysed

Table 57. Effect of organic N sources and inorganic N levels on agronomic efficiency (kg grain / kg N) of rice - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	-	18.5	20.6	18.5	19.2	-	18.6	20.7	18.6	19.3	-	18.6	20.7	18.6	19.3
S ₂	-	15.3	17.1	15.7	16.0	-	15.3	17.2	15.8	16.1	-	15.3	17.2	15.8	16.1
S ₃	-	14.7	16.0	14.7	15.1	-	14.9	16.2	14.9	15.3	-	14.9	16.2	14.9	15.3
S ₄	-	13.9	14.1	13.3	13.8	-	14.1	14.4	13.5	14.0	-	14.1	14.4	13.5	14.0
S ₅	-	13.7	14.0	13.0	13.6	-	14.0	14.3	13.3	13.9	-	14.0	14.3	13.3	13.9
S ₆	-	13.4	10.9	10.4	11.6	-	13.6	11.1	10.5	11.7	-	13.6	11.1	10.5	11.7
Mean	-	14.9	15.5	14.3		-	15.1	15.7	14.4		-	15.1	15.7	14.4	

Data not statistically analysed

N tended to decrease the AE values in *kharif* season. During *rabi* season, increasing levels of N increased the AE values upto 75 per cent recommended level of N, thereafter the value was reduced. Combination of 100 per cent recommended N and rice + green manure+ *Azolla* resulted in the lowest values of AE in all the seasons.

4.5.7.2. Physiological efficiency (Table 58 and 59)

Organic N sources resulted in lower PE values. Increased levels of N to decreased the PE values. The lowest value of PE was registered by combination of rice+green manure+*Azolla* and 100 per cent recommended level of N.

4.5.7.3. Apparent N recovery (ANR) (Table 60 and 61)

Organic sources resulted in lower apparent N recovery values. Increased levels of N tended to increase the ANR values, upto 75 per cent recommended N, thereafter the value was reduced. Rice+green manure+*Azolla* and 100 per cent N application resulted in lower ANR values.

4.5.7.4. Nitrogen harvest index (NHI) (Table 62 and 63)

Organic N sources and inorganic N levels influenced the nitrogen harvest index. Organic N sources resulted in higher NHI values. Increased levels of N tended to improve the NHI values in all the seasons. Highest NHI was associated with 100 per cent recommended N in rice+green manure+*Azolla*, while it was the least, when N was not provided through any source.

Table 58. Effect of organic N sources and inorganic N levels on physiological efficiency (kg grain/kg absorbed N) of rice -

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	-	47.8	46.7	42.7	45.7	-	47.0	45.4	40.9	44.4	-	47.0	45.4	40.9	44.4
S ₂	-	36.4	37.8	36.3	36.8	-	35.6	36.7	34.2	35.5	-	35.6	36.7	34.2	35.5
S ₃	-	34.4	34.9	33.8	34.4	-	33.4	33.8	31.7	32.9	-	33.4	33.8	31.7	32.9
S ₄	-	37.2	35.8	35.1	36.0	-	37.4	34.9	33.7	35.3	-	37.4	34.9	33.7	35.3
S ₅	-	38.4	35.5	35.4	36.4	-	36.6	34.5	33.8	34.9	-	36.6	34.5	33.8	34.9
S ₆	-	38.3	36.4	35.2	36.6	-	41.6	40.1	39.3	40.3	-	41.6	40.1	39.3	40.3
Mean	-	38.7	37.9	36.4	36.6	-	38.6	37.5	35.6	36.6	-	38.6	37.5	35.6	36.6

Data not statistically analysed

Table 59. Effect of organic N sources and inorganic N levels on physiological efficiency (kg grain / kg absorbed N) of rice -

Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	-	47.5	45.7	41.5	44.9	-	47.3	45.4	41.1	44.6	-	47.3	45.4	41.1	44.6
S ₂	-	38.6	37.5	35.2	37.1	-	38.4	37.2	34.9	36.8	-	38.4	37.2	34.9	36.8
S ₃	-	36.7	34.9	32.8	34.8	-	35.7	34.9	32.7	34.4	-	35.7	34.9	32.7	34.4
S ₄	-	35.2	31.2	29.9	32.1	-	35.4	31.6	30.0	32.3	-	35.4	31.6	30.0	32.3
S ₅	-	35.3	31.1	29.6	32.0	-	35.5	31.7	29.9	32.4	-	35.5	31.7	29.9	32.4
S ₆	-	36.2	34.5	36.0	35.6	-	36.6	35.4	37.3	36.4	-	36.6	35.4	37.3	36.4
Mean	-	38.2	35.8	34.2		-	38.2	36.0	34.3		-	38.2	36.0	34.3	

Data not statistically analysed

Table 60. Effect of organic N sources and inorganic N levels on apparent N recovery (%) of rice - Kharif 2000 and 2001

Treatments	Kharif 2000					Kharif 2001				
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	-	47.5	54.1	53.2	51.6	-	48.6	56.0	56.0	53.5
S ₂	-	48.3	55.0	52.5	51.9	-	49.6	56.9	56.2	54.2
S ₃	-	49.0	55.8	52.7	52.5	-	50.3	57.6	56.4	54.8
S ₄	-	44.2	37.4	33.6	38.4	-	43.8	38.3	35.1	39.0
S ₅	-	42.6	37.4	32.7	37.6	-	43.3	37.4	33.8	38.1
S ₆	-	42.5	36.3	32.7	37.1	-	38.0	29.6	25.2	30.9
Mean	-	45.7	46.0	42.9		-	45.6	46.0	43.7	

Data not statistically analysed

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c

Table 61. Effect of organic N sources and inorganic N levels on apparent N recovery (%) of rice - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	-	38.9	44.9	44.6	42.8	-	39.2	45.5	45.3	43.3	-	39.2	45.5	45.3	43.3
S ₂	-	39.4	45.5	44.7	43.2	-	39.9	46.0	45.3	43.7	-	39.9	46.0	45.3	43.7
S ₃	-	40.0	46.0	45.0	43.6	-	41.7	46.5	45.6	44.6	-	41.7	46.5	45.6	44.6
S ₄	-	39.3	45.3	44.4	43.0	-	39.8	45.7	45.0	43.5	-	39.8	45.7	45.0	43.5
S ₅	-	38.9	44.9	44.0	42.6	-	39.5	45.2	44.5	43.0	-	39.5	45.2	44.5	43.0
S ₆	-	37.0	31.8	28.8	32.5	-	37.3	31.4	28.1	32.3	-	37.3	31.4	28.1	32.3
Mean	-	38.9	43.0	41.9		-	39.5	43.4	42.3		-	39.5	43.4	42.3	

Data not statistically analysed

Table 62. Effect of organic N sources and inorganic N levels on nitrogen harvest index (%) of rice - Kharif 2000 and 2001.

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	55.6	59.1	61.5	62.9	59.8	56.1	59.6	62.1	63.4	60.3	56.1	59.6	62.1	63.4	60.3
S ₂	57.4	60.8	63.1	63.5	61.2	58.0	61.4	63.8	64.1	61.8	58.0	61.4	63.8	64.1	61.8
S ₃	57.9	61.2	63.4	63.7	61.5	58.6	61.9	64.2	64.4	62.3	58.6	61.9	64.2	64.4	62.3
S ₄	59.5	62.6	64.2	64.4	62.7	60.3	63.4	65.1	65.2	63.5	60.3	63.4	65.1	65.2	63.5
S ₅	59.7	62.7	64.3	64.6	62.8	60.7	63.7	65.3	65.4	63.8	60.7	63.7	65.3	65.4	63.8
S ₆	59.8	62.8	64.4	64.6	62.9	61.6	64.4	65.7	65.7	64.3	61.6	64.4	65.7	65.7	64.3
Mean	58.3	61.5	63.5	63.9		59.2	62.4	64.4	64.7		59.2	62.4	64.4	64.7	

Data not statistically analysed

Table 63. Effect of organic N sources and inorganic N levels on nitrogen harvest index (%) of rice - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	56.8	60.4	62.9	64.2	61.0	57.6	61.3	63.9	65.1	61.9	57.6	61.3	63.9	65.1	61.9
S ₂	58.8	62.3	64.6	65.1	62.7	59.6	63.1	65.6	66.1	63.6	59.6	63.1	65.6	66.1	63.6
S ₃	59.2	62.6	64.8	65.2	62.9	60.1	63.5	65.9	66.2	63.9	60.1	63.5	65.9	66.2	63.9
S ₄	59.8	63.1	65.2	65.4	63.4	60.6	63.9	66.2	66.4	64.3	60.6	63.9	66.2	66.4	64.3
S ₅	60.2	63.3	65.3	65.5	63.6	60.9	64.1	66.3	66.5	64.4	60.9	64.1	66.3	66.5	64.4
S ₆	60.9	65.6	65.8	65.9	64.5	61.4	64.4	66.6	66.7	64.8	61.4	64.4	66.6	66.7	64.8
Mean	59.3	62.8	64.7	65.2		60.0	63.4	65.7	66.2		60.0	63.4	65.7	66.2	

Data not statistically analysed

4.6. Residual effect of organic N sources and inorganic N levels on greengram

(Summer, 2001)

The residual greengram during summer, 2001 did not receive any rainfall during the crop growth and only two irrigations could be given to the crop. Subsequently, the growth of greengram was not substantial and there were only immature pods. The entire crop was incorporated into the soil.

4.6.1. Growth components (Table 64)

The residual effect of green manure, biofertilizer, and fertilizer N on the growth components viz., plant height at maturity, LAI at flowering and DMP at maturity of greengram was not significant. However, there was marginal improvement in growth parameters due to the residual effect of green manure, *Azolla* and fertilizer N levels compared to control.

4.6.2. Nutrient uptake (Table 65)

Green manuring, *Azolla* and levels of N did not exert any residual effect on the uptake of N,P and K of greengram.

The data on nutrient removal clearly indicated that the residual effect of different sources of N was little.

4.7. Residual effect of organic N sources and inorganic N levels on greengram

(Summer, 2002)

4.7.1. Growth components (Table 66)

The residual effect of organic N sources and inorganic N levels did not exert any residual effect on the growth of the greengram. Plant height and DMP at

Table 64. Effect of organic N sources and inorganic N levels on growth components of residual greengram – Summer 2001

Treatments	Plant height at maturity (cm)	Leaf area index at flowering	Dry matter production at maturity (kg ha ⁻¹)
Organic sources			
S ₁	44.8	3.27	2889
S ₂	45.1	3.37	2920
S ₃	45.2	3.38	2928
S ₄	45.4	3.38	2944
S ₅	45.5	3.40	2952
S ₆	45.7	3.55	2961
SEd	0.49	0.13	34.2
CD (P=0.05)	NS	NS	NS
N levels			
N ₀	44.4	3.31	2878
N ₁	45.3	3.40	2924
N ₂	45.6	3.43	2957
N ₃	45.8	3.44	2970
SEd	0.83	0.15	47.3
CD (P=0.05)	NS	NS	NS

Interaction : Not significant

Table 65. Effect of organic N sources and inorganic N levels on nutrient uptake (kg ha^{-1}) of residual greengram – Summer 2001

Treatments	Nutrient		
	N	P	K
Cropping system			
S ₁	38.1	7.3	42.4
S ₂	38.3	7.4	42.5
S ₃	38.4	7.4	42.5
S ₄	38.6	7.4	42.5
S ₅	38.7	7.5	42.5
S ₆	38.8	7.5	42.6
SEd	0.40	0.17	0.22
CD (P=0.05)	NS	NS	NS
N levels			
N ₀	37.8	7.3	42.3
N ₁	38.4	7.4	42.5
N ₂	38.8	7.5	42.6
N ₃	39.0	7.5	42.6
SEd	0.74	0.24	0.29
CD (P=0.05)	NS	NS	NS

Interaction : Not significant

Table 66. Effect of organic N sources and inorganic N levels on growth components of residual greengram – Summer 2002

Treatments	Plant height at maturity (cm)	Leaf area index at flowering	Dry matter production at maturity (kg ha ⁻¹)
Organic sources			
S ₁	48.4	3.37	3156
S ₂	48.8	3.48	3201
S ₃	48.9	3.48	3209
S ₄	49.1	3.52	3220
S ₅	49.3	3.62	3231
S ₆	49.7	3.65	3247
SEd	0.67	0.14	42.3
CD (P=0.05)	NS	NS	NS
N levels			
N ₀	48.1	3.42	3137
N ₁	49.0	3.51	3201
N ₂	49.4	3.56	3242
N ₃	49.7	3.58	3263
SEd	0.89	0.16	64.2
CD (P=0.05)	NS	NS	NS

Interaction : Not significant

maturity and LAI at flowering were unaltered by the green manure, *Azolla* and fertilizer N levels. Though there were marginal variations in growth components under the influence of different N sources applied to preceding crop, those were statistically not significant.

4.7.2. Yield attributes (Table 67)

The residual effect of green manuring, *Azolla* and varied levels of inorganic N did not bring about considerable variations in the yield attributes viz., number of clusters per plant, number of pods per plant, pod length, number of seeds per pod and 100 grain weight of greengram.

4.7.3. Nutrient uptake (table 68)

The residual effect of different N sources applied to previous crop did not alter the uptake of N, P and K of greengram. The data on nutrient removal of clearly indicated that variations were small and residual effect was non detectable.

4.7.4. Yield (Table 69)

Green manuring, *Azolla* and N supply to rice crops did not exert any appreciable effect on the grain and haulms yield of greengram.

Yield variations recorded under different treatments were not significant. Among the organic N sources, rice+green manure+*Azolla* to the preceding rice crop resulted in 4.8 per cent yield increase in greengram over preceding sole rice treatment. Among the inorganic N levels, 100 per cent recommended N to the preceding rice crops resulted in 11.9 per cent yield increase in greengram over no

Table 67. Effect of organic N sources and inorganic N levels on yield attributes of residual greengram – Summer 2002

Treatments	Number of clusters plant ⁻¹	Number of pods plant ⁻¹	Pod length (cm)	Number of seeds pod ⁻¹	100 grain weight (g)
Organic sources					
S ₁	7.5	25.7	6.2	10.7	7.28
S ₂	7.6	26.1	6.4	10.8	7.28
S ₃	7.6	26.2	6.5	10.9	7.28
S ₄	7.7	26.2	6.6	10.9	7.29
S ₅	7.7	26.3	6.6	11.2	7.29
S ₆	7.8	26.4	6.7	11.4	7.30
SEd	0.27	0.54	0.31	0.40	0.02
CD (P=0.05)	NS	NS	NS	NS	NS
N levels					
N ₀	7.5	25.8	6.3	10.7	7.28
N ₁	4.6	26.1	6.5	10.9	7.29
N ₂	7.7	26.3	6.6	11.1	7.30
N ₃	7.8	26.6	6.7	11.2	7.30
SEd	0.35	0.64	0.39	0.49	0.03
CD (P=0.05)	NS	NS	NS	NS	NS

Interaction : Not significant

Table 68. Effect of organic N sources and inorganic N levels on nutrient uptake (kg ha⁻¹) of residual greengram – Summer 2002

Treatments	Nutrient		
	N	P	K
Organic sources			
S ₁	44.2	7.5	43.2
S ₂	44.4	7.6	43.5
S ₃	44.6	7.6	43.5
S ₄	44.8	7.7	43.5
S ₅	45.0	7.8	43.5
S ₆	45.2	7.8	43.6
SEd	0.54	0.22	0.27
CD (P=0.05)	NS	NS	NS
N levels			
N ₀	43.9	7.4	43.2
N ₁	44.5	7.6	43.4
N ₂	45.0	7.7	43.6
N ₃	45.3	7.9	43.7
SEd	0.79	0.29	0.35
CD (P=0.05)	NS	NS	NS

Interaction : Not significant

Table 69. Effect of organic N sources and inorganic N levels on yield (kg ha⁻¹) of residual greengram – Summer 2001

Treatments	Grain yield	Haulms yield
Organic sources		
S ₁	562	2453
S ₂	574	2515
S ₃	576	2524
S ₄	580	2550
S ₅	583	2559
S ₆	589	2569
SEd	14.2	54.6
CD (P=0.05)	NS	NS
N levels		
N ₀	540	2435
N ₁	572	2516
N ₂	594	2569
N ₃	604	2594
SEd	33.5	80.3
CD (P=0.05)	NS	NS

Interaction : Not significant

nitrogen application to preceding rice crop. The interaction effect between organic N sources and inorganic N levels was not significant.

4.8. Effect of integrated N management practices on the cropping system

Performance of the cropping system as a whole as reflected by productivity, soil fertility and economics is presented in this section.

4.8.1. Productivity of the cropping system as a whole

The total production from wet seeded rice-rice-greengram cropping system as a whole is considered in this section. Total dry matter produced by all the three component crops of the cropping system was taken in to account for total dry matter production of the cropping system. In first cropping cycle, total grain production included grain yield in *kharif* and *rabi* seasons only. In second cropping cycle total grain production of the cropping system included *kharif* and *rabi* rice crops and greengram grain yield converted into rice equivalent.

4.8.1.1. Total dry matter production of the cropping system

4.8.1.1.1. First cropping cycle (2000-'01) (Table 70 and Fig. 14)

Organic N sources and inorganic N levels considerably influenced the total dry matter production of the cropping system.

Rice+green manure+*Azolla* in *kharif* as well as *rabi* seasons resulted in substantially higher dry matter production. Sole rice recorded the lowest dry matter production. Application of 100 per cent recommended N level significantly registered the higher dry matter production, while lower dry matter production was observed in the control.

