

FEASIBILITY STUDIES ON
in situ **GREEN MANURING IN WET SEEDED RICE**

*Thesis submitted in part fulfilment of the requirements for the degree of
Doctor of Philosophy (Agriculture) in Agronomy to the
Tamil Nadu Agricultural University, Coimbatore-3.*

By

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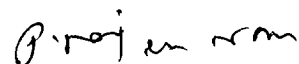
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CERTIFICATE

This is to certify that the thesis entitled "**FEASIBILITY STUDIES ON *in situ* GREEN MANURING IN WET SEEDED RICE**" submitted in part fulfilment of the requirement 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 **Ms. R. V. SELVI**, under my supervision and guidance and that no part of this thesis has 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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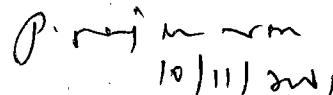
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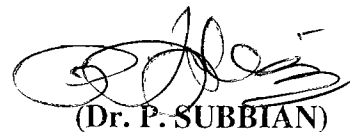


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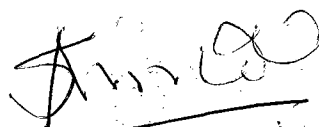


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(R. V. SELVI)

Abstract

ABSTRACT

“FEASIBILITY STUDIES ON *in situ* GREEN MANURING IN WET SEEDED RICE”

BY

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Degree : **Doctor of Philosophy (Agriculture)
in Agronomy**

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Feasibility of intercropping dhaincha (*Sesbania aculeata*) in wet seeded rice was studied using the TNAU rice cum green manure seeder. The intercropped green manure was trampled using the IRRI Conoweeder at different heights from 40 to 70 cm at 10 cm increment, for each height applying three levels of fertiliser N *viz.*, 50, 75 and 100 per cent of recommended dose. Sole rice with 100 per cent N, skipping or including basal green manure and similar two treatments in transplanted rice were included in the study for comparison. The field experiment was conducted for three seasons *viz.*, *rabi*, 1999 at TNAU, Coimbatore and *kharif* and *rabi*, 2000 at Agricultural Research Station, Bhavanisagar altogether with sixteen treatments in randomised block design.

The population of dhaincha intercrop got thinned out while it grew obviously indicating intraspecies competition and suppression of weeds in

between rice rows. The nodulation, biomass production and N contribution from dhaincha were all satisfactory tolerating the water stagnation in which the associated rice was grown. Dhaincha N contribution was unaffected regardless of fertiliser N dose to rice indicating its insensitivity to external source of nitrogen. Minimum biomass production of dhaincha is 7.3 t ha^{-1} and it was as high as 28.4 t ha^{-1} showing the feasibility of intercropping it in wet seeded rice.

The population of rice in intercropped stands was high as compared to transplanted rice despite the latter receiving 100 per cent fertiliser N. This shows that wider inter row spacing of rice (25 cm) to accommodate dhaincha is not a limitation. The DMP, yield attributes and the rice yield were also not affected by such wide interrow spacing.

Trampling dhaincha (intercrop) at tender state (40 cm height) was found optimum from the point of releasing most of the 'fast' N showing higher soil available N and P at the crucial stage of rice flowering. Coupled with 100 per cent N *i.e.*, the treatment, Rice + dhaincha inc. 40 cm + 100 per cent N to rice, high soil available N and P at flowering, better uptake of nutrients and more rice DMP, number of panicles m^{-2} and filled grains panicle⁻¹ were ensured resulting in higher grain and straw yields. It was comparable with basal incorporation of green manure at 6.25 t ha^{-1} in terms of rice growth and yield as indicated by the above parameters. Thus, intercropping green manure was found as a better alternative to basal incorporation provided it is grown upto 40 cm height and buried at tender stage.

Absence of green manuring affected all the above growth and yield related parameters resulting in lower grain and straw yields. Thus, green manuring is inevitable for soil sustainability leading to crop sustainability.

By comparison of the farmers' practice of transplanting rice + 100 per cent N with Rice + dhaincha inc. 40 cm, it was found that 50 per cent fertiliser N could be substituted for securing similar yields. But if higher yields are the target, trampling of such tender green manure has to be combined with 100 per cent N to

rice. This practice was also found more profitable in terms of net returns and B-C ratio.