Table 70. Effect of organic N sources and inorganic N levels on total dry matter production (t ha⁻¹) of the cropping system - 2000-'01 and 2001-'02

Treatments	Cropping system 2000-'01						Cropping system 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	17.18	22.86	26.78	28.83	23.91	17.81	23.71	27.45	29.52	24.62	17.81	23.71	27.45	29.52	24.62
S ₂	21.24	25.91	29.43	31.24	26.96	21.89	26.68	30.13	32.01	27.68	21.89	26.68	30.13	32.01	27.68
S ₃	22.61	26.90	30.07	31.71	27.82	23.09	27.64	30.84	32.56	28.53	23.09	27.64	30.84	32.56	28.53
S ₄	24.79	29.13	30.85	32.12	29.22	25.55	29.83	31.65	32.96	30.00	25.55	29.83	31.65	32.96	30.00
S ₅	25.39	29.47	31.17	32.40	29.61	25.99	30.45	32.26	33.55	30.56	25.99	30.45	32.26	33.55	30.56
S ₆	26.58	30.94	31.89	32.74	30.54	28.19	32.82	33.95	34.43	32.35	28.19	32.82	33.95	34.43	32.35
Mean	22.97	27.54	30.03	31.51	30.54	23.75	28.52	31.05	32.51	30.54	23.75	28.52	31.05	32.51	30.54
	SEd						SEd						CD (P = 0.05)		
S	0.573						0.546						1.217		
N	0.667						0.653						1.325		
S at N	0.896						0.768						1.573		
N at S	0.962						0.865						1.756		
	CD (P = 0.05)						CD (P = 0.05)						CD (P = 0.05)		
	1.276						1.217						1.217		
	1.354						1.325						1.325		
	1.834						1.573						1.573		
	1.952						1.756						1.756		

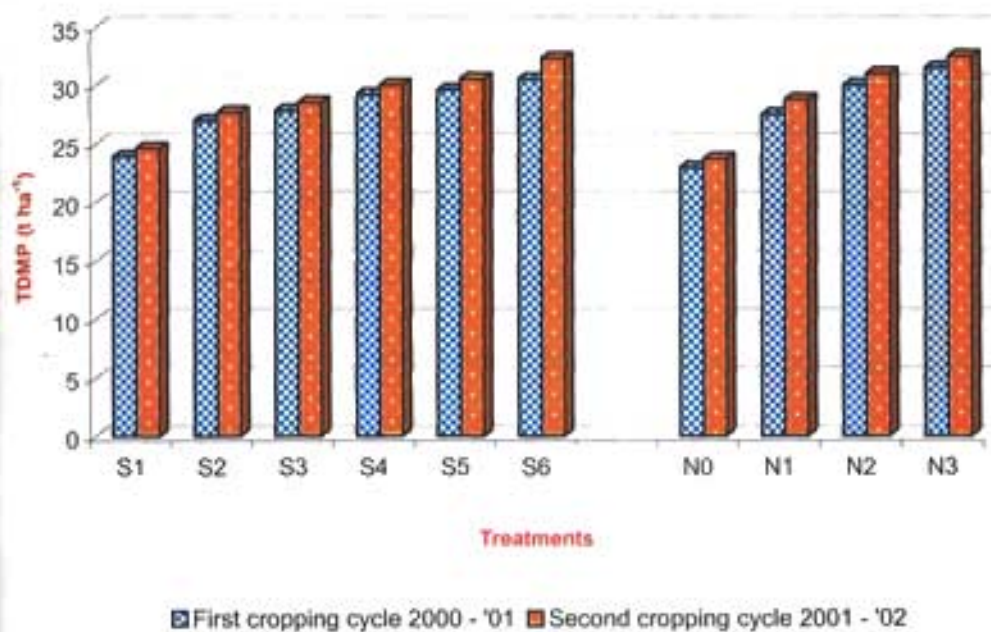


Fig. 14. Effect of organics and inorganic N on total dry matter production.

Interaction effect due to organic N sources and inorganic N levels was significant. There was response in DMP in sole rice upto 100 per cent N level. In case of rice + *Azolla* or rice + green manure, the DMP showed substantial improvement upto 75 per cent level. But in rice + *Azolla* + green manure, the DMP increased upto 50 per cent recommended N level only.

4.8.1.1.2. Second cropping cycle (2001-'02) (Table 70 and Fig. 14)

Organic N sources and added levels of N exerted marked influence on the total dry matter production of the cropping system.

Rice + green manure + *Azolla* in both the seasons recorded markedly higher dry matter production, while the lowest dry matter production was registered with sole rice.

Among the N levels, application of 100 per cent recommended N level to both the rice crops resulted in significantly higher dry matter production of the cropping system. The lowest dry matter production was observed with non provision of N to both the rice crops.

Interaction between organic N sources and inorganic N levels was significant and the trend was similar to that of first year cycle.

4.8.1.2. Total grain production of the cropping system

4.8.1.2.1. First cropping cycle (2000-'01) (Table 71 and Fig. 15)

Total grain production of the cropping system was significantly influenced by the organic N sources and graded levels of N supply. Interaction between organic N sources and inorganic N levels was also significant.

Table 71. Effect of organic N sources and inorganic N levels on total grain production (t ha⁻¹) of the cropping system - 2000-'01 and 2001-'02

Treatments	Total grain production 2000-'01					Total grain* production 2001-'02				
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	6.15	8.89	10.74	11.66	9.36	8.33	11.23	13.17	14.15	11.72
S ₂	8.13	10.33	11.92	12.78	10.79	10.40	12.73	14.42	15.33	13.22
S ₃	8.76	10.87	12.32	13.11	11.27	11.03	13.28	14.82	15.66	13.70
S ₄	9.89	11.92	12.69	13.30	11.95	12.18	14.34	15.21	15.86	14.39
S ₅	10.09	12.10	12.86	13.44	12.12	12.41	14.53	15.39	16.01	14.59
S ₆	10.70	12.68	13.13	13.63	12.54	13.45	15.54	15.97	16.43	15.35
Mean	8.95	11.13	12.28	12.99		11.30	13.61	14.83	15.57	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
S	0.245	0.546	0.266	0.592
N	0.332	0.674	0.322	0.654
S at N	0.433	0.886	0.403	0.824
N at S	0.474	0.962	0.466	0.946

* The greengram yield is converted to rice equivalent

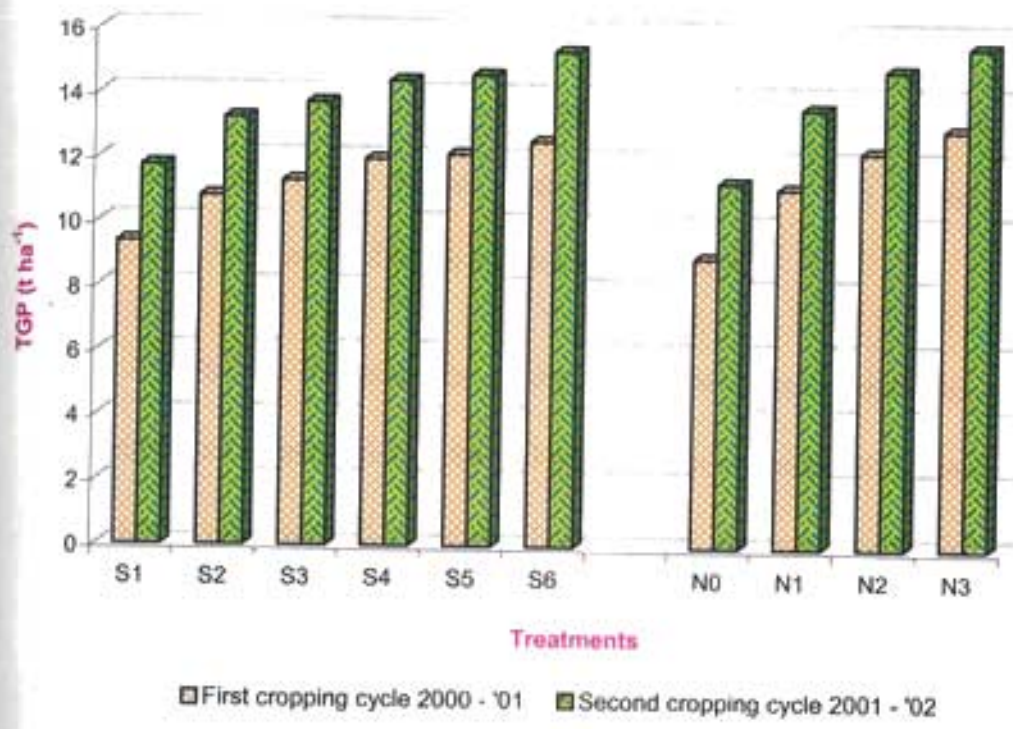


Fig. 15 Effect of organics and inorganic N on total grain production.

Among the organic sources, rice + green manure + *Azolla* in *kharif* and *rabi* seasons resulted in significantly higher total grain production of the cropping system, while the lowest total grain production was observed with sole crop of rice in both the seasons.

Increased levels of fertilizer N tended to improved the total grain production. Application of 100 per cent recommended N to both the rice crops registered substantially higher total grain production. The lowest total grain production was recorded in the absence of fertilizer N.

Sole rice in both the *kharif* and *rabi* seasons recorded progressive improvement in grain yield upto 100 per cent recommended N. However, the total grain production with 75 per cent of N application was comparable with that of 100 per cent N level during first year. But rice, either intercropped with *Sesbania rostrata* or dual cropped with *Azolla*, registered increase in grain yield upto 75 per cent N. In case of rice + *Azolla* + green manure in both the seasons, considerable increase in yield was observed only upto 50 per cent N and beyond which, the grain yields were comparable in 50, 75 and 100 per cent N levels.

4.8.1.2.2. Second cropping cycle (2001-'02) (Table 71 and Fig. 15)

Organic N sources and graded levels of N to rice crops had impact on the total grain production of the cropping system. Interaction between organic N sources and inorganic N levels was significant.

Rice + green manure + *Azolla* registered markedly higher total grain production of the cropping system. The lower total grain production was observed in the sole crop of rice.

Application of 100 per cent inorganic N to each of the rice crops resulted in substantially higher total grain production, while the lower total grain production was recorded in the absence of fertilizer N to the rice crops.

The total grain production was significantly higher in rice + green manure + *Azolla* and 100 per cent recommended level of N to each of the rice crops which was however comparable to rice + green manure + *Azolla* coupled with 50 per cent recommended N level to both the rice crops. The lowest total grain production of the cropping system was observed with the absence of organic and inorganic N to each of the rice crops. The influence of fertilizer N in the presence of rice + green manure + *Azolla* was pronounced only up to 50 per cent recommended level of N.

4.8.2. Soil fertility dynamics in the cropping system

Soil fertility as influenced by different sources and combination of sources of N and inorganic N levels on to rice crops in the cropping system is presented in this section. Organic carbon, available N, P and K in the soil, post harvest of each of the crops in the cropping system are presented separately. Soil available N balance in the cropping system as influenced by treatments is also presented.

4.8.2.1. Soil organic carbon at post harvest of rice (Table 72)

Organic N sources and inorganic N levels markedly influenced the post harvest soil organic carbon content.

Rice + green manure + *Azolla* resulted in significantly higher soil organic carbon content over control.

Among the N levels, application of 100 per cent inorganic N substantially higher organic carbon content. The lower organic carbon content was registered with no organic N. The interaction effect between organic N sources and inorganic N levels was not significant.

4.8.2.2. Soil organic carbon at post harvest of greengram (Table 72)

The residual effect of organic sources was significant on the soil organic carbon content after the harvest of residual crop of greengram. Green manuring + *Azolla* to both rice crops in the annual cropping cycle resulted in build up of soil organic carbon content.

4.8.2.3. Dynamics of the soil organic carbon content in the cropping system

After two years of cropping, there was an appreciable build up in the soil organic carbon content as compared to the initial status (6.9 g kg^{-1}). Green manuring + *Azolla* applications resulted in substantial improvement of soil organic carbon. There was progressive soil build up of organic carbon with the increase in the quantity of inorganic N used in the cropping system. Incorporation of greengram haulm alone,

Table 72. Effect of organic N sources and inorganic N levels on soil organic carbon at post harvest stage of rice and residual greengram

Treatments	Soil organic carbon (g kg ⁻¹) at post harvest stage					
	<i>Khariif</i> 2000	<i>Rabi</i> 2000-'01	Summer 2001	<i>Khariif</i> 2001	<i>Rabi</i> 2001-'02	Summer 2002
Organic sources						
S ₁	6.5	6.7	7.0	6.6	6.9	7.1
S ₂	6.7	6.9	7.3	6.8	7.2	7.3
S ₃	6.8	7.0	7.5	6.9	7.3	7.4
S ₄	6.9	7.2	7.6	7.2	7.6	7.6
S ₅	6.9	7.2	7.7	7.3	7.7	7.7
S ₆	6.9	7.3	7.9	7.5	7.8	7.9
SEd	0.07	0.10	0.13	0.08	0.12	0.08
CD (P=0.05)	0.16	0.23	0.28	0.19	0.28	0.18
N levels						
N ₀	6.3	6.5	7.0	6.5	6.8	7.0
N ₁	6.7	6.9	7.3	7.0	7.2	7.4
N ₂	6.9	7.2	7.6	7.2	7.6	7.7
N ₃	7.0	7.3	7.8	7.3	7.9	7.8
SEd	0.10	0.14	0.18	0.13	0.17	0.12
CD (P=0.05)	0.21	0.29	0.36	0.28	0.35	0.24

Interaction : Not significant

besides rice crop stubbles during the two years of continuous cropping resulted in a fairly good build up of soil organic carbon.

4.8.2.4. Soil available N at post harvest of rice (Table 73 and 74)

Green manuring, *Azolla* and application and inorganic N levels had profound influenced on the soil available N. Combination of green manure + *Azolla* and fertilizer N exerted marked effect on the available N status of soil.

Organic sources improved the soil available N status. Increased levels of N upto 100 per cent recommended level enhanced the soil available N.

The highest value of soil available N was recorded in rice + green manure + *Azolla* and 100 per cent inorganic N level. Soil available N was the lowest in the absence of fertilizer N as well as organic N source.

4.8.2.5. Soil available N at post harvest of greengram (Table 75)

Residual effect of different treatments applied to preceding rice crops was significant in exerting influence on the soil available N after harvest of the greengram.

Green manure + *Azolla* application to preceding rice resulted in markedly higher soil available N, while lower soil available N was registered in plots without organic sources. Application of 100 per cent recommended N considerably enhanced higher soil available N. Lower soil available N was recorded with absence of inorganic N application.

**Table 73. Effect of organic N sources and inorganic N levels on soil available N (kg ha⁻¹) at post harvest stage of rice -
Kharif 2000 and 2001**

Treatments	Kharif 2000						Kharif 2001								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	243	256	273	285	264	212	247	286	299	261	243	256	273	285	264
S ₂	270	279	291	296	284	246	263	289	302	275	270	279	291	296	284
S ₃	272	281	293	297	286	248	265	290	303	276	272	281	293	297	286
S ₄	278	286	296	298	290	256	272	296	304	282	278	286	296	298	290
S ₅	279	287	297	299	291	258	274	298	305	284	279	287	297	299	291
S ₆	280	288	298	299	291	267	281	302	306	289	280	288	298	299	291
Mean	270	279	291	296	291	248	267	294	303	289	270	279	291	296	291
		SEd	CD (P = 0.05)			SEd	CD (P = 0.05)				SEd	CD (P = 0.05)			
S		1.39	3.1			1.88	4.2				1.88	4.2			
N		2.12	4.3			3.45	7.0				3.45	7.0			
S at N		3.90	8.2			4.45	9.1				4.45	9.1			
N at S		4.93	10.0			5.52	11.2				5.52	11.2			

Table 74. Effect of organic N sources and inorganic N levels on soil available N (kg ha⁻¹) at post harvest stage of rice - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	221	247	267	283	254	178	227	265	296	242	242	227	265	296	242
S ₂	245	256	278	286	266	232	240	286	304	265	265	240	286	304	265
S ₃	247	258	279	287	268	234	242	287	305	267	267	242	287	305	267
S ₄	252	262	287	293	274	239	250	290	316	274	274	250	290	316	274
S ₅	257	265	291	296	277	242	253	292	318	276	276	253	292	318	276
S ₆	262	269	292	297	280	250	262	314	320	287	287	262	314	320	287
Mean	247	260	282	290	280	229	246	289	310	280	280	246	289	310	280
		SEd	CD (P = 0.05)				SEd	CD (P = 0.05)				SEd	CD (P = 0.05)		
S		1.8	4.0				2.8	6.2				2.8	6.2		
N		2.9	6.2				3.9	8.3				3.9	8.3		
S at N		4.4	9.1				5.9	12.1				5.9	12.1		
N at S		5.9	12.2				7.8	16.2				7.8	16.2		

Table 75. Effect of organic N sources and inorganic N levels on soil available N (kg ha^{-1}) at post harvest stage of residual greengram - Summer 2001 and 2002

Treatments	Summer 2001						Summer 2002								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	230	254	272	286	260	188	235	270	299	248					
S ₂	252	260	282	290	271	233	247	290	307	269					
S ₃	256	262	284	292	273	242	251	297	310	275					
S ₄	259	266	291	297	278	247	259	309	318	283					
S ₅	260	268	293	298	280	250	261	313	322	287					
S ₆	264	271	295	299	282	256	267	318	324	291					
Mean	254	263	286	294		236	253	300	313						
	SEd		CD (P = 0.05)			SEd		CD (P = 0.05)							
S	1.8		4.3			3.2		7.2							
N	3.0		6.2			5.5		11.3							
S at N	3.6		7.5			7.8		16.3							
N at S	4.6		9.4			9.4		19.1							

Combination of rice + green manure + *Azolla* and 100 per cent recommended N level to the preceding rice registered the highest value of soil available N, while the lowest soil available N was recorded in the plots which did not receive any source of inorganic N in the preceding rice.

4.8.2.6. Dynamics of soil available N in the cropping system

Soil available N tended to decrease after the harvest of rice crops and improve with the application of organic sources. The overall status of soil available N after two years of continuous cropping was marginally lower than the initial level (276 kg ha⁻¹). In general, organic sources improved the soil available N status. Incorporation of greengram haulms as organic manure also enhanced the soil available N appreciably, though it did not have much residual effect. Added inorganic N levels tended to enrich the soil available N. Different combinations of N sources exerted positive influence on soil available N, commensurating with the quantity of N applied. Skipping of inorganic N for two years resulted in a drastic decrease of soil available N status.