Transplanted rice with 100 per cent N showed poor values of soil fertility, rice growth (DMP), uptake of nutrients and yield attributes with the resultant low grain and straw yields as compared to rice + dhaincha intercropping and incorporating it at 40 or 50 cm height with similar full dose of nitrogen (100 per cent).

Thus, Rice + dhaincha inc. 40 cm + 100 per cent N to rice with recommended P and K is clearly seen to be a profitable preference to transplanting and a feasible alternative to basal incorporation of green manure. Such intercropping and trampling green manure could be done by the TNAU seeder and IRRRI Conoweeder. This needs large scale demonstration in farmers' holdings in comparison with basal application of green manure and transplanting rice.

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Introduction

CHAPTER I

INTRODUCTION

Our country witnessed 'ship to mouth economy' till mid sixties due to alarming food shortage faced mainly by the subsistence agriculture. Thereafter with the introduction of varieties with dwarfing genes in major cereals *viz.*, wheat and rice, radical changes took place in the food scenario. They were input responsive and coupled with more use of fertilisers and other chemicals, we witnessed a 'quantum jump' in our food production *i.e.*, from a level of food scarcity to the level of food sufficiency (Klaus Lampe, 1988).

The agriculture of the modern chemical era concentrates on maximum output but overlooks input efficiency as a result of which it has not been sustainable (Ladha, 1995). Stagnation in maximum yield potential during the recent years in crops like rice and wheat is a real concern for agricultural scientists and professional technocrats. Reversing the declining trend of rice yield is one of the key objectives now for the International Rice Research Institute (IRRI), Philippines. Undoubtedly the decreasing rate of increase in cereal production is mainly attributed to too much dependence on inorganic fertilisers mainly high analysis fertilisers. As a result the soil is mined out with more depletion of nutrients. Deficiency of micro nutrients *viz.*, zinc, iron, copper and manganese in Tamil Nadu soils is 52, 28, 7 and 6 per cent respectively (Ramalingam *et al.*, 2000). Both physical and chemical properties of soils are affected with increasing trends of salinity, alkalinity, water logging *etc.* Truly the trend has to be reversed. Under high input production systems where productivity cannot be further increased with incremental use of mineral fertilisers alone, addition of organic sources could increase yields through increased soil productivity and higher fertiliser use efficiency (Santhi and Selvakumari, 2000). The thought provoking statement of Summer and Farina (1986), "Crops do not respond to fertiliser application *per se*, but rather to the soil's response to that application" would clearly spell out that crop sustainability is in turn linked to soil sustainability.

Soil fertility maintenance necessary for sustainable rice production is enhanced by a judicious combination of green manures and inorganic fertilisers (Garrity, 1988). Green manuring is an age old practice and even research on it has been for long. Maiden experiment on green manuring was first commenced as early as 1882 at Kanpur in India (Krishnamurthy, 1978). It continues to be researched, while the practice of green manuring is, in fact, getting phased out as it is not appealing to the farmers who do not want to give a slot in their cropping programme to raise a green manure ever since fertilisers came handy to them. Green manures are neither cash crops nor food crops and this is yet another factor for green manures not becoming popular in the present day agriculture. Cost involved in its collection, transport and trampling also stand in the way of green manuring rice. In many countries, the absence of appropriate machinery combined with shortage or high cost of labour are the major green manure production constraints (Becker *et al.*, 1995). But considering soil health and the need for sustainable rice production, green manuring has to be extensively practised. It is essential that green manures be fitted into local cropping patterns without competing with other economic enterprises. The technology will be viable if unit cost of green manure production including capital and labour are low (Garrity, 1988; Palaniappan and Siddeswaran, 1999).

Keeping aside the emphasis given above for the revival of green manuring rice, it is high time for the resource management researchers to reorient their approach towards production costs. The focus should be to ensure cost reduction in crop production, keeping up the returns at the same time particularly in cereals like rice where the profit is low.

The two key labour intensive operations in rice cultivation are transplanting and harvesting. Wet seeding (direct seeding of sprouted seeds onto the puddled bed) holds special significance in the present day production systems with regard to saving time, labour, energy required for nursery and planting leading to considerable reduction in cost of rice cultivation with increased profits. IRRI designed drum seeder could be used for direct seeding. After systematic and concerted efforts, the Tamil Nadu Agricultural University (TNAU) has developed

a rice *cum* green manure seeder (Rajendran *et al.*, 1999), the use of which not only ensures cost reduction but also provides a major breakthrough in rice cultivation by way of promoting sustainability. What should be the optimal duration of intercropped green manure, how about the changes in soil fertility upon its incorporation in between standing rice rows, and to what extent fertiliser N could be saved are all relevant research focus to popularise this seeder.