4.8.2.7. Soil available nitrogen balance in the cropping system

4.8.2.7.1. First cropping cycle (2000-'01) (Table 76)

Different sources and combinations of sources of N used in the cropping system had profound influence on the balance of soil available N differentially. Net loss of soil available N was the highest, when both crops of rice did not receive any organic or inorganic N. Increased levels of inorganic N applied to rice crops tended to improve the status of soil available N. The soil available N balance was positive

Table 76. Effect of organic sources and inorganic N levels on soil available nitrogen balance (kg ha⁻¹) in the cropping system - 2000-'01

Treatments	Initial Soil N (2)	N applied to crops		N added through crop residues		Total quantity of N applied (8)	N uptake by crops			Total quantity of N removed (12)	Computed balance (13)	Actual balance (14)	Net gain or loss (15)
		Kharif 2000 rice (3)	Rabi 2000-'01 rice (4)	Kharif 2000 rice (5)	Rabi 2000-'01 rice (6)		Summer 2001 Green gram (7)	Kharif 2000 rice (9)	Rabi 2000-'01 rice (10)				
(1)	276	0	0	4.3	4.8	46.5	43.8	47.9	37.4	129.1	-82.6	230	-46
S ₁ N ₀	276	60	75	7.8	8.4	189.2	72.3	77.1	38.0	187.4	+1.8	254	-22
S ₁ N ₁	276	90	112.5	10.1	10.8	261.8	92.5	98.5	38.4	229.4	+32.4	272	-4
S ₁ N ₂	276	120	150.0	11.3	12.1	332.1	107.7	114.9	38.7	261.3	+70.8	286	+10
S ₂ N ₀	276	38.4	58.8	6.1	7.4	148.4	59.9	68.0	37.7	165.6	-17.2	252	-24
S ₂ N ₁	276	102.2	134.4	9.5	10.8	295.1	88.9	98.0	38.2	225.1	+70.0	260	-16
S ₂ N ₂	276	134.4	172.8	11.7	12.9	370.4	109.4	119.8	38.6	267.8	+102.6	282	+6
S ₂ N ₃	276	166.2	210.8	12.9	14.0	442.8	122.9	135.5	38.9	297.3	+145.5	290	+14
S ₃ N ₀	276	50.6	47.4	6.8	6.9	149.5	62.7	65.1	37.8	165.6	-16.1	256	-20
S ₃ N ₁	276	111.5	125.6	10.1	10.2	295.7	92.1	94.7	38.3	225.1	+70.6	262	-14

Contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
S_3N_2	276	142.4	165.1	12.2	12.5	38.7	370.9	112.9	116.3	38.7	267.9	+103.0	284	+8
S_3N_3	276	172.9	204.4	13.4	13.7	39.0	443.4	126.0	132.1	39.0	297.1	+146.3	292	+16
S_4N_0	276	92.8	49.9	8.4	8.3	38.0	197.4	88.9	71.0	38.0	197.9	-0.5	259	-17
S_4N_1	276	157.5	128.1	11.5	11.6	38.5	347.2	115.4	100.5	38.5	254.4	+92.8	266	-10
S_4N_2	276	191.4	167.6	13.4	13.5	38.9	424.8	122.6	122.0	38.9	283.5	+141.3	291	+15
S_4N_3	276	223.8	206.9	14.5	14.4	39.1	498.7	129.2	137.6	39.1	305.9	+192.8	297	+21
S_5N_0	276	93.8	59.8	8.5	8.9	38.1	209.1	90.0	73.8	38.1	201.9	+7.2	260	-16
S_5N_1	276	159.1	135.3	11.6	12.1	38.6	356.7	115.6	103.0	38.6	257.2	+99.5	268	-8
S_5N_2	276	192.6	173.3	13.5	13.9	39.0	432.3	122.7	124.4	39.0	286.1	+146.2	293	+17
S_5N_3	276	225.2	211.2	14.6	14.5	39.2	504.7	129.3	139.9	39.2	308.4	+196.3	298	+22
S_6N_0	276	94.7	113.5	8.6	10.6	38.2	265.6	90.2	98.0	38.2	226.4	+39.2	264	-12
S_6N_1	276	160.1	192.2	11.7	13.7	38.7	416.4	115.7	125.8	38.7	280.2	+136.2	271	-5
S_6N_2	276	193.6	232.1	13.5	14.5	39.1	492.8	122.9	133.8	39.1	295.8	+197.0	295	+19
S_6N_3	276	226.2	288.1	14.6	14.9	39.3	583.1	129.4	141.2	39.3	309.9	+273.2	299	+23

indicating a net gain, when both the rice crops received 100 per cent recommended N level each. Combination of rice + green manure + *Azolla* and 100 per cent recommended level of N perceptibly improved the soil available N status.

4.8.2.7.2. Second cropping cycle (2001-'02) (Table 77)

Post harvest soil available N status followed a similar trend as that of first cropping cycle with regard to the graded levels of N supply. Green manure + *Azolla* application and 100 per cent recommended N application to both the rice crops resulted in a net gain of soil available N.

A close perusal of the data on soil available N balance at the end of two years of cropping cycle clearly indicated that application of 100 per cent recommended N with green manure + *Azolla* application to both the rice crops and greengram haulms incorporation during the two years cropping cycles of rice-rice-greengram, maintained the soil N status. This was followed by combination of green manure + *Azolla* with 75 per cent recommended N and greengram haulm incorporation. All the other treatments resulted in a net loss of the available N in the soil.

4.8.2.8. Soil available P at post harvest of rice (Table 78 and 79)

Organic N sources and inorganic N levels significantly influenced the soil available P. Among the organic N sources, rice + green manure + *Azolla* resulted in substantially higher soil available P. Increased supply of N improved the soil available P status, while lower P was registered in no nitrogen treatment.

Table 77. Effect of organic sources and inorganic N levels on soil available nitrogen balance (kg ha^{-1}) in the cropping system - 2001-'02

Treatments	Initial Soil N (2)	N applied to crops			N added through crop residues			Total quantity of N applied (8)	N uptake by crops			Total quantity of N removed (12)	Computed balance (13)	Actual balance (14)	Net gain or loss (15)
		Kharif 2000 rice (3)	Rabi 2001-'02 rice (4)	Kharif 2001 rice (5)	Rabi 2001-'02 rice (6)	Summer 2002 Green gram (7)	Kharif 2001 rice (9)		Rabi 2001-'02 rice (10)	Summer 2002 Green gram (11)					
(1) S_1N_0	230	0	0	4.5	4.9	36.7	46.1	45.2	48.5	43.3	137.0	-90.9	188	-42	
S_1N_1	254	60	75	8.1	8.6	37.3	189.0	74.4	77.9	44.0	196.3	-7.3	235	-19	
S_1N_2	272	90	112.5	10.4	11.1	37.7	261.7	95.6	99.7	44.5	239.8	+21.9	270	-2	
S_1N_3	286	120	150	11.5	12.3	38.0	331.8	112.4	116.5	44.9	273.8	+58.0	299	+13	
S_2N_0	252	40.8	61.0	6.4	7.5	37.1	152.8	61.5	68.9	43.6	174.0	-12.2	233	-19	
S_2N_1	260	104.0	136.5	9.9	11.0	37.6	299.0	91.3	99.2	44.2	234.7	+64.3	247	-13	
S_2N_2	282	136.6	174.4	12.1	13.2	37.9	374.2	112.7	121.3	44.7	278.7	+95.5	290	+8	
S_2N_3	290	168.4	212.5	13.1	14.2	38.2	446.4	128.9	137.4	45.0	311.3	+135.1	307	+17	
S_3N_0	256	53.7	48.2	7.1	6.8	37.2	153.0	64.4	65.9	43.8	174.1	-21.1	242	-14	
S_3N_1	262	114.6	127.1	10.5	10.4	37.7	300.3	94.6	95.8	44.4	234.8	+65.5	251	-11	

Contd....

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
S ₃ N ₂	284	145.6	166.8	12.6	12.8	38.0	375.8	116.3	117.7	44.9	278.9	+96.9	297	+13
S ₃ N ₃	292	176.1	206.5	13.5	13.9	38.3	448.3	132.1	133.9	45.2	311.2	+137.1	310	+18
S ₄ N ₀	259	97.9	51.8	8.9	8.4	37.8	204.8	92.5	72.1	44.2	208.8	-4.0	247	-12
S ₄ N ₁	266	162.9	130.5	12.1	11.8	37.9	355.2	118.8	102.0	44.7	265.5	+89.7	259	-7
S ₄ N ₂	291	196.0	169.9	14.0	13.8	38.2	431.9	127.0	123.6	45.2	295.8	+136.1	309	+18
S ₄ N ₃	297	228.4	207.8	14.6	14.6	38.4	503.8	134.6	139.6	45.4	319.6	+184.2	318	+21
S ₅ N ₀	260	100.2	62.0	9.2	9.1	38.1	218.6	95.3	75.3	44.4	215.0	+3.6	250	-10
S ₅ N ₁	268	164.0	137.5	12.3	12.4	38.2	364.4	121.3	104.9	44.9	271.1	+93.3	261	-7
S ₅ N ₂	293	196.8	175.4	14.2	14.2	38.4	439.0	129.0	126.2	45.4	300.6	+138.4	313	+20
S ₅ N ₃	298	229.3	213.4	14.7	14.8	38.6	510.8	135.9	142.1	45.6	323.6	+187.2	322	+24
S ₆ N ₀	264	100.9	117.8	11.2	10.8	38.5	279.2	114.7	101.5	44.6	260.8	+18.4	256	-8
S ₆ N ₁	271	164.8	196.6	14.1	14.0	38.7	428.2	137.5	129.5	45.1	312.1	+116.1	267	-4
S ₆ N ₂	295	197.5	236.4	14.6	14.7	38.8	502.0	141.4	136.9	45.6	323.9	+178.1	318	+23
S ₆ N ₃	299	230.0	276.5	14.8	14.9	38.9	575.1	144.9	143.7	45.7	334.3	+240.8	324	+25

**Table 78. Effect of organic N sources and inorganic N levels on soil available P (kg ha^{-1}) at post harvest stage of rice -
Kharif 2000 and 2001**

Treatments	Kharif 2000						Kharif 2001											
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean			
S ₁	17.2	17.5	17.8	18.0	17.6	17.9	18.6	19.1	19.4	18.7	17.9	18.6	19.1	19.4	18.7			
S ₂	18.0	18.5	18.7	18.8	18.5	18.8	19.6	20.0	20.3	19.6	18.8	19.6	20.0	20.3	19.6			
S ₃	18.1	18.6	18.8	18.9	18.6	18.9	19.7	20.1	20.4	19.7	18.9	19.7	20.1	20.4	19.7			
S ₄	19.0	19.5	19.7	19.8	19.5	20.0	20.7	20.9	21.0	20.6	20.0	20.7	20.9	21.0	20.6			
S ₅	19.0	19.5	19.7	19.8	19.5	20.2	20.8	21.0	21.1	20.7	20.2	20.8	21.0	21.1	20.7			
S ₆	19.0	19.5	19.7	19.9	19.5	20.8	21.1	21.2	21.3	21.1	20.8	21.1	21.2	21.3	21.1			
Mean	18.4	18.8	19.0	19.2	19.5	19.4	20.0	20.4	20.6	19.5	19.4	20.0	20.4	20.6	19.5			
	SEd						SEd						CD (P = 0.05)					
S	0.07						0.08						0.18					
N	0.08						0.09						0.19					
S at N	0.12						0.13						0.26					
N at S	0.13						0.14						0.29					
	CD (P = 0.05)						CD (P = 0.05)						CD (P = 0.05)					
	0.16						0.18						0.28					

Table 79. Effect of organic N sources and inorganic N levels on soil available P (kg ha⁻¹) at post harvest stage of rice - Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01					Rabi 2001-'02				
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	18.0	18.8	19.4	19.8	19.0	18.5	19.1	19.5	19.9	19.2
S ₂	18.9	19.8	20.4	20.6	19.9	19.2	20.0	20.6	20.8	20.1
S ₃	19.0	19.9	20.5	20.7	20.0	19.3	20.1	20.7	20.9	20.2
S ₄	19.2	20.1	20.6	20.8	20.2	19.5	20.2	20.8	21.0	20.3
S ₅	19.3	20.1	20.6	20.8	20.2	19.7	20.3	20.9	21.2	20.4
S ₆	20.2	20.6	20.7	20.9	20.6	20.5	21.0	21.3	21.4	21.0
Mean	19.1	19.9	20.4	20.6		19.4	20.1	20.6	20.9	
	SEd	CD (P = 0.05)			SEd	CD (P = 0.05)				
S	0.07	0.17			0.11	0.25				
N	0.09	0.19			0.14	0.28				
S at N	0.17	0.35			0.16	0.33				
N at S	0.18	0.38			0.18	0.36				

Soil available P was the highest with the combined application of rice + green manure + *Azolla* and 100 per cent recommended N and lowest with non supply of N from any source.

4.8.2.9. Soil available P at post harvest of greengram (Table 80)

Green manure + *Azolla* application to preceding rice crop resulted in significantly higher soil available P. The lower soil available P was registered in plots without organics. Increased level of N improved the soil available P status of greengram, while lower P was recorded in absence of inorganic N.

Application of 100 per cent recommended N to rice + green manure + *Azolla* in the preceding seasons resulted in the highest value of post harvest soil available P, while the lowest soil available P was recorded with the absence of any source of N.

4.8.2.10. Dynamics of the soil available P in the cropping system

Soil available P tended to increase after raising of rice crops and improve with the organic sources. This trend was observed in both the annual cropping cycles. The overall soil P status after two years of cropping with four rice crops fertilized with recommended dose of P and two greengram crops raised as residual crops without P showed a build up over the initial P status of the soil. In general, green manuring and *Azolla* application resulted in build up of soil available P. Graded levels of inorganic N also tended to improve the soil P status. Incorporation of greengram haulm also enhanced the soil available P to a limited extent.

Table 80. Effect of organic N sources and inorganic N levels on soil available P (kg ha⁻¹) of post harvest stage of residual greengram - summer 2001 and 2002

Treatments	Summer 2001						Summer 2002								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	15.2	15.7	16.1	16.3	15.8	16.8	17.3	17.6	17.8	17.3	16.8	17.3	17.6	17.8	17.3
S ₂	16.1	16.8	17.2	17.4	16.9	17.7	18.4	18.6	18.9	18.4	17.7	18.4	18.6	18.9	18.4
S ₃	16.3	17.0	17.3	17.5	17.0	17.9	18.5	18.7	19.0	18.5	17.9	18.5	18.7	19.0	18.5
S ₄	16.9	17.4	17.6	17.7	17.4	18.4	18.9	19.0	19.1	18.8	18.4	18.9	19.0	19.1	18.8
S ₅	16.9	17.4	17.7	17.9	17.5	18.6	19.0	19.1	19.2	18.9	18.6	19.0	19.1	19.2	18.9
S ₆	17.6	17.9	18.1	18.3	17.9	19.3	19.7	20.0	20.1	19.8	19.3	19.7	20.0	20.1	19.8
Mean	16.5	17.0	17.3	17.5		18.1	18.6	18.8	19.0		18.1	18.6	18.8	19.0	
		SEd	CD (P = 0.05)			SEd	CD (P = 0.05)				SEd	CD (P = 0.05)			
S		0.05	0.13			0.07	0.16				0.07	0.16			
N		0.08	0.16			0.09	0.18				0.09	0.18			
S at N		0.12	0.24			0.12	0.25				0.12	0.25			
N at S		0.13	0.27			0.14	0.28				0.14	0.28			

4.8.2.11. Soil available K at post harvest of rice (Table 81 and 82)

Organic sources and inorganic N application significantly influenced the soil available K status.

Soil available K was lower with organic sources of N supply. Increased level of inorganic N reduced the soil available K. The interaction between organic and inorganic N was not significant.

4.8.2.12. Soil available K at post harvest of greengram (Table 83)

Application of organic sources reduced the soil available K and also increased fertilizer N tended to decrease the soil available K status. Combination of organic sources to preceding rice crops depleted soil available K even after raising a residual crop of greengram.

4.8.2.13. Dynamics of the soil available K in the cropping system

Soil available k tended to decrease with raising of rice and greengram crops. The overall soil available K status after two years of cropping declined slightly compared to the initial status. Graded level of N progressively decreased the soil available K. Regardless of the source of N, 100 per cent recommended level of N used in the cropping system decreased the soil available K.

4.8.3. Economic analysis of integrated N management in the cropping system

Various economic parameters worked out for the cropping system as a whole are presented in this section, separately for each cropping cycle.

**Table 81. Effect of organic N sources and inorganic N levels on soil available K (kg ha⁻¹) at post harvest stage of rice -
Kharif 2000 and 2001**

Treatments	Kharif 2000						Kharif 2001											
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean			
S ₁	562	548	540	535	546	534	529	526	524	528	534	529	526	524	528			
S ₂	546	536	531	529	535	527	520	518	516	520	527	520	518	516	520			
S ₃	544	534	529	528	534	525	518	516	514	518	525	518	516	514	518			
S ₄	536	528	525	523	528	521	515	513	511	515	521	515	513	511	515			
S ₅	536	528	524	522	528	519	513	511	509	513	519	513	511	509	513			
S ₆	535	527	524	522	527	515	510	509	508	510	515	510	509	508	510			
Mean	543	534	529	526		524	517	515	513		524	517	515	513				
	SEd						SEd						CD (P = 0.05)					
S	2.3						2.7						6.1					
N	4.4						3.2						NS					
S at N	7.9						6.5						NS					
N at S	9.0						7.2						NS					
	CD (P = 0.05)						CD (P = 0.05)						CD (P = 0.05)					
	5.2						5.2						6.1					
	NS						NS						NS					
	NS						NS						NS					
	NS						NS						NS					

Table 82. Effect of organic N sources and inorganic N levels on soil available K (kg ha⁻¹) at post harvest stage of rice -
Rabi 2000-'01 and 2001-'02

Treatments	Rabi 2000-'01						Rabi 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	552	543	537	533	541	524	519	515	512	518	524	519	515	512	518
S ₂	540	533	528	525	532	516	512	509	507	511	516	512	509	507	511
S ₃	538	531	526	524	530	514	511	508	506	509	514	511	508	506	509
S ₄	535	529	524	522	528	506	504	503	501	503	506	504	503	501	503
S ₅	533	527	522	521	526	508	506	505	503	505	508	506	505	503	505
S ₆	525	521	518	516	520	504	503	502	501	502	504	503	502	501	502
Mean	537	530	526	523		512	509	507	505		512	509	507	505	
	SEd	CD (P = 0.05)						SEd	CD (P = 0.05)						
S	2.5	5.6						2.9	6.5						
N	4.8	NS						3.5	NS						
S at N	6.8	NS						7.2	NS						
N at S	7.9	NS						7.6	NS						

Table 83. Effect of organic N sources and inorganic N levels on soil available K (kg ha^{-1}) at post harvest stage of residual greengram - Summer 2001 and 2002

Treatments	Summer 2001						Summer 2002								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	556	550	546	543	549	530	524	520	517	523	530	524	520	517	523
S ₂	545	541	538	536	540	520	516	513	510	515	520	516	513	510	515
S ₃	543	539	536	535	538	521	517	515	512	516	521	517	515	512	516
S ₄	535	532	531	530	532	513	510	509	506	509	513	510	509	506	509
S ₅	533	530	529	527	530	511	508	507	505	507	511	508	507	505	507
S ₆	529	527	526	525	527	507	505	504	502	504	507	505	504	502	504
Mean	540	536	534	532		517	513	511	509		517	513	511	509	
	SEd	CD (P = 0.05)						SEd	CD (P = 0.05)						
S	3.6	8.2						3.2	7.2						
N	5.1	NS						3.6	NS						
S at N	7.4	NS						7.4	NS						
N at S	8.2	NS						8.0	NS						

4.8.3.1. Net returns from the cropping system

4.8.3.1.1. First cropping cycle (2000-'01) (Table 84 and Fig.16)

Use of different sources and combination of sources of N in the cropping system had profound influence on the net returns of the cropping system as a whole.