As the rice *cum* green manure seeder is designed to suit the farmers needs, investigations were carried out in detail in the present study with the following objectives ultimately to fulfill the core objective of sustainable, cost reduced rice cultivation.

1. To fix up optimal duration of intercrop green manure, *Sesbania aculeata*
2. To find out the extent of reduction in the usage of fertiliser N by supplementation of *in situ* green manuring
3. To find out changes in the soil fertility status in terms of organic carbon status, N, P and K content and
4. To find out relative yield and economic advantages of wet seeding over transplanting rice.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Green manuring is an age old practice dating back to the beginning of the Christian era and is researched in India for long. Research on green manuring is ample and continued to be studied on potential green manures, their method of establishment, utility and release pattern of nitrogen, its role in INM for rice, as an intercrop in rice, incorporation methods and similar other aspects. Literature on green manuring and rice wet seeding which are the key subjects of the present study are reviewed and presented below.

2.1. Green manuring rice

2.1.1. Advantages of green manuring

Green manuring refers to addition of green plant tissue to soil. Objectives of green manuring are to increase organic matter content of soils, maintain and improve soil structure, reduce loss of nutrients particularly N, provide a source of N for the succeeding crop and reduce soil erosion and thereby increase the production of crops (Greenland *et al.*, 1979). Green manuring is an inexpensive, eco-friendly alternative to mounting prices of fertiliser nitrogen and has become an effective technology in economizing the agricultural production system ensuring productive capacity of soil without causing environmental problem (Bana and Pant, 2000).

2.1.1.1. Nitrogen contribution

Green manures, particularly the legumes have relatively more N, low C-N ratio and behave almost like chemical nitrogenous fertilisers (Bhuiyan and Zaman, 1996). Green manuring rice is a well established practice and saving of fertiliser N through green manuring ranged from 30 to 100 kg N ha⁻¹ and in most cases it was around 50 to 60 kg N ha⁻¹ (Ladha *et al.*, 1988); 45 to 60 kg N ha⁻¹ (Sharma, *et al.*, 1985); 90 kg N ha⁻¹ (Ghai *et al.*, 1988); 120 kg N ha⁻¹ (Beri *et al.*, 1989a); 30 to 60 kg N ha⁻¹ (George and Prasad, 1989); 34 to 53 per cent (Nagarajah *et al.*, 1989); 50 per cent (Bal *et al.*, 1993); 100 per cent (Matiwade and Sheelavantar,

1994) and 45 kg N ha⁻¹ (Nazemi *et al.*, 1995). At 45 days *S. aculeata* and *S. rostrata* accumulated 185 and 219 kg N ha⁻¹ respectively (Palaniappan *et al.*, 1990).

There was an increase of 27.6 to 46.5 per cent available soil N after raising and *in situ* incorporation of sunnhemp than fallowed plots in two years of study (Salu reddy *et al.*, 1995). After two cycles of rice-wheat cropping, soil N decreased except in green manured plots fertilized with 120 kg N ha⁻¹ (Tiwari *et al.*, 1995).

2.1.1.2. Reduction in N losses

Green manuring plus fertiliser N application and so also, fertiliser N in splits showed minimum leaching loss of N and more of its uptake by rice (Bhagat *et al.*, 1988). The magnitude of leaching, denitrification and NH₃ volatilization losses may be lower for green manure – N than for fertiliser – N, especially in the presence of a rice crop, because of relatively slower rate of N release from plant materials (Nagarajah, 1988). In a laboratory study, it was observed that soil amended with green manure alone was not having any NH₃ volatilization (Khind *et al.*, 1989a; Rekhi and Bajwa, 1994).

The average N loss in flooded soils from applied green manures was considerably lower (14 per cent) than that of split applied urea (35 per cent) thus resulting in less pollution to the environment (Becker *et al.*, 1994). With similar N use efficiencies, green manure – N is less prone to loss mechanisms than mineral N fertiliser and may therefore contribute to long term residual effects of soil productivity (Becker *et al.*, 1995). Application of green manure with urea may reduce NH₃ losses from urea lowering pH in the flood water (De Datta, 1995). Combined application of green manures and prilled urea is the most efficient fertilization method with relatively low N losses due to volatilization and leaching compared to prilled urea alone (Das *et al.*, 1995). Green manuring significantly reduced both leaching and gaseous loss of fertiliser as confirmed from ¹⁵N studies and remained most efficient under drought prevailing at the rice vegetative stage (Bhattacharyya and Mandal, 1997). After considering various losses, the

economy of fertiliser – N through green manure ranged from 38 to 136 kg ha⁻¹ (Sankaran *et al.*, 2000)

2.1.1.3. Contribution of other nutrients

The effectiveness of green manuring was attributed to the presence of other nutrients also. Besides, the decomposing green manure produced rapid reduction of waterlogged paddy soil which in turn led to more release of phosphate from ferric combinations (Pandey and Morris, 1983). In waterlogged soils, green manures increased the availability of P through the mechanism of reduction, chelation and favourable changes in soil pH (Hundal *et al.*, 1987). Better utilization of P and K to an extent of 10 to 12 per cent was observed due to green manure incorporation (Lekha Sreekantan and Palaniappan, 1990). Besides nitrogen, green manure crops also contain appreciable amounts of other nutrients including trace elements (Bhuiyan and Zaman, 1996). They also mobilize S, P, Si, Zn, Cu, Mn and other nutrient elements as a result of increased microbial activity (CO₂ formation) and decreased redox potential (Becker, 1990). Higher levels of Zn, Cu, Mn and Fe were observed in plots treated with FYM followed by plots treated with prickly sesban (Dhaincha) and wheat straw. Further, dhaincha reclaimed soil sodicity faster than FYM and paddy straw (Kumar and Yadav, 1995). Green manuring with *S.rostrata* increased both availability in soil and accumulation in plant of Fe, Mn and Cu due to the development of intense reducing condition, complex formation and greater nutrient binding capacity (Bhattacharyya and Mandal, 1996). In addition to provision of N and other mineral nutrients for the immediate need of the growing rice crop, there is abundant evolution of CO₂ which might benefit the growing crop by influencing its photosynthetic activity (Bharadwaj and Dutt, 1995).

2.1.1.4. Improvement in soil physico – chemical properties

Green manures not only supply N to rice but also improve physical and chemical properties of soils (Buresh and De Datta, 1991, Becker *et al.*, 1995; Misra *et al.*, 1996). Green manures are readily decomposable and result in faster aggregate stability (Lekha Sreekantan, 1987). In the long term field experiments,

green manuring decreased bulk density, increased water stable aggregates, pore space, water intake and water retention (Sur *et al.*, 1993). Under rice-wheat rotation, green manuring with *S. aculeata* or *Leucaena* brought out various improvements in soil physical properties such as profile water content and hydraulic conductivity. Soil settling and dispersion got decreased due to green manuring (Joshi *et al.*, 1994).

2.1.1.5. Improvement in soil organic matter

Due to green manure incorporation, soil organic matter content got increased (Lekha Sreekantan, 1987; Somasundaram *et al.*, 1996; Sur *et al.*, 1993). There was considerable built up of soil organic carbon content due to the addition of organic N sources especially green manures (Siddeswaran, 1992; Kolar *et al.*, 1993; Ventura and Watanabe, 1993; Gurung and Sherchen, 1996; Kumar *et al.*, 1999; Singh *et al.*, 1999). *Sesbania aculeata* application recorded higher availability of soil organic carbon (Sreeramachandrasekaran *et al.*, 1996). Addition of green foliage of *Glyricidia* increased organic soil carbon (Chaphale *et al.*, 2000).

2.1.1.6. Green manuring and rice yield

Constant N supply due to slow release from the incorporated green manure would match with the absorption pattern of rice resulting in improved crop performance (Westcott and Mikkelson, 1987). Yield response of rice to green manuring in India ranged from 0.65 to 3.1 t ha⁻¹ in high yielding varieties (Yadvinder Singh *et al.*, 1991). Green manuring with *S. aculeata* increased the growth, yield parameters, nutrient uptake and yield of rice (Padmavathy, 1992). Prickly sesban (*Sesbania cannabina*) green manuring significantly increased the grain yield of rice (Hiremath and Patel 1998). Green manuring with *S. aculeata* gave higher rice production and was at par with 20 t ha⁻¹ of FYM (Misra *et al.*, 1996). Green manures raised during pre-season rice recorded higher values of growth parameters and yield of succeeding rice than pre-season fallow (Solaiappan *et al.*, 1996 and Subbalakshmi Loganadhan *et al.*, 1999).