Rice with intercrop of green manure and dual crop of *Azolla* resulted in substantially higher net returns, while sole rice recorded lower net returns. Application of 100 per cent recommended N level registered significantly higher net returns. The lower net return was observed in the control.

The highest net returns were obtained with rice + green manure + *Azolla* with 100 per cent recommended level of N. However this was comparable with 75 per cent and 50 per cent recommended levels of N application. Net returns from the cropping system were the lowest where N supply, either through organics or inorganic sources is skipped.

4.8.3.1.2. Second cropping cycle (2001-'02) (Table 84 and Fig.16)

Organic N sources and graded levels of fertilizer N influenced the net returns from the cropping system to a considerable extent.

Rice + green manure + *Azolla* registered markedly higher net returns. Sole crop of rice recorded lower net returns. Application of 100 per cent recommended N resulted in significantly higher net returns, while lower net returns was recorded in the absence of inorganic N supply.

Table 84. Effect of organic N sources and inorganic N levels on net returns (Rs. ha⁻¹) for the cropping system as a whole-2000-'01 and 2001-'02

Treatments	Cropping system 2000-'01						Cropping system 2001-'02								
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	9621	24434	34632	39464	27038	19251	34866	45605	50759	37620					
S ₂	19369	31056	39853	44273	33638	29435	41903	51156	55863	44589					
S ₃	23039	34178	42109	46096	36356	33064	45012	53447	57735	47315					
S ₄	28791	39457	43576	46614	39610	39035	50381	55061	58300	50694					
S ₅	29995	40456	44499	47346	40574	40256	51532	56115	59235	51785					
S ₆	33137	43558	45500	47855	42513	45851	57037	58912	61005	55701					
Mean	23992	35523	41695	45275		34482	46789	53383	57150						
		SEd	CD (P = 0.05)			SEd	CD (P = 0.05)								
S		1447.3	3224.6			1506.4	3356.4								
N		1685.4	3418.5			1815.8	3682.6								
S at N		2161.7	4425.2			2256.1	4618.3								
N at S		2254.4	4572.6			2382.9	4832.5								

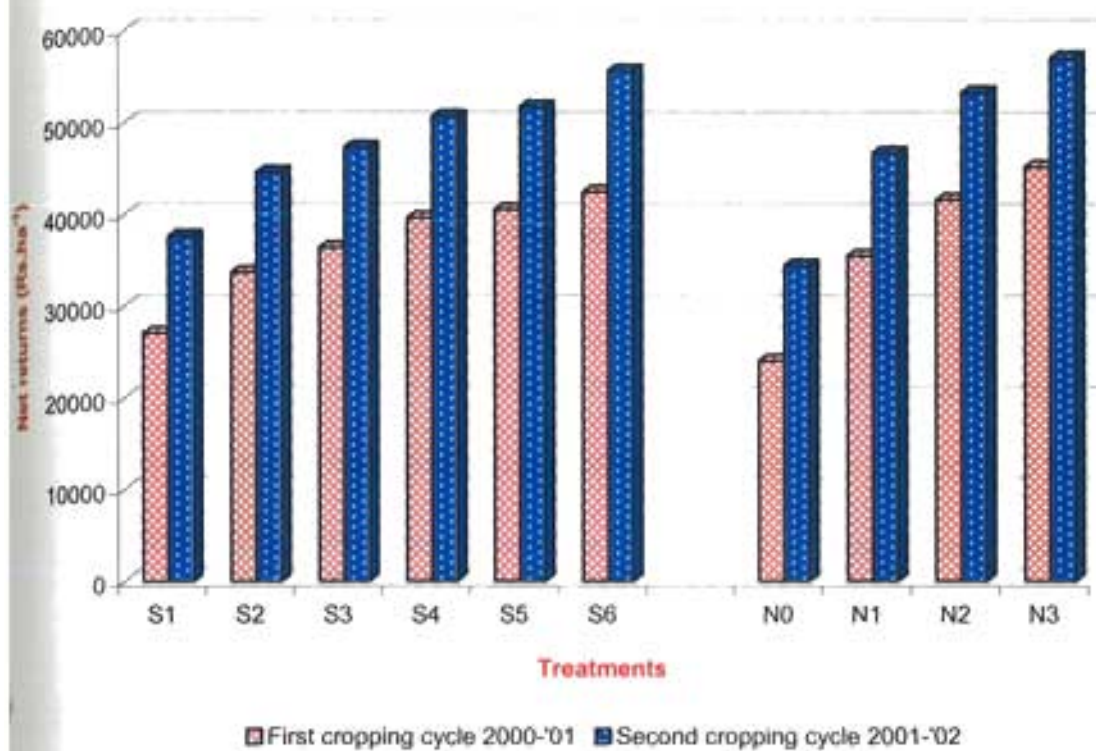


Fig.16. Effect of organics and inorganic N on net returns the cropping system.

Net returns were the highest, when combination of rice + green manure + *Azolla* and N was applied at 100 per cent recommended level. However, this was on par with 75 and 50 per cent recommended levels of N. The lowest net returns were obtained with the absence of any source of N both the rice crops.

4.8.3.2. Benefit cost ratio for the cropping system

4.8.3.2.1. First cropping cycle (2000-01) (Table 85)

Organic sources of N highly influenced the B:C ratio. Rice + green manure + *Azolla* in both the seasons increased the B:C ratio. Sole rice recorded lower B:C ratio than other treatments. Among the N levels, 100 per cent recommended level of N substantially improved the B:C ratio, while no nitrogen plots registered lower B:C ratio. The highest B:C ratio was registered with the combined use of rice + green manure + *Azolla* and 100 per cent fertilizer N application. The lowest B:C ratio was associated with the non application of N through any source to both the rice crops.

4.8.3.2.2. Second cropping cycle (2000-'02) (Table 85)

Rice + green manure + *Azolla* in both the seasons improved the B:C ratio, while sole rice resulted in lower B:C ratio. Application of 100 per cent recommended N recorded higher B:C ratio than other N levels. Lower B:C ratio was observed with no fertilizer N. The highest B:C ratio was observed with rice + green manure + *Azolla* with 100 per cent recommended level of N, while the lowest B:C ratio was noticed in the absence of N through organics and inorganic N source to both the rice crops.

Table 85. Effect of organic N sources and inorganic N levels on Benefit : Cost ratio for the cropping system as a whole - 2000-'01 and 2001-'02

Treatments	Cropping system 2000-'01					Cropping system 2001-'02				
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
S ₁	1.35	1.85	2.17	2.30	1.92	1.65	2.13	2.45	2.58	2.20
S ₂	1.66	2.01	2.27	2.38	2.08	1.94	2.28	2.53	2.64	2.35
S ₃	1.78	2.11	2.34	2.43	2.17	2.05	2.38	2.60	2.69	2.43
S ₄	1.96	2.26	2.36	2.42	2.25	2.22	2.51	2.62	2.68	2.51
S ₅	1.99	2.28	2.38	2.44	2.27	2.25	2.54	2.64	2.70	2.53
S ₆	2.07	2.35	2.39	2.43	2.31	2.40	2.67	2.69	2.72	2.62
Mean	1.80	2.14	2.32	2.40	2.31	2.09	2.42	2.59	2.67	2.62

Data not statistically analysed

4.8.4. Partial budgeting (Table 86 and 87)

Partial budgeting refers to estimating change in net income due to some change in resource use. It is the technique commonly used to estimate the effects of a technology in the farming. It provides a method for deciding how far expenses and yields should be increased of a particular farming activity.

Partial budgeting technique was imposed to compare the economical viability of the various organic sources and levels of N in the cropping system. Only the estimated changes were computed with the introduction of the technologies and the data are presented in Tables 86 and 87.

With due consideration of the added costs and returns, and similarly the reduced costs and returns, rice + green manure + *Azolla* was found to be economically viable as compared to individual application of either green manure or *Azolla* to rice crops. Combination of organic sources with progressive increase in inorganic levels improved the profitability. However the estimated profit increased at a decreasing rate beyond 50 per cent inorganic N level.

Table 86. Partial budgeting for the cropping system as a whole - 2000-'01

Losses (Rs. ha ⁻¹)		Gains (Rs. ha ⁻¹)	
(S ₁ V _s S ₂)			
Added costs	= 1877	Added returns	= 8477
Reduced returns	= -	Reduced cost	= -
	-----		-----
	1877		8477
	-----		-----
Estimated change = (+) 6600			
(S ₁ V _s S ₃)			
Added costs	= 1877	Added returns	= 11197
Reduced returns	= -	Reduced cost	= -
	-----		-----
	1877		11197
	-----		-----
Estimated change = (+) 9320			
(S ₁ V _s S ₄)			
Added costs	= 2521	Added returns	= 15093
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2521		15093
	-----		-----
Estimated change = (+) 12572			
(S ₁ V _s S ₅)			
Added costs	= 2628	Added returns	= 16164
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2628		16164
	-----		-----
Estimated change = (+) 13536			

Contd...

Losses (Rs. ha ⁻¹)		Gains (Rs. ha ⁻¹)	
(S ₁ V _S S ₆)			
Added costs	= 3272	Added returns	= 18747
Reduced returns	= -	Reduced cost	= -
	-----		-----
	3272		18747
	-----		-----
Estimated change = (+) 15475			
(S ₆ N ₀ V _S S ₆ N ₁)			
Added costs	= 1348	Added returns	= 11769
Reduced returns	= -	Reduced cost	= -
	-----		-----
	1877		11769
	-----		-----
Estimated change = (+) 10421			
(S ₆ N ₀ V _S S ₆ N ₂)			
Added costs	= 2021	Added returns	= 14384
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2021		14384
	-----		-----
Estimated change = (+) 12363			
(S ₆ N ₀ V _S S ₆ N ₃)			
Added costs	= 2695	Added returns	= 17413
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2695		17413
	-----		-----
Estimated change = (+) 14718			

Table 87. Partial budgeting for the cropping system as a whole - 2001-'02

Losses (Rs ha ⁻¹)		Gains (Rs ha ⁻¹)	
(S ₁ V _S S ₂)			
Added costs	= 1877	Added returns	= 8846
Reduced returns	= -	Reduced cost	= -
	-----		-----
	1877		8846
	-----		-----
Estimated change = (+) 6969			
(S ₁ V _S S ₃)			
Added costs	= 1877	Added returns	= 11572
Reduced returns	= -	Reduced cost	= -
	-----		-----
	1877		11572
	-----		-----
Estimated change = (+) 9695			
(S ₁ V _S S ₄)			
Added costs	= 2521	Added returns	= 15591
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2521		15591
	-----		-----
Estimated change = (+) 13070			
(S ₁ V _S S ₅)			
Added costs	= 2628	Added returns	= 16793
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2628		16793
	-----		-----
Estimated change = (+) 14165			

Contd...

Losses (Rs. ha ⁻¹)		Gains (Rs. ha ⁻¹)	
(S ₁ V _s S ₆)			
Added costs	= 3272	Added returns	= 21353
Reduced returns	= -	Reduced cost	= -
	-----		-----
	3272		21353
	-----		-----
Estimated change = (+) 18081			
(S ₆ N ₀ V _s S ₆ N ₁)			
Added costs	= 1348	Added returns	= 12534
Reduced returns	= -	Reduced cost	= -
	-----		-----
	1348		12534
	-----		-----
Estimated change = (+) 11186			
(S ₆ N ₀ V _s S ₆ N ₂)			
Added costs	= 2021	Added returns	= 15082
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2021		15082
	-----		-----
Estimated change = (+) 13061			
(S ₆ N ₀ V _s S ₆ N ₃)			
Added costs	= 2695	Added returns	= 17849
Reduced returns	= -	Reduced cost	= -
	-----		-----
	2695		17849
	-----		-----
Estimated change = (+) 15154			

DISCUSSION

CHAPTER V

DISCUSSION

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore, with a view to develop an integrated nitrogen management strategy for wet seeded rice-rice-greengram cropping system. The experimental results presented in chapter IV are discussed in this chapter.

5.1. Seasonal effect

The experimentation was confined to two seasons, viz., *kharif* and *rabi* seasons of 2000-'01 and 2001-'02. The mean maximum and minimum temperatures were 31.3 and 22.4°C during *kharif* 2000, 31.6 and 22.4°C during *kharif* 2001, 30.1 and 19.7°C during *rabi* 2000-'01 and 29.7 and 20.1°C during *rabi* 2001-'02 respectively. However, the mean solar radiation and mean sunshine hours were higher in *rabi* season than in *kharif* season in both the years.

The perusal of weather data from the date of inoculation to the date of incorporation of *Azolla* showed that lower mean maximum and minimum temperatures, higher mean relative humidity and high mean solar radiation prevailed during *rabi* season resulted in higher biomass production as well as N accumulation in *Azolla*. Kempuchetty (1989) also reported that cooler day and night temperatures favoured *Azolla* multiplication during *rabi* season at Coimbatore.

The weather prevailed from the date of sowing to the date of incorporation of *Sesbania rostrata* also showed that weather during *kharif* and *rabi* seasons had almost similar effect on biomass production and N accumulation in *Sesbania rostrata* in both the years.

Combination of *Sesbania rostrata* intercropping and *Azolla* dual cropping might have created favourable microclimate for both the crops to produce higher biomass and accumulate greater N when compared to either green manuring or dual cropping individually in rice.

The growth parameters, yield components and yield of rice during *rabi* season were favourably influenced by higher mean solar radiation and higher mean sunshine hours compared to that prevailed during *kharif* season in both the years. Moreover, the *rabi* season rice had a longer growth duration as compared to *kharif* season rice.

The residual greengram produced comparatively lesser dry matter production during the first year due to irrigation constraints. Greengram in the second year could produce higher biomass and dry matter yield because of the provision of irrigations at critical stages and occurrence of 32 mm of rainfall. Considerable grain yield also could be obtained in the second year.

Among the *kharif* crops, *kharif* 2001 rice crop recorded slightly higher grain yield than that in *kharif* 2000. This might be due to the residual effect of greengram haulms incorporation in the preceding summer season. As for the *rabi* rice, the grain



yields followed a similar trend in *rabi* 2000-'01 and 2001-'02. This might be due to almost similar weather conditions prevailed during the cropping periods in both the years.

In general, *rabi* rice yields were marginally higher than *kharif* rice yields. This was due to longer growth duration of *rabi* rice compared to *kharif* rice.

5.2. Effect of organic N sources on rice

5.2.1. Effect of *Azolla* on rice

Dual cropping of *Azolla* resulted in improved performance of rice in both the years of study. The ammoniacal N could be detected with the flood water from 5 days after incorporation of *Azolla* and thereafter steadily increased upto 15 days and then declined (Fig. 17 to 20). Mian and Stewart (1985) reported that with dual culturing *Azolla* in rice, the decomposition started within a few days after incorporation with the release of ammoniacal N. The release of N into soil solution was steady and continuous for about 30 days, which the rice plant could readily absorb and utilize for its growth.

Increased absorption of N due to *Azolla* incorporation favoured the growth of rice. Taller plants, more number of tillers, larger LAI and greater dry matter production all resulted due to *Azolla* application. Panicle production was also higher and number of filled grains per panicle were more under the influence of *Azolla*. The release of N from *Azolla* might have matched the requirement of rice plant, thus making the N supply adequate for favourable growth of rice.

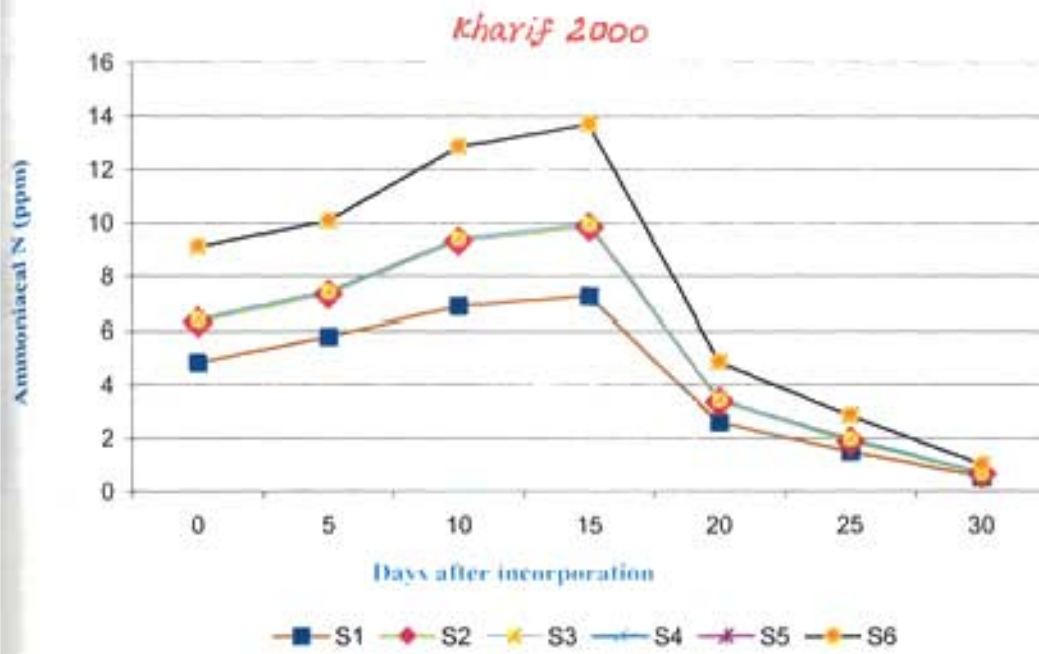


Fig.17. Flood water ammoniacal N after incorporation of organics

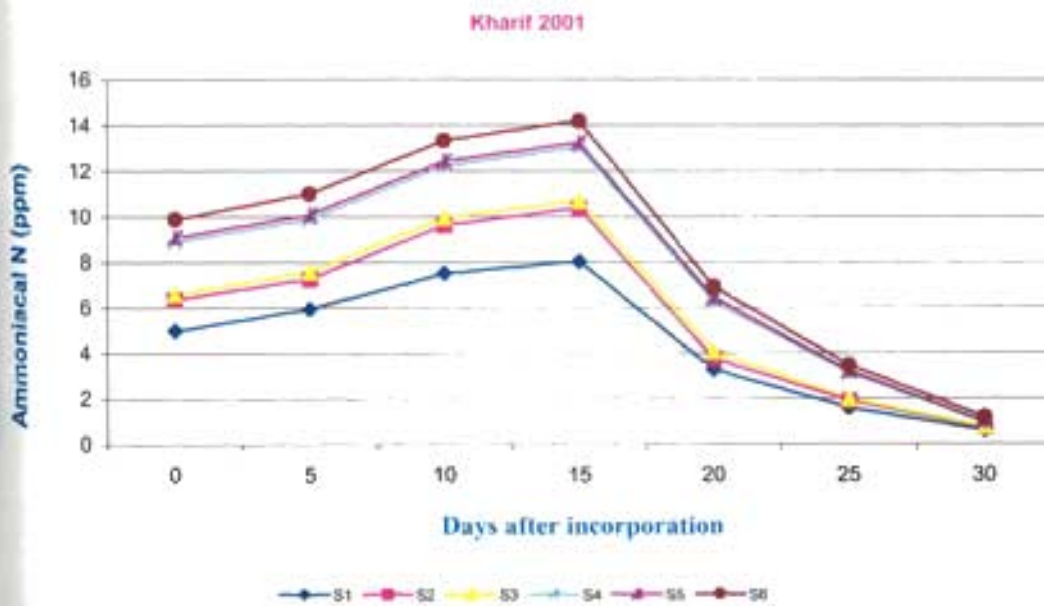


Fig.18. Flood water ammoniacal N after incorporation of organics

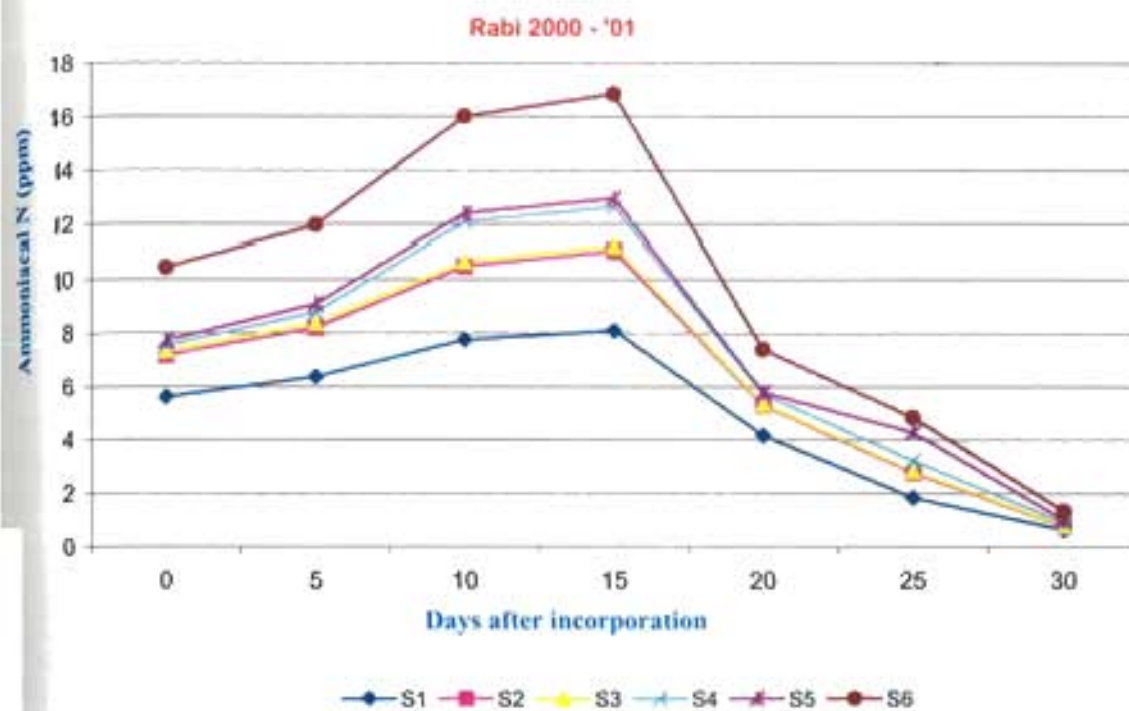


Fig.19. Flood water ammoniacal N after incorporation of organics

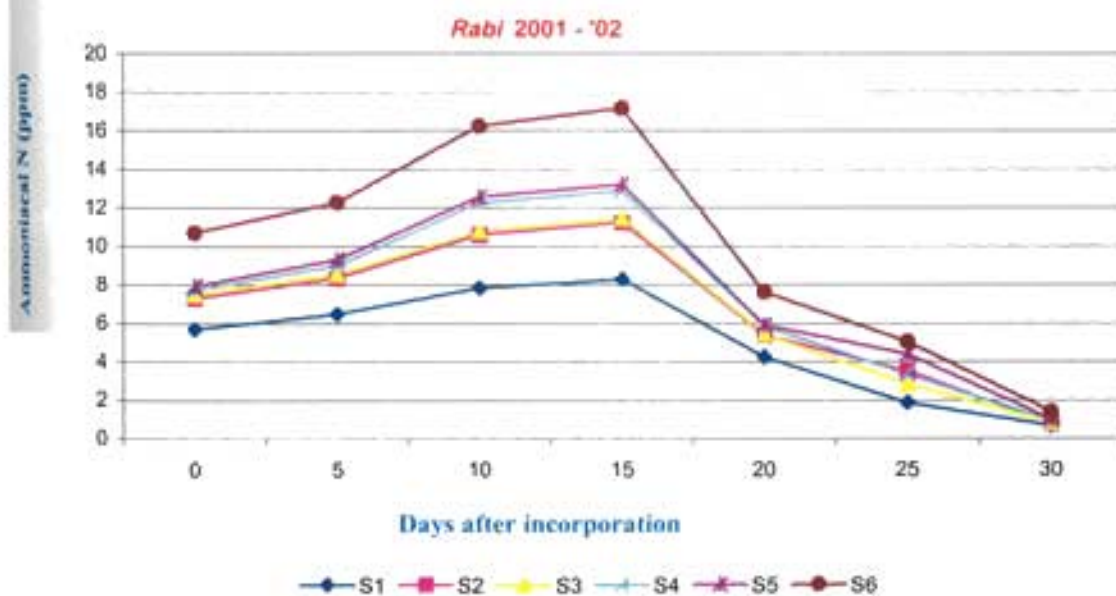


Fig.20. Flood water ammoniacal N after incorporation of organics

Nutrient uptake by rice was also substantially enhanced by *Azolla* application. Higher dry matter production and increased N absorption might have resulted in increased N uptake. *Azolla* also contained considerable P and K which might have been supplied to rice crop during decomposition consequently the uptake of P and K by rice were also improved.

Azolla application resulted in increased grain yield of rice. Better growth and improved yield components due to *Azolla* enhanced the yield. Higher straw yield of rice associated with *Azolla* inoculation was due to taller plants and more tillers.

5.2.2. Effect of *Sesbania rostrata* on rice

Regardless of the season, green manuring with *Sesbania rostrata* exerted favourable effect on rice, in all the four seasons. In lowland rice soils, green manure undergoes decomposition at a steady rate resulting in the release of ammoniacal N into the soil solution, which is readily usable by rice crop (Nagarajah, 1987).

Enhanced levels of N available in the rhizosphere soil invariably resulted in better N uptake by rice. Improved vegetative growth was indicated by taller plants, more number of tillers and leaves and increased leaf size leading to larger LAI. In the presence of adequate N and larger photosynthesising surface, the dry matter production proceeded at a rapid rate and as a result, the DMP was greater in rice.

Higher tiller production was due to green manuring in the early stages and higher number of panicle were the result of steady supply of N. Adequate N promoted the supply of assimilates to 'sink' or 'yield container', thus enlarging size of

the panicle with more number of spikelets. Continuous supply of N due to slow and steady release of mineralised green manure N into soil solution improved the yield structure.

Green manuring to rice enhanced the uptake of N, P and K to a considerable extent. Increased DMP and higher N concentration in plants due to better absorption of N especially from green manure enhanced the N uptake. Improved uptake of P by rice due to green manuring might be due to the contribution of P from green manure itself (Table 4) coupled with the solubilization of native P by organic acids produced during the decomposition of green manure. These two factors improved the absorption of P by rice. Increased DMP due to green manuring coupled with higher P concentration resulted in greater P uptake. Higher K uptake under the influence of green manuring was due to greater DMP and K absorption.

Green manuring increased the rice yield markedly. Green manure contributed N, which resulted in better growth expressed in terms of tillering, LAI and DMP. Increased levels of yield attributes as reflected by more number of panicles per unit area with more number of filled grains and higher weight were manifested by green manuring. The cumulative effect of all these parameters led to higher grain yield.

Higher straw yield of rice obtained with green manuring was due to taller plants, more number of tillers and higher quantity of total biomass production.

5.2.3. Effect of combination *Azolla* and *Sesbania rostrata* on rice

Dual cropping of *Azolla* and intercropping of green manure combination augmented the growth and yield of rice in all the seasons. Nitrogen mineralised during decomposition of *Sesbania rostrata* and *Azolla* resulted in increased contribution of nitrogen to the crop. Organic materials acting as slow release source of N supplied N to meet the rice N demand (Becker *et al.*, 1986) and hence more N was available to the plant. This enhanced nitrogen availability in rhizosphere favoured higher nutrient uptake resulting in better growth. Higher release of N by *Azolla* and *Sesbania rostrata* promoted the supply of assimilates to sink, thus enlarging the yield structure.

Combination of *Azolla* and green manuring increased the uptake of N,P and K to a considerable extent. Improved uptake of P by rice due to green manuring and *Azolla* combination might be due to contribution of P from *Azolla* and *Sesbania rostrata* coupled with solubilization of native P by organic acids produced during the decomposition of these organic sources. The above factors could have increased the concentration of P in rice plants. Higher K uptake under the influence of organic N sources is due to greater DMP and K absorption.

The beneficial effect of green manure and *Azolla* on the growth, yield attributes and nutrient uptake of rice has already been discussed. Combination of *Azolla* and green manuring resulted in the growth, yield attributes and nutrient uptake and yield is increased to a greater extent.

5.2.4. Effect of Greengram

Incorporation of greengram haulms before *kharif* 2001 rice exerted favourable effect on the performance of rice. Upon incorporation, greengram haulms were decomposed resulting in mineralisation of N which was brought into soil solution to be readily available for absorption by rice crop. Taller plants, more tillers, larger LAI and higher DMP resulted with the greengram haulm incorporation due to better nutritional environment. Yield attributes viz., panicle numbers, panicle length and filled grains per panicle were improved due to greengram haulms incorporation. Nutrient uptake was enhanced by greengram haulm incorporation. Higher DMP coupled with increased absorption resulted in increased uptake of N,P and K. Increased absorption of N and K might be due to mobilization of native resources in addition to the contribution by greengram haulms, while that of the P might be due to solubilization of native P under the influence of added organic manure.

Grain yield of rice was enhanced by incorporating greengram haulms. Improved growth and yield structure resulted in higher grain yield. Lekha Sreekanthan (1987) also reported that incorporation of greengram straw resulted in improved growth and yield attributes of rice and consequently higher nutrient uptake and yield.

5.3. Effect of fertilizer N on rice

Increase in inorganic N level upto 100 per cent recommended level improved the growth and yield components, grain and straw yield in sole rice. However, inclusion of either *Azolla* or *Sesbania rostrata* in rice also improved the

yield levels. Significant response to applied N was observed upto 75 per cent level where either *Azolla* was dual cropped or *Sesbania rostrata* was intercropped. *Azolla* or *Sesbania rostrata* contributed about 33 per cent of the N requirement of the crop.

However, their combination contributed about 80 per cent of the N requirement during *kharif* season as well as *rabi* season. Because of the significant contribution of N from organic sources, the crop response to inorganic N was upto 50 per cent level only.

Increased uptake of N was the result of higher DMP and enhanced absorption of N, while that of P and K might be due to better foraging of soil and vigorous root growth.

Higher grain yield associated with higher levels of fertilizer N was the cumulative effect of pronounced expression of various yield attributes. Efficient accumulation and effective partitioning of assimilates to yield container might have resulted in higher yield. Better vegetative growth with higher level of N nutrition led to enhanced straw yield of rice. This is in conformity with the findings of Dhurandher and Tripathy (1999) and Jaiswal and Singh (2001).

Increase in levels of fertilizer N progressively increased the yield of rice. Most of the growth and yield attributes responded to added N upto the 100 per cent recommended N level. Increased N supply might have resulted in higher assimilate accumulation and finally higher yield.

5.4. Interaction effect of organic N sources and inorganic N levels on rice

The interaction effect between organic sources and inorganic N levels was significant. Rice dual cropped with *Azolla* was positively influenced in its growth characters, yield attributes and yield in both the seasons. The effect was considerable in rice intercropped with *Azolla* upto the inorganic N level of 75 per cent, Similar results have been reported by Gopaldaswamy and Anthoniraj (1997). The same trend could be observed in rice intercropped with *Sesbania rostrata* also. Premsekhar (2000) also observed similar results in rice at Coimbatore. However, the magnitude of the effect of *Sesbania rostrata* was slightly higher than that from *Azolla*. The contributions of *Azolla* and *Sesbania rostrata* to rice crop in a single season were about 30 to 35 per cent and 40 to 45 per cent respectively. However, when these two organic sources viz., *Azolla* and *Sesbania rostrata* were combined in a rice crop, their contribution rose upto 80 per cent of the N requirement. Considerable response in growth and yield components and yield could be observed upto 50 per cent level of inorganic N if these two sources are combined. Application of 75 per cent and 100 per cent N levels were comparable with 50 per cent level in respect of rice with *Azolla* and *Sesbania rostrata*. The results of the study showed the possibility of substitution of inorganic N upto 25 per cent, if *Azolla* or *Sesbania rostrate* is included, and upto 50 per cent when *Azolla* and *Sesbania rostrata* are combined.

5.5. Nitrogen use efficiency as influenced by organic N sources and inorganic N levels

Nitrogen use efficiency was assessed for the organic sources and graded levels of fertilizer N in rice.

Agronomic efficiency (AE) indicated the quantity of rice produced per unit quantity of N applied. This is also termed as productive efficiency and often expressed as the product of efficiency of absorption and efficiency of utilization. Increased levels of N tended to lower the productive efficiency. This was because with increased quantity of N application, the losses of N from lowland rice soil and flood water became larger. Dual cropping of *Azolla* and intercropping of *Sesbania rostrata* combined with lower level of N (50 per cent recommended N) improved the AE. Such interactive effect of organic and lower levels of inorganic sources of N, leading to higher AE was reported by Babu (1995) and Geethalakshmi (1996).

Physiological efficiency (PE) indicates the efficiency of utilization of absorbed N, usually expressed as the quantity of grain produced per unit quantity of N absorbed by the crop. Increasing the level of fertilizer N reduced the values of PE.

Apparent N recovery (ANR), indicates the efficiency of absorption of applied N. The ANR was computed based on the difference between uptake of specific treatment and control. Dual cropping of *Azolla* and intercropping of green manure tended to decrease the ANR. The ANR values showed increasing trend upto 75 per cent recommended level of N supply and decreasing trend beyond that level of inorganic N. With dual cropping of *Azolla* and intercropping of *Sesbania rostrata*, the uptake of N by rice was fairly high. These organic sources might have contributed considerable quantity of N upon mineralisation making more N available to plants. Consequently ANR became higher with increased N availability and decreased with higher levels of fertilizer N.

Nitrogen harvest index (NHI), indicates the proportion of N taken up by the crop that is utilised for grain production and may be considered as an indicator of translocation from source to sink. Application organic sources positively influenced NHI, by making steady supply of N to rice crop, In rice crop most of the assimilates produced in the post flowering stage would be utilised for grain formation and more than 75 per cent of grain yield is decided by the amount of photosynthates that accrue after flowering. The N uptake was enhanced by organic sources throughout the crop growth period, and this might have enhanced NHI in organic sources applied treatments. Increased NHI due to application of green manure was also reported by Siddeswaran (1992) and Geethalakshmi (1996). In contrast to the three parameters viz., AE, PE and ANR, the increase in N level progressively increased the NHI. Higher values of NHI, at higher levels of application has been reported by Srinivasulu Reddy (1988).

5.6. Residual effect of organic sources and inorganic N levels on greengram

Greengram was raised as a residual crop after *rabi* rice in both the years. The residual effect of treatments applied to the preceding rice crops was not noticed in greengram. Growth components, yield attributes, nutrient uptake and grain yield of greengram did not vary much in various treatments imposed to preceding rice crops.

Organic sources and levels of inorganic N applied to rice left varying levels of residual N in the soils that could be used by the succeeding crop. Greengram, being a leguminous crop, did not show any marked variation due to varying levels of soil N in different plots. Regardless of the N status of the soil, greengram performed

uniformly well. Similar result was reported by Balasubramaniyan and Palaniappan (1990).

5.7. Organic sources of N in the Cropping System

Organic sources of N had positive influence on rice crops. Intercropping of green manure *Sesbania rostrata* in *kharif* rice and dual cropping of *Azolla* in *rabi* rice resulted in more benefits than dual cropping of *Azolla* in *kharif* rice and intercropping of *Sesbania rostrata* in *rabi* rice. However, combination of intercropping of green manure and dual cropping of *Azolla* in rice in both *kharif* and *rabi* seasons had higher benefits when compared to either green manuring or dual cropping individually in rice. The result of the present study indicates the possibility of including green manure and *Azolla* combination as better organic sources of N in the wet seeded rice-rice-greengram cropping system.

The usefulness of greengram haulms as green manure in rice based cropping system could also be observed. Greengram haulms as organic manure for wet seeded rice crops improved the soil fertility. Srinivasulu Reddy (1988) and Siddeswaran (1992) also reported that the practice of incorporating greengram haulms as green manure in rice based cropping system improved soil fertility at Coimbatore.

5.8. Productivity of the Cropping System

Different sources and combination of sources of N influenced the total productivity of the cropping system to varying levels.

Inclusion of organic sources in the cropping system tended to increase the total dry matter production (TDMP) to an appreciable extent.

Considerably higher TDMP of the cropping system was recorded with green manuring and *Azolla* combination in both the rice crops. This was followed by either green manuring or dual cropping alone in rice. Application of 100 per cent recommended N to each of the rice crops considerably increased the TDMP of the cropping system. Various combinations of sources of N resulted in higher TDMP. Beyond 50 per cent recommended level of N, the increase in TDMP was marginal and statistically not significant. Similar trend was also seen in both the years of study.

The cumulative performance of the two rice crops in the system under the influence of different N management practices was the basis to assess the superiority of treatments with regard to the grain productivity of the cropping system, because there was little residual effect for summer greengram.

Total grain production (TGP) of the cropping system was substantially higher when green manure and *Azolla* were applied to each of the rice crops and 50 per cent inorganic N was applied to both the rice crops of the system. Beyond 50 per cent recommended N level, increase in TGP was not significant, even when manure and *Azolla* were applied along with 75 and 100 per cent inorganic N levels.

Increased grain yields of component crops under the above said situations resulted in higher grain productivity of the second cropping cycle. However, close

perusal of grain yield data of individual crops in cropping system as a whole reveals that conjunctive use of different N sources was better than their use individually. Better performance of cropping system as indicated by the increased TDMP and corresponding increased TGP by integrated use of green manure, biofertilizer and fertilizer N in different combinations has already been observed by Meelu and Morris (1987) and Srinivasulu Reddy (1988).

The study clearly shows the beneficial effects of integrated N use practice on the productivity of the cropping system. However, the choice of an integrated N management practice does not depend upon productivity criteria alone. Economic analysis and soil fertility maintenance should also be taken into account.

5.9. Dynamics of soil fertility in the cropping system

Different sources and combination of sources of N used in the cropping system had considerable influence on the dynamics of soil fertility.

5.9.1. Soil organic carbon

The changes in soil organic carbon in different treatments are given in table 72 and Fig 21. There was decline in soil organic carbon in sole rice, rice+Azolla and rice + *Sesbania rostrata* at the end of *kharif* 2000. But in rice+Azolla+*Sesbania rostrata* plots, the soil organic carbon remained the same. Inclusion of both *Azolla* and *Sesbania rostrata* in rice added about 15.6 tonnes of biomass, which on incorporation might have enriched the organic carbon content of the soil.

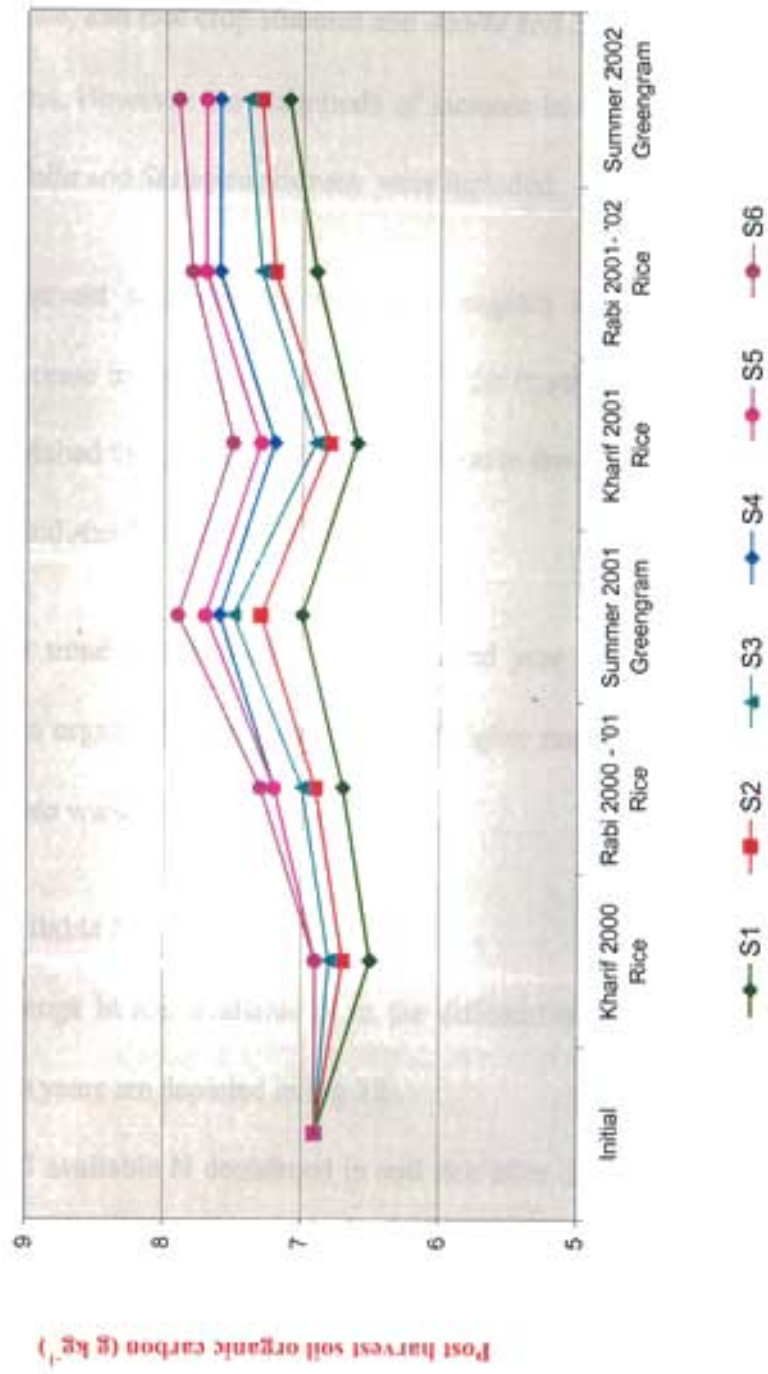


Fig.2.1 . Dynamics of soil organic carbon in the cropping system

Post harvest soil after *rabi* crop harvest showed an increase in soil organic carbon in all the treatments indicating the contribution of *kharif* rice crop stubbles alone in sole rice, and rice crop stubbles and *Azolla* and *Sesbania rostrata* biomass in other systems. However the magnitude of increase in organic carbon was higher where both *Azolla* and *Sesbania rostrata* were included.

Post harvest soil after harvest of greengram in summer 2001 showed perceptible increase in soil organic carbon in all the treatments. Greengram haulms, might have enriched the organic carbon, in addition to the contribution from two rice crop stubbles and *Azolla* and *Sesbania rostrata*.

Similar trend was observed in the second year cropping cycle also. The improvement in organic carbon content was of higher magnitude where *Azolla* and *Sesbania rostrata* were included in rice.

5.9.2. Soil Available N

The change in soil available N in the different treatments of the cropping systems for two years are depicted in Fig 22.

The soil available N declined in soil rice after the *kharif* season, whereas rice with organics, either with *Azolla* or *Sesbania rostrata* or combination of *Azolla* and *Sesbania rostrata*, resulted in an increase in soil available N. This might be due to the addition of biomass from organic sources of N.

In general, there was decline in post harvest soil available N after harvest of the crop, irrespective of organics are included or not. However, the decline in soil

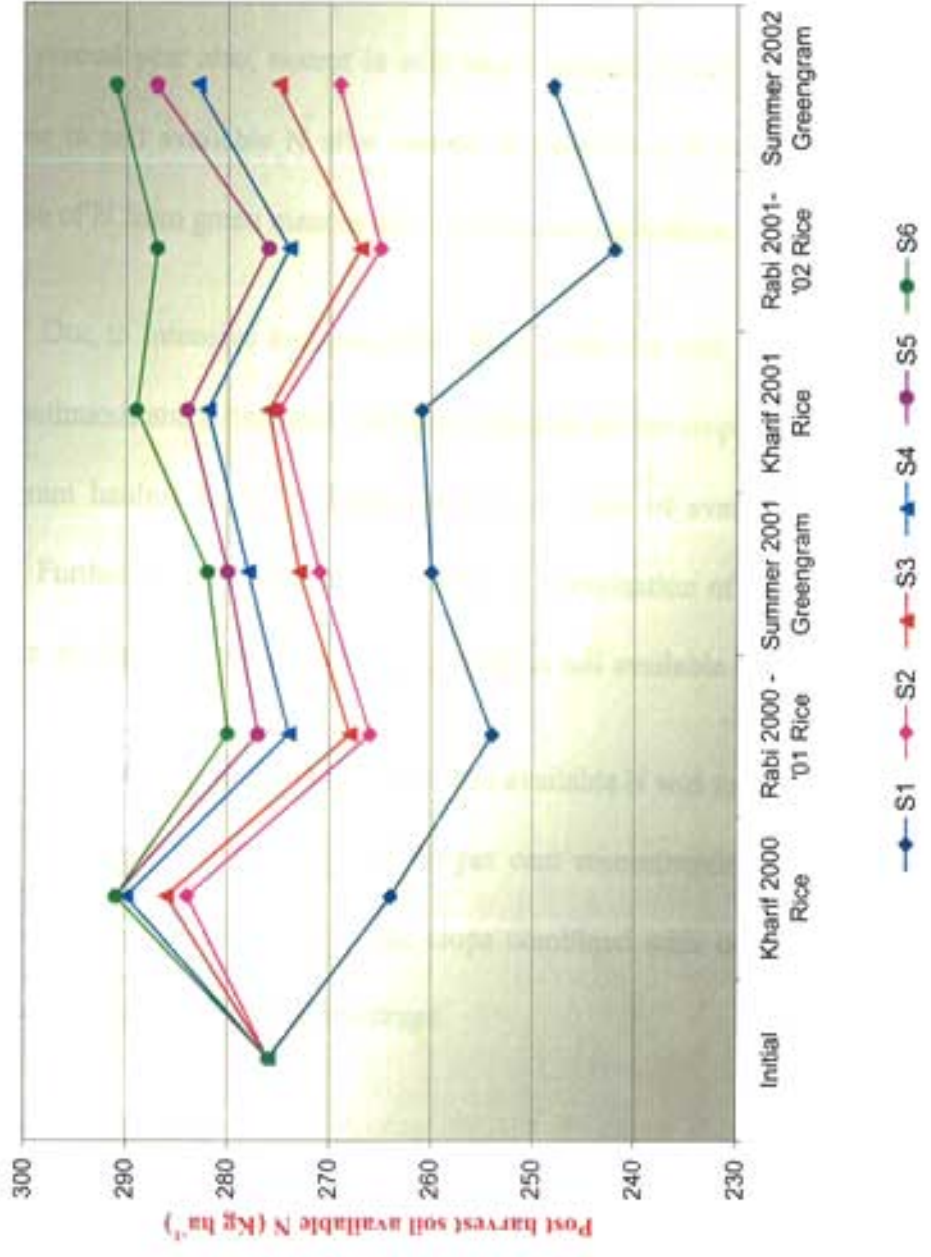


Fig. 22. Dynamics of soil available N in the cropping system

available N was higher in sole crop. Post harvest soil after harvest of summer greengram had higher soil available N in all the treatments indicating the contribution of N through fixation by greengram. The same trend could be observed in the second year also, except in sole crop treatment where there was a marginal increase in soil available N after harvest of *kharif* rice. This might be due to the addition of N from green manure and two rice crop stubbles as in other treatments.

Due to intensive cropping, with three crops per year, the nutrient removal was continuous and substantial. However, addition of rice crop stubbles and summer greengram haulms to the soil reduced the depletion of available N to a greater extent. Further, organic sources especially the combination of *Azolla* and *Sesbania rostrata* in rice crops considerably improved the soil available N status.

In the present study, the status of soil available N was maintained, when each of the rice crops was fertilised at 100 per cent recommended N or 75 per cent recommended N to each of the rice crops combined with combination of green manure and *Azolla* to both the rice crops.

5.9.4. Soil available P

The changes in soil available P in different treatments of the cropping system are depicted in Fig 23. There was increase in soil available P after the harvest of *kharif* rice as well as *rabi* rice. This was due to the higher availability of P under lowland conditions. But, the post harvest soil after the harvest of greengram had lesser soil available P compared to that after *rabi* rice. Greengram, being a legume,

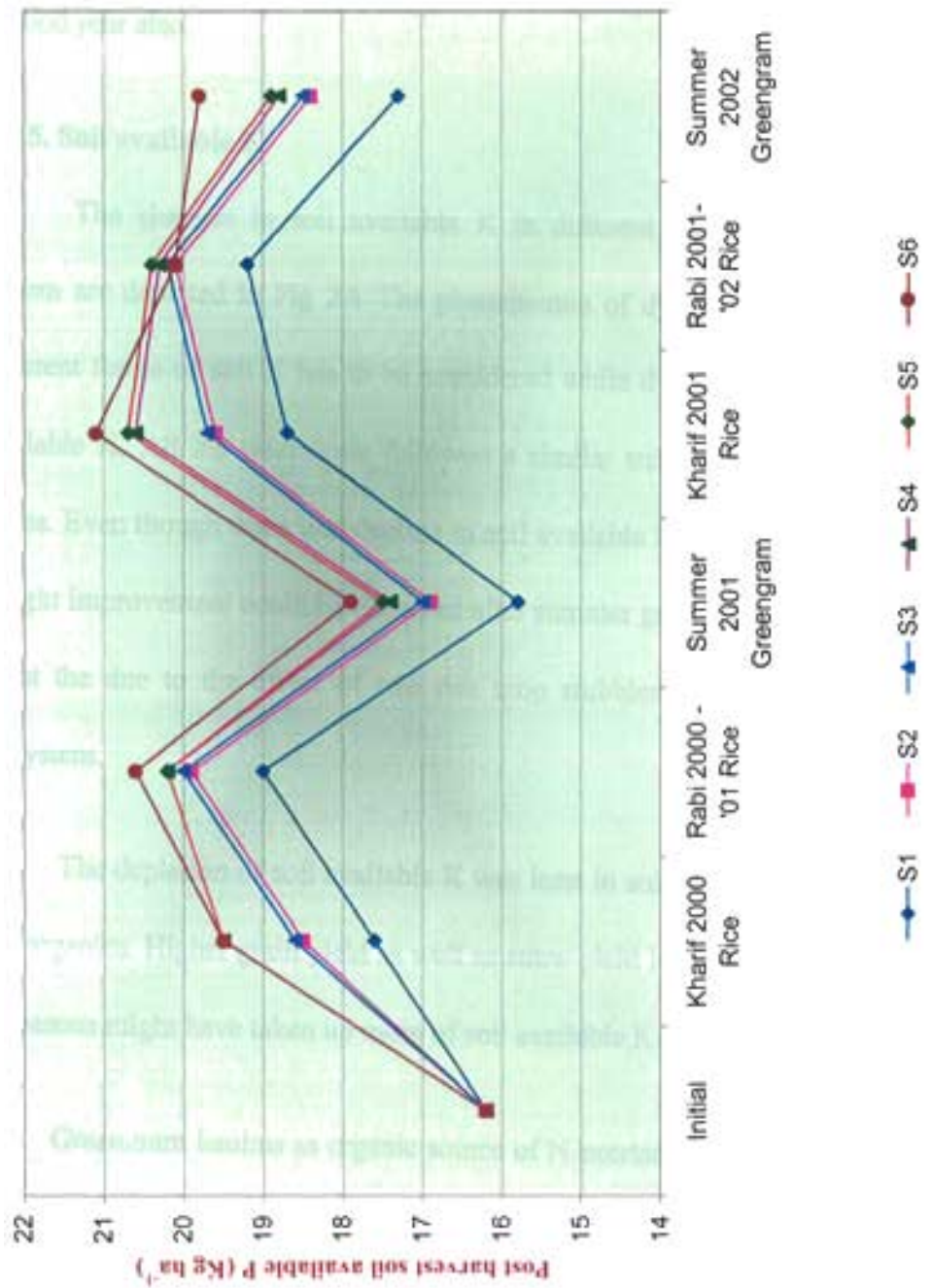


Fig. 23. Dynamics of soil available P in the cropping system

and efficient nutrients of P might have taken up more of P from soil alone to its root exudation and solubilising available P. The same trend could be observed in the second year also.

5.9.5. Soil available K

The changes in soil available K in different treatments of the cropping system are depicted in Fig 24. The phenomenon of dynamic equilibrium between different forms of soil K has to be considered while discussing the changes in soil available K. All the treatments followed a similar trend in the two year cropping cycles. Even though there was decline in soil available K after *kharif* and *rabi* rice, a slight improvement could be observed after summer greengram in both years. This might be due to the effect of two rice crop stubbles and greengram haulms to the system.

The depletion of soil available K was least in sole rice compared that in rice with organics. Higher grain yield as well as straw yield in rice with organics in both the seasons might have taken up more of soil available K.

Greengram haulms as organic source of N exerted considerable influence on the soil fertility.

5.10. Economic analysis of the cropping system

Various combinations of organic sources and inorganic N levels had marked effect on the economics of the wet seeded rice-rice-greengram cropping system.

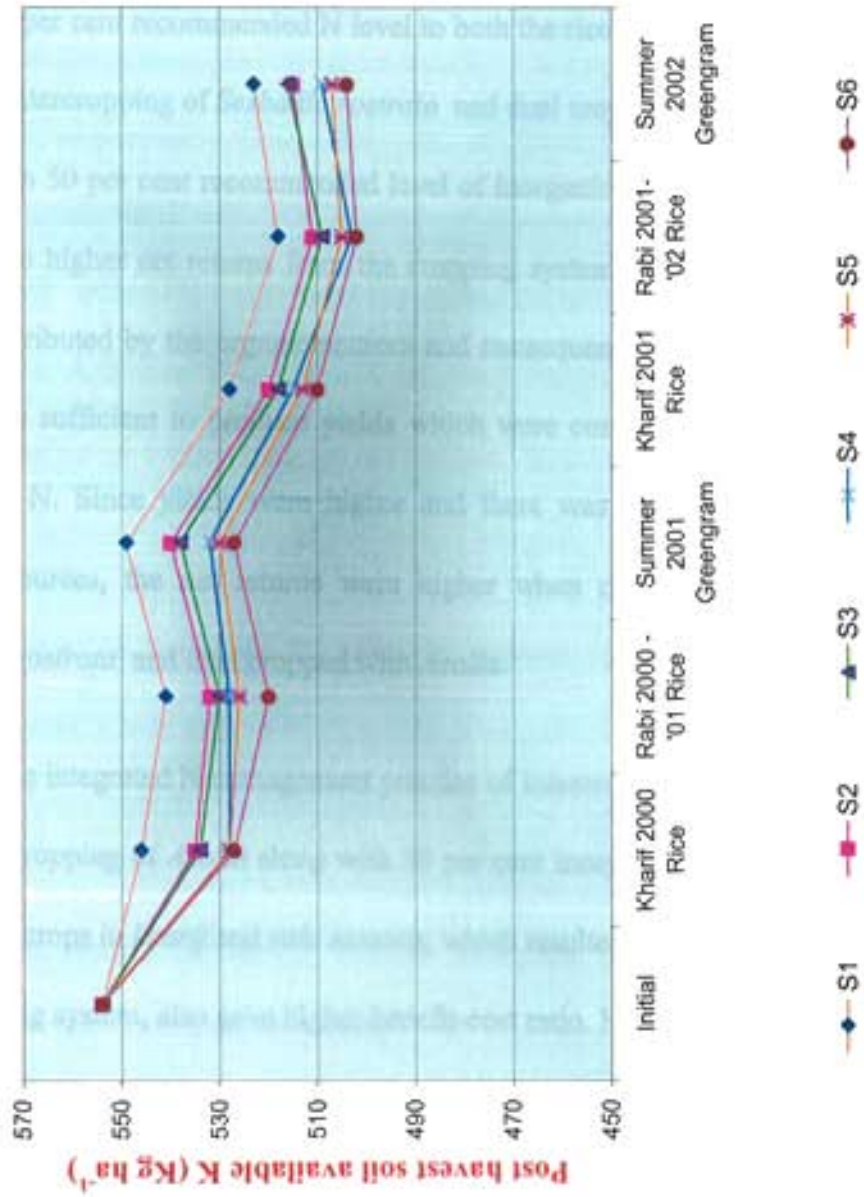


Fig. 24.-Dynamics of soil available K in the cropping system

Combination of intercropping of green manure and dual cropping of *Azolla* to each of the rice crops enhanced the net returns, because higher grain yield of rice was recorded by this treatment in both the years. Increased levels of inorganic N upto 100 per cent recommended N level to both the rice crops also enhanced the net returns. Intercropping of *Sesbania rostrata* and dual cropping of *Azolla* combination along with 50 per cent recommended level of inorganic N to each of the rice crops resulted in higher net returns from the cropping system. Substantial amounts of N were contributed by the organic sources and consequently 50 per cent inorganic N alone was sufficient to produce yields which were comparable with 100 per cent inorganic N. Since yields were higher and there was not much expenditure for organic sources, the net returns were higher when rice was intercropped with *Sesbania rostrata* and dual cropped with *Azolla*.

The integrated N management practice of intercropping of *Sesbania rostrata* and dual cropping of *Azolla* along with 50 per cent inorganic N application to each of the rice crops in *kharif* and *rabi* seasons, which resulted in higher net returns from the cropping system, also gave higher benefit-cost ratio. Higher grain productivity of the cropping system along with lesser cost of the integrated N management practice, resulted in greater profitability.

5.10.1. Partial budgeting for the use of organic sources in the cropping system

Partial budgeting analysis indicates the most profitable level of a component technology. This is employed to identify the best treatment based on the highest difference between the added costs + reduced returns and added returns + reduced

costs. In the present investigation, all the organic sources were evaluated against control. The results indicated that combination of *Azolla* dual cropping and *Sesbania rostrata* intercropping in *kharif* rice as well as *rabi* rice followed by residual greengram resulted in the highest profit of Rs. 15475 and Rs. 18081 during 2000-'01 and 2001-'02 respectively. Conjunctive use of *Sesbania rostrata* and *Azolla microphylla* combination with 100 percent recommended level of N resulted in estimated profit of Rs.14718 and Rs.15154 during 2000-'01 and 2001-'02 cropping system. Higher yield level obtained with relatively cheaper organic sources of N obviously resulted in higher level of net income. However, the estimated profit increased at a decreasing rate beyond 50 per cent inorganic N level.

This study on integrated nitrogen management for wet seeded rice-rice-greengram system shows differential response to organic sources with inorganic N levels in rice. Combination of intercropping of *Sesbania rostrata* and dual cropping of *Azolla microphylla* with 50 per cent inorganic N level to each of the crops during *kharif* and *rabi* seasons followed by residual greengram in summer was the best integrated nitrogen management package for wet seeded rice-rice-greengram cropping system. Greengram haulms, also could be effectively utilised after picking pods as green manure to *kharif* rice.

From the viewpoints of productivity of economic yields of crops, profitability of cropping system as a whole and sustainable soil fertility, the integrated N management package consisting of intercropping of *Sesbania rostrata* and dual cropping of *Azolla* along with 50 percent inorganic N to each of the wet seeded rice crops in *kharif* and *rabi* seasons followed by residual summer greengram

rice crops in wet seeded rice-rice-greengram system is the best option Western Region of Tamil Nadu.

The second option is combination of intercropping of *Sesbania rostrata* and dual cropping of *Azolla* along with 50 per cent inorganic N in *kharif* rice followed by either intercropping of *Sesbania rostrata* or dual cropping of *Azolla* along with 50 per cent inorganic N in *rabi* rice followed by residual summer greengram.

SUMMARY AND CONCLUSIONS

CHAPTER VI

SUMMARY AND CONCLUSION

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif*, *rabi* and summer seasons of 2000-'01 and 2000-'02 with a view to develop an integrated N management package for the wet seeded rice-rice-greengram cropping system. The field experiments were laid out in a split plot design with three replications keeping the layout undisturbed throughout the course of two years of experimentation and two annual cropping cycles of wet seeded rice-rice-greengram were tested. Main plot treatments consisted of sole rice, intercropping of *Sesbania rostrata* in rice, dual cropping of *Azolla microphylla* in rice and combination of these two organic sources were alternated in *kharif* and *rabi* seasons. Graded levels of inorganic N viz., 0,50,75 and 100 per cent recommended N were assigned to sub plots. The treatments were imposed only to rice crops and greengram was raised as residual crop. After completing the first cropping cycle (2000-'01), the entire biomass of the greengram was incorporated into all the treatment plots. In second cropping cycle (2001-'02), greengram haulms, after picking the pods, were incorporated into the soil. The rice varieties ADT 36 and ADT 39 were used during *kharif* and *rabi*, and greengram variety Pusa Bold was used in summer seasons respectively in both the years of study. Paddy and *Sesbania rostrata* seeds were line sown by using rice cum green manure seeder in alternate

rows of 12.5 cm apart. Intercropped green manure and dual cropped *Azolla* were incorporated into the soil by using cono weeder at 35 DAS. The summary of the findings of the experiments and the conclusions drawn are presented hereunder.

Sesbania rostrata population at 15 DAS did not vary in different treatments. However, the dry matter production and N accumulation were marginally higher in *rabi* season than in *kharif* season.

Azolla biomass production and N accumulation were also slightly higher in *rabi* season than in *kharif* season.

Dual cropped *Azolla* considerably suppressed the grass weeds and sedges. However, broad leaved weeds were suppressed only to a limited extent. Intercropped *Sesbania rostrata* markedly suppressed the grass weeds, sedges and broad leaved weeds. Combination of *Sesbania rostrata* and *Azolla* in rice also had broad spectrum weed control. Inorganic N levels did not influence the weed suppression considerably in both *kharif* and *rabi* seasons.

The flood water ammoniacal nitrogen was at its peak 15 days after incorporation of *Azolla* and green manure in *kharif* and *rabi* seasons of both the years. Intercropping of *Sesbania rostrata* or dual cropping *Azolla* recorded markedly higher ammoniacal N than that from sole rice. However, combination of these organic sources produced higher ammoniacal N than those from individual application of *Azolla* or green manure. Fertilization of 100 per cent N recorded higher ammoniacal N than other levels.

Organic N sources and inorganic N levels did not alter the rice plant population at 15 DAS.

Growth, yield components and ultimately yield of rice were higher in *rabi* as compared to *kharif* season.

Rice, which was intercropped with *Sesbania rostrata* and dual cropped with *Azolla*, had taller plants at maturity, higher tiller production, larger LAI at flowering stage. Fertilization with 100 per cent recommended N also considerably improved these characters.

Rice with *Sesbania rostrata* and *Azolla* recorded significantly higher DMP at active tillering, panicle initiation, flowering and at maturity. Application of 100 per cent inorganic N resulted in significantly higher DMP than other levels of N in all the four stages.

In the presence of *Sesbania rostrata* or *Azolla* in rice, marked response in terms of growth characters of rice to applied N was observed only upto 75 per cent inorganic N. However, 50 per cent recommended N was sufficient to produce the same response in growth characters of rice when both green manure and *Azolla* were included in rice.

Among the yield components of rice, panicles per unit area, panicle length and filled grains panicle⁻¹ were considerably influenced by organic sources as well as inorganic N levels. The test grain weight did not vary in different treatments.

Combination of intercropping and dual cropping in rice along with the application of 100 per cent inorganic N to rice resulted in substantial increase in panicle number, panicle length and filled grains panicle⁻¹. The sole rice in control recorded the lowest values of all these yield components.

When both green manure and *Azolla* were applied to rice in addition to 50 per cent inorganic N, the uptake of N,P and K was considerably higher in all the four seasons. Either green manure or *Azolla* in rice also resulted in higher comparatively uptake of N, P and K with 75 per cent inorganic N application.

Inclusion of *Sesbania rostrata* intercropping or *Azolla* dual cropping or both in rice had substantial improvement in grain yield as well as straw yield in all the four seasons of study. Among the inorganic N levels 100 per cent N recorded higher grain yield in sole rice. However, with either *Sesbania rostrata* intercropping or *Azolla* dual cropping with 75 per cent inorganic N recorded comparatively higher grain yields. But the combination of green manure intercropping and *Azolla* dual cropping in rice recorded the highest grain yield in both *kharif* and *rabi* seasons in both the years.

Among the nitrogen use efficiency parameters, the agronomic efficiency (AE) and apparent N recovery (ANR) were higher in *kharif* rice than in *rabi* rice. The AE was comparatively higher in sole rice than in other systems. The lowest AE was in rice intercropped with green manure and dual cropped with *Azolla* in *kharif*

and *rabi* seasons. The physiological efficiency (PE) was also higher in sole crop compared to other systems.

The ANR was higher in sole rice and rice with *Sesbania rostrata* or *Azolla* in *kharif* season. The ANR was low when rice was intercropped with green manure and dual cropped with *Azolla* in *rabi* season. There was increase in nitrogen harvest index (NHI) with corresponding increase in inorganic N application. Intercropping or dual cropping or combination of both in rice recorded higher NHI with higher levels of inorganic N.

Both organic sources and inorganic N levels to preceding rice crops in *kharif* and *rabi* seasons did not alter the growth characters, yield parameters, uptake and yield of residual greengram in summer season.

Any inclusion of organic sources, either intercropped green manure or dual cropped *Azolla* or both of them in rice, considerably increased the total dry matter production (TDMP) of the cropping system. The response of TDMP in sole rice was significantly higher upto 100 per cent N. In rice + *Sesbania rostrata* or rice + *Azolla*, the TDMP was substantially improved upto 75 per cent N level. In rice + *Sesbania rostrata* + *Azolla*, the TDMP markedly improved at 50 per cent recommended N application.

Fertilization of 100 per cent N to rice considerably improved the total grain production (TGP) of the wet seeded rice-rice-greengram cropping system. But rice,

either intercropped *Sesbania rostrata* or dual cropped with *Azolla*, registered marked increase in TGP with higher TGP of 75 per cent inorganic N. Rice + green manure + *Azolla* in both the seasons recorded only upto 50 per cent N application and beyond that the TGP was comparable with 75 and 100 per cent inorganic N levels in both the years of study.

Improvement in soil organic carbon content was observed after first cropping cycle, with marginal improvement where either *Sesbania rostrata* or *Azolla* was used individually, and with higher magnitude of improvement when both the sources were included. There was substantial improvement in organic carbon status after the harvest of summer greengram.

Marginal improvement in soil available N was observed where both green manure and *Azolla* were included in *kharif* rice and *Azolla* or *Sesbania rostrata* in *rabi* rice. Combination of these two organic sources to both the rice crops improved the soil available N considerably. In sole rice crop, the soil available N decreased progressively.

The sole rice in control after 2 years of cropping had the least soil available N with the highest net loss from the initial soil status. Rice intercropped with *Sesbania rostrata* and dual cropped with *Azolla* in both the *kharif* and *rabi* seasons recorded the highest soil available N indicating the largest net gain from the initial N status.

The soil available P improved after *kharif* and *rabi* rice. But it decreased after summer greengram in all the treatments during both the years of study.

There was a gradual reduction in soil available K in all the treatments after 2 years of cropping except very marginal improvement after summer residual greengram.

The highest net returns from wet seeded rice-rice-greengram system were obtained when rice was intercropped with *Sesbania rostrata* and dual cropped with *Azolla* along with 100 per cent inorganic N application in *kharif* and *rabi* seasons. However, this was comparable with 75 per cent and 50 per cent inorganic N application. The sole crop of rice in control recorded the lowest net returns. Similar trend was also observed in B:C ratio also.

Partial budgeting analysis of using different organic sources and inorganic N level in cropping system showed that inclusion of organic sources either individually or in combination improved the profitability. Combination of organic sources with progressive increase in inorganic levels also improved the profitability. However, estimated profit increased at a decreasing rate beyond 50 per cent inorganic N level.

The present investigation clearly shows that combination of *Sesbania rostrata* intercropping and *Azolla microphylla* dual cropping in rice along with 50 per cent inorganic N application in both *kharif* and *rabi* seasons followed by summer residual greengram is the best integrated N management package for wet seeded

rice-rice-greengram cropping system at Coimbatore for higher productivity, greater profitability and sustainable soil fertility. The second best management strategy is combination of *Sesbania rostrata* intercropping and *Azolla microphylla* dual cropping in *kharif* rice followed by either *Sesbania rostrata* intercropping or *Azolla microphylla* dual cropping in *rabi* rice along with 75 per cent of inorganic N application to each of the rice crops followed by summer residual greengram.

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PLATES



Plate 3. Rice + *Azolla* at 35 DAS



Plate 4. Rice + *Sesbania rostrata* at 35 DAS



Plate 5. Rice + *Sesbania rostrata* + *Azolla* at 35 DAS



Plate 6. Combined incorporation of *Sesbania rostrata* and *Azolla* at 35 DAS



Plate 7. General view of the experimental field



Plate 8. Rice + *Sesbania rostrata* + *Azolla* with 50 % N



Plate 9. General view of the experimental field (Residual greengram)

APPENDICES

APPENDIX - I

Weekly weather parameters during the cropping periods (*Kharif* 2000; *Rabi* 2000-'01; Summer 2001; *Kharif* 2001; *Rabi* 2001-'02; Summer 2002)

No.	Standard week		Rain fall (mm)	No. of rainy days	Mean temperature (°C)		Relative humidity (per cent)		Solar radiation (Cal cm ⁻² min ⁻¹)	Mean sunshine hours d ⁻¹
	Period	(2)			Max.	Min.	07.22 hrs	14.22 hrs		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
<i>Kharif</i> 2000										
25	Jun.	18-24	2.0	-	32.2	23.1	79	51	362.8	5.6
26		25-1	2.3	-	31.5	22.4	76	50	337.9	4.5
27	Jul.	2-8	2.5	1	30.5	22.2	78	51	307.9	2.1
28		9-15	12.0	1	30.8	24.2	64	51	380.0	6.1
29		16-22	-	-	32.2	22.5	77	47	417.7	7.5
30		23-29	-	-	32.8	21.9	88	50	394.1	7.7
31		30-Aug. 5	41.4	2	32.8	22.6	92	53	380.4	7.8
32	Aug.	6-12	6.2	1	30.2	22.8	75	55	399.5	4.5
33		13-19	89.0	1	31.6	22.1	88	56	374.4	5.9
34		20-26	22.9	3	28.4	22.8	75	70	255.4	0.8

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
35	27-Sep. 2	4.1	1	29.8	21.8	86	54	402.5	6.3
36	Sep. 3-9	-	-	32.2	22.1	86	54	431.3	8.7
37	10-19	3.6	1	32.3	22.1	85	59	382.1	6.4
38	17-23	89.6	3	31.9	22.5	88	60	328.9	5.2
39	24-30	117.2	5	29.6	22.3	89	70	288.2	4.5
40	Oct. 1-7	10.3	2	29.3	21.4	92	65	303.0	3.5
Rabi 2000-'01									
41	Oct. 8-14	11.3	3	30.9	21.6	91	60	339.0	5.7
42	15-21	10.0	1	31.1	21.7	90	63	338.9	4.7
43	22-28	5.2	1	31.7	19.4	93	46	378.4	7.3
44	29-Nov. 4	-	-	30.8	21.2	91	54	360.3	7.0
45	Nov. 5-11	-	-	31.0	21.5	89	48	420.2	7.9
46	12-18	1.2	-	30.0	21.4	89	49	368.4	5.7
47	19-25	52.1	3	28.2	21.8	87	66	243.5	3.2
48	26-Dec. 2	30.2	2	29.0	18.0	93	50	357.1	6.5
49	Dec. 3-9	-	-	28.9	19.1	92	50	410.1	7.8
50	10-16	-	-	28.5	15.2	88	35	515.5	10.5
51	17-23	-	-	28.7	17.3	88	41	450.0	8.8

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
52	24-31	14.4	2	28.6	19.4	88	53	334.1	5.3
1	1-7	-	-	30.0	20.9	91	48	371.7	6.3
2	8-14	-	-	30.0	19.4	88	43	419.9	7.4
3	15-21	-	-	30.2	17.8	90	40	446.8	7.9
4	22-28	-	-	31.2	20.8	81	44	386.8	5.0
5	29-Feb.4	-	-	30.2	21.0	86	50	321.5	3.0
6	Feb. 5-11	-	-	33.3	17.8	84	32	466.2	9.1
Summer 2001									
6	Feb. 5-11	-	-	33.3	17.8	84	32	466.2	9.1
7	12-18	-	-	33.4	22.7	88	33	441.6	9.1
8	19-25	-	-	34.9	21.1	87	37	424.1	9.0
9	26-Mar.4	-	-	34.3	20.6	87	33	451.3	9.6
10	Mar. 5-11	-	-	34.7	21.8	74	34	375.7	7.7
11	12-18	-	-	35.4	21.7	78	33	404.8	9.1
12	19-25	-	-	36.1	22.9	84	38	407.0	8.4
13	26-April. 1	-	-	36.2	23.4	83	38	422.9	8.7

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
14	Apr. 2-8	-	-	36.1	24.5	79	36	376.5	7.2
Kharif 2001									
24	Jun. 11-17	34.1	4	29.0	22.5	80	63	278.7	2.7
25	18-24	0.5	-	31.2	23.3	72	48	428.4	7.2
26	25-Jul. 1	-	-	32.6	23.2	73	45	396.4	5.1
27	Jul. 2-8	4.4	1	31.1	23.9	69	52	370.2	4.8
28	9-15	5.5	1	30.4	22.7	81	56	357.2	4.3
29	16-22	0.5	-	31.6	22.1	81	51	394.1	6.9
30	23-29	9.5	1	31.5	21.3	87	55	374.6	6.7
31	30-Jul.5	11.5	2	28.7	22.0	85	67	305.5	2.2
32	Jul. 6-12	-	-	31.9	22.1	85	50	387.4	7.3
33	13-19	0.7	-	32.2	23.0	81	49	375.7	6.1
34	20-26	4.0	1	32.1	22.2	85	51	373.6	6.0
35	27-Sep. 2	10.6	2	32.2	21.3	90	49	374.3	7.1
36	Sep. 3-9	-	-	33.5	21.2	86	44	426.4	10.1

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
37	10-16	48.6	1	33.6	22.9	90	49	360.0	7.1
38	17-23	6.5	1	32.9	23.2	87	50	364.3	5.4
39	24-30	41.5	2	30.9	22.2	92	59	334.1	4.1
Rabi 2001-'02									
41	Dec. 8-14	-	-	31.4	22.7	88	61	334.4	4.8
42	15-21	152.3	3	31.7	21.7	93	60	354.8	6.3
43	22-28	130.4	3	30.3	19.3	92	63	334.4	5.4
44	29-Nov. 4	17.6	1	30.3	21.7	91	60	359.2	6.3
45	Nov. 5-11	30.9	3	30.4	22.2	93	66	352.4	5.3
46	12-18	48.5	2	29.6	22.1	91	71	308.4	4.7
47	19-25	34.1	3	28.3	20.9	92	65	383.3	7.5
48	26-Dec. 2	8.3	1	28.7	20.9	91	56	364.6	6.9
49	Dec. 3-9	0.5	-	28.9	18.0	92	53	463.0	8.2
50	10-16	-	-	28.6	15.1	90	37	502.7	9.7
51	17-23	14.3	2	27.4	19.9	90	70	231.4	2.0
52	24-31	0.5	-	28.0	20.6	90	57	370.1	6.0

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	Jan. 1-7	-	-	29.3	19.9	86	50	409.7	7.6
2	8-14	-	-	29.7	19.1	88	45	432.6	8.3
3	15-21	-	-	30.1	17.0	90	49	454.1	9.1
4	22-28	-	-	31.7	21.0	89	54	358.7	4.4
Summer 2002									
4	Jan. 22-28	-	-	31.7	21.0	89	54	358.7	4.4
5	29-Feb.4	-	-	29.7	20.0	87	56	261.9	3.8
6	Feb. 5-11	-	-	29.8	21.0	86	53	333.9	4.6
7	12-18	-	-	32.2	20.2	87	35	434.6	9.0
8	19-25	-	-	33.2	17.6	84	21	504.7	10.2
9	26-Mar. 4	-	-	34.6	19.0	82	27	478.4	10.3
10	Mar. 5-11	-	-	35.1	19.4	78	23	460.9	10.6
11	12-18	28.0	1	35.3	21.7	84	34	424.6	9.5
12	19-25	4.0	1	34.6	22.1	88	34	435.6	8.7

APPENDIX - II

Details of cost of rice and residual greengram production

S.No.	Particulars	Inputs	Rate (Rs.)	Total cost (Rs. ha ⁻¹)
(1)	(2)	(3)	(4)	(5)
I. Cost of rice and residual greengram production ha ⁻¹ excluding treatment cost				
1. Preparatory cultivation				
	a. Dry ploughing with tractor drawn disc harrow	1 tractor for 2 hrs	150.00 hr ⁻¹	300.00
	b. Puddling with country plough	Farm pair (2)	100.00 d ⁻¹	200.00
	c. Puddling with tractor drawn cage wheel	1 tractor for 1 hr	150.00 hr ⁻¹	150.00
	d. Levelling with bullock drawn wooden levelling plank	Farm pair (1)	100.00 d ⁻¹	100.00
	e. Trimming, plastering and levelling	20 men days	72.00 d ⁻¹	1440.00
2. Seeds and sowing				
	a. Cost of seeds (Paddy)			
	i) ADT 36 (<i>Kharif</i>)	75 kg	16.00 kg ⁻¹	1200.00
	ii) ADT 39 (<i>Rabi</i>)	75 kg	20.00 kg ⁻¹	1500.00
	b. Seed treatment (Bavistin)	150 g	610.00 kg ⁻¹	91.50
	c. Cost of seeds (Greengram)			
	i) Pusa Bold (Summer)	25 kg	40.00 kg ⁻¹	1000.00
	ii) Seed treatment (Rhizobium)	600 g (3 pockets)	5.00 pocket ⁻¹	15.00
3. Fertilizers and application charges				
	a. Cost of fertilizers			
	i) SSP			
	<i>Kharif</i>	237.5 kg	3.05 kg ⁻¹	724.37
	<i>Rabi</i>	312.5 kg	3.05 kg ⁻¹	953.12
	ii) Mop			
	<i>Kharif</i>	63.08 kg	4.35 kg ⁻¹	274.40
	<i>Rabi</i>	83.0 kg	4.35 kg ⁻¹	361.05
	iii) ZnSO ₄	25.0 kg	21.00 kg ⁻¹	525.00
	b. Application charges	2 men days	72.00/kg ⁻¹	144.00
4. Weeding				
	a. Pretilachlor plus	1000 ml	425.00 l ⁻¹	425.00
	b. Application charges	½ men day	72.00 d ⁻¹	36.00
	c. Hand weeding on 35 DAS	8 women days	72.00 d ⁻¹	576.00

Contd...

(1)	(2)	(3)	(4)	(5)
5.	Plant Protection			
	a. Cost of chemicals	500 ml	392.50 l ⁻¹	196.25
	Dimecron	1000 ml	364.00 l ⁻¹	364.00
	Nuvacron	200 ml	628.00 l ⁻¹	125.60
	Hinoson	2 men days	72.00 d ⁻¹	144.00
	b. Application charges	2 women days	72.00 d ⁻¹	144.00
6.	Irrigation			
	Guiding water			
	<i>Kharif</i>	12 men days	72.00 d ⁻¹	864.00
	<i>Rabi</i>	10 men days	72.00 l ⁻¹	720.00
7.	Harvesting			
	a. Rice	15 men days	72.00 d ⁻¹	1080.00
	i) Harvesting, threshing and cleaning	30 women days	72.00 d ⁻¹	2160.00
	b. Greengram	15 women days		
	i) Sowing		72.00 d ⁻¹	1080.00
	ii) Guiding water			
	Summer 2001	1 men day	72.00 d ⁻¹	72.00
	Summer 2002	3 men days	72.00 d ⁻¹	216.00
	iii) Harvesting threshing and cleaning Summer 2002	25 women days	72.00 d ⁻¹	1800.00
8.	Land rent	1 season	500.00	500.00
	Total cost			
	I. Cropping cycle (2000-'01)		26686.00	
	II. Cropping cycle (2001-'02)		28630.00	
II. Cost of treatments ha⁻¹				
1.	Sole rice			
	a. Rent for drum seeder	1 day	75.00 d ⁻¹	75.00
	b. Sowing	5 men days	72.00 d ⁻¹	360.00
2.	Rice + <i>Azolla</i>			
	a. Rent for drum seeder	1 day	75.00 d ⁻¹	75.00
	b. <i>Azolla</i>	1.0 t	0.50 kg ⁻¹	500.00
	c. Application charges	2 men days	72.00 d ⁻¹	144.00
	d. Incorporation of <i>Azolla</i> by using conoweeder	8 men days	72.00 d ⁻¹	576.00
	e. Rent for cono weeder	1 day	25.00 d ⁻¹	25.00

Contd...

(1)	(2)	(3)	(4)	(5)
3.	Rice + <i>Sesbania rostrata</i>			
	a. Rent for drum seeder	1 day	75.00 d ⁻¹	75.00
	b. <i>Sesbania rostrata</i> seed (Co.1)	25 kg	25.00 kg ⁻¹	625.00
	c. Seed treatment (Comercial H ₂ SO ₄)	2.5 lit	36.00 lit ⁻¹	90.00
	d. Treatment charges	½ men day	72.00 d ⁻¹	36.00
	e. Trampling <i>Sesbania rostrata</i> by using cono weeder	8 men days	72.00 d ⁻¹	576.00
	f. Rent for cono weeder	1 day	25.00 d ⁻¹	25.00
4.	Rice + <i>Sesbania rostrata</i> + <i>Azolla</i>			
	a. Rent for drum seeder	1 day	75.00 d ⁻¹	75.00
	b. <i>Sesbania rostrata</i> seed (Co.1)	2.5 kg	25.00 kg ⁻¹	625.00
	c. Seed treatment (commercial H ₂ SO ₄)	2.5 l	36.00 l ⁻¹	90.00
	d. Treatment charges	½ men day	72.00 d ⁻¹	36.00
	e. <i>Azolla</i>	1.0 t	0.50 kg ⁻¹	500.00
	f. Application charges	2 men days	72.00 d ⁻¹	144.00
	g. Trampling <i>Sesbania rostrata</i> along with <i>Azolla</i> by using conoweeder	8 men days	72.00 d ⁻¹	576.00
	h. Rent for conoweeder	1 day	25.00 d ⁻¹	25.00
5.	N ₀ - control			
	<i>Kharif</i>	-	-	-
	<i>Rabi</i>	-	-	-
6.	N ₁ - 50% Rec. N			
	<i>Kharif</i>	130.20	4.60 kg ⁻¹	598.92
	<i>Rabi</i>	162.75	4.60 kg ⁻¹	748.65
7.	N ₂ - 75% Rec. N			
	<i>Kharif</i>	195.30 kg	4.60 kg ⁻¹	898.38
	<i>Rabi</i>	244.12 kg	4.60 kg ⁻¹	1122.95
8.	N ₃ - 100% Rec. N			
	<i>Kharif</i>	260.40 kg	4.60 kg ⁻¹	1197.84
	<i>Rabi</i>	325.50 kg	4.60 kg ⁻¹	1497.30
III. Cost of outputs				
	a. Rice grain			
	i) ADT 36		4.75 kg ⁻¹	
	ii) ADT 39		5.75 kg ⁻¹	
	b. Rice straw		0.60 kg ⁻¹	
	c. Pusa Bold grain		20.00 kg ⁻¹	

Note : 1 men / women day = 8 hours

APPENDIX - III

Effect of organic N sources and inorganic N levels on economics of the cropping system as a whole - 2000-'01

Treatments	Cost of cultivation excluding treatment (Rs. ha ⁻¹)	Cost of treatment (Rs. ha ⁻¹)	Total cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C ratio
S ₁ N ₀	26686	870	27556	37177	9621	1.35
S ₁ N ₁	26686	2218	28904	53338	24434	1.85
S ₁ N ₂	26686	2891	29577	64209	34632	2.17
S ₁ N ₃	26686	3565	30251	69715	39464	2.30
S ₂ N ₀	26686	2747	29433	48802	19369	1.66
S ₂ N ₁	26686	4095	30781	61837	31056	2.01
S ₂ N ₂	26686	4768	31454	71307	39853	2.27
S ₂ N ₃	26686	5442	32128	76401	44273	2.38
S ₃ N ₀	26686	2747	29433	52472	23039	1.78
S ₃ N ₁	26686	4095	30781	64959	34178	2.11
S ₃ N ₂	26686	4768	31454	73563	42109	2.34
S ₃ N ₃	26686	5442	32128	78234	46096	2.44
S ₄ N ₀	26686	3391	30077	58868	28791	1.96
S ₄ N ₁	26686	4739	31425	70882	39457	2.26
S ₄ N ₂	26686	5412	32098	75674	43576	2.36
S ₄ N ₃	26686	6086	32772	79386	46614	2.42
S ₅ N ₀	26686	3498	30184	60179	29995	1.99
S ₅ N ₁	26686	4846	31532	71988	40456	2.28
S ₅ N ₂	26686	5519	32205	76704	44499	2.38
S ₅ N ₃	26686	6193	32879	80225	47346	2.44
S ₆ N ₀	26686	4142	30828	63965	33137	2.07
S ₆ N ₁	26686	5490	32176	75734	43558	2.35
S ₆ N ₂	26686	6163	32849	78349	45500	2.39
S ₆ N ₃	26686	6837	33523	81378	47855	2.43

APPENDIX - IV

Effect of organic N sources and inorganic N levels on economics of the cropping system as a whole - 2001-'02

Treatments	Cost of cultivation excluding treatment (Rs. ha ⁻¹)	Cost of treatment (Rs. ha ⁻¹)	Total cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C ratio
S ₁ N ₀	28630	870	29500	48751	19251	1.65
S ₁ N ₁	28630	2218	30848	65714	34866	2.13
S ₁ N ₂	28630	2891	31521	77126	45605	2.45
S ₁ N ₃	28630	3565	32195	82954	50759	2.58
S ₂ N ₀	28630	2747	31377	60812	29435	1.94
S ₂ N ₁	28630	4095	32725	74628	41903	2.28
S ₂ N ₂	28630	4768	33398	84554	51156	2.53
S ₂ N ₃	28630	5442	34072	89935	55863	2.64
S ₃ N ₀	28630	2747	31377	64441	33064	2.05
S ₃ N ₁	28630	4095	32725	77737	45012	2.38
S ₃ N ₂	28630	4768	33398	86845	53447	2.60
S ₃ N ₃	28630	5442	34072	91807	57735	2.69
S ₄ N ₀	28630	3391	32021	71056	39035	2.22
S ₄ N ₁	28630	4739	33369	83750	50381	2.51
S ₄ N ₂	28630	5412	34042	89103	55061	2.62
S ₄ N ₃	28630	6086	34716	93016	58300	2.68
S ₅ N ₀	28630	3498	32128	72384	40256	2.25
S ₅ N ₁	28630	4846	33476	85008	51532	2.54
S ₅ N ₂	28630	5519	34149	90264	56115	2.64
S ₅ N ₃	28630	6193	34823	94058	59235	2.70
S ₆ N ₀	28630	4142	32772	78623	45851	2.40
S ₆ N ₁	28630	5490	34120	91157	57037	2.67
S ₆ N ₂	28630	6163	34793	93705	58912	2.69
S ₆ N ₃	28630	6837	35467	96472	61005	2.72

APPENDIX – V

Crop residues (kg ha⁻¹) returned to the soil

Treatments	Post harvest of					
	Rice <i>Kharif</i> 2000	Rice <i>Rabi</i> 2000-'01	Greengram Summer 2001	Rice <i>Kharif</i> 2001	Rice <i>Rabi</i> 2001-'02	Greengram Summer 2002
S ₁ N ₀	872	994	2828	884	1028	2352
S ₁ N ₁	1530	1665	2880	1546	1702	2439
S ₁ N ₂	1968	2113	2915	1988	2152	2497
S ₁ N ₃	2188	2337	2932	2210	2376	2526
S ₂ N ₀	1208	1336	2863	1220	1372	2417
S ₂ N ₁	1855	2003	2912	1876	2043	2501
S ₂ N ₂	2286	2446	2946	2315	2489	2557
S ₂ N ₃	2503	2664	2961	2532	2708	2584
S ₃ N ₀	1262	1384	2873	1272	1416	2429
S ₃ N ₁	1905	2047	2920	1924	2081	2511
S ₃ N ₂	2334	2487	2953	2360	2524	2565
S ₃ N ₃	2544	2698	2967	2572	2739	2591
S ₄ N ₀	1556	1496	2891	1654	1532	2459
S ₄ N ₁	2195	2156	2935	2302	2193	2538
S ₄ N ₂	2476	2589	2969	2586	2632	2590
S ₄ N ₃	2624	2796	2982	2714	2844	2615
S ₅ N ₀	1561	1538	2903	1688	1578	2470
S ₅ N ₁	2202	2194	2943	2334	2235	2547
S ₅ N ₂	2483	2621	2976	2614	2670	2598
S ₅ N ₃	2629	2824	2988	2738	2879	2622
S ₆ N ₀	1565	1820	2914	1846	1862	2482
S ₆ N ₁	2205	2469	2953	2487	2516	2558
S ₆ N ₂	2486	2746	2984	2725	2796	2607
S ₆ N ₃	2632	2880	2995	2843	2941	2630