2.1.2. Integration of fertiliser N and green manures

A survey on current green manure management practices in South, South East and East Asia revealed that green manuring in no case substituted entirely the chemical N (Garrity and Flinn, 1987) indicating the essentiality of integration of fertiliser N with green manures.

2.1.2.1. Nitrogen substitution by green manures

Comparison of the relative efficiency of green manures with inorganic N sources is difficult even on equivalent nutrient basis. A more rational way is to work out the extent to which green manures could substitute for nutrients applied through fertilisers to obtain similar crop yields. (Singh, 1984).

Addition of dhaincha and subabul as green manure with 50 per cent of the recommended fertiliser gave as high yield as that of full recommended dose. Besides green manures added around 50 to 60 kg N ha⁻¹ to the soil for the succeeding rice (Singh and Bhattacharyya, 1989). Green manure – N was equal to or better than urea-N in increasing grain yield and the N equivalence was 15 per cent higher than that of urea (Singh *et al.*, 1990). *Sesbania* could effectively substitute part of fertiliser N requirements (Chakraborty and Mandal, 1992). Green manures at the least substituted 60 kg N besides giving maximum rice yield in combination with 120 kg fertiliser N ha⁻¹ (Rekhi and Bajwa, 1994). Application of 30 kg N ha⁻¹ after green manuring produced higher yield than that of 90 kg N ha⁻¹ without green manuring (Atkar *et al.*, 1993). Rice yields were similar with either 180 kg N (150 per cent of the recommended fertiliser) or 100 per cent of the recommended N fertiliser with dhaincha green manure (Sharma and Kuhad, 1993; Gill *et al.*, 1994; Matiwade and Sheelavantar, 1994). With *S. aculeata*, fertiliser N to rice could be reduced to 50 per cent of the recommended dose (Bindra and Thakur, 1995). Highest grain yield was obtained with the combined application of green manure and 200 kg fertiliser N and it was on par with fertiliser source at 222 kg ha⁻¹ (Budhar and Palaniappan, 1996). Application of 75 per cent N as inorganic fertiliser and 25 per cent N through *S. cannabina* produced 5.49 t ha⁻¹ of grain yield whereas application of 100 per cent N as

inorganic fertiliser alone produced a grain yield of 3.86 t ha⁻¹ (Balasubramanian and Veerabadrán, 1997). Application of 100 kg N ha⁻¹ with green manuring using *S. aculeata* or *Crotalaria juncea* increased the growth, yield parameters and yield than using 100 kg N alone (Hiremath and Patel, 1998). Combined application of green manures and 120 kg N ha⁻¹ registered maximum grain yield than either of them (Geethalakshmi *et al.*, 1999).

2.1.2.2. Nitrogen losses due to integration of fertiliser N and green manure

The cumulative volatilization loss of nitrogen was higher (13 per cent of the applied amount) when N was applied in the form of urea alone as basal dressing and it was lower (six per cent) when it was applied in combination with dhaincha on 1:1 basis (Santra *et al.*, 1988). Increasing dose of fertiliser N enhanced the volatilization loss whereas application of green manure at lower levels of N (upto 40 kg ha⁻¹) minimised it (Chakravorti *et al.*, 1989; Khind *et al.*, 1989b; Somasundaram, 1991). Mixed application of *Sesbania* green manure and ammonium sulphate increased overall utilization of nitrogen than when they were applied separately (Huang and Liao, 1992). Green manure and prilled urea applied in splits resulted in higher yields with relatively low N losses through volatilization and leaching (Das *et al.*, 1995).

The physiological efficiency in rice was more with green manuring alone and it was better than fertiliser and integrated N sources (Budhar and Palaniappan, 1996). Combined application of fertiliser and green manure or FYM increased the efficiency of each other (Srivastava, 1998).

2.1.3. Mineralisation of green manures

The fate and availability of N from green manures depended upon the magnitude and extent of its decomposition and associated N mineralisation process (Palm *et al.*, 1988).

2.1.3.1. N release pattern

The NH₄ – N released from green manure is rapidly adsorbed into the

cation exchange complex of the soil leaving the balance in the soil solution (Ponnamperuma, 1965).

Release of organic N from green manure was initially rapid, but slowed down markedly in a fairly short time (Bharadwaj and Dev, 1985). Following incorporation of dhaincha, the accumulation of soil ammonia reached its peak at 7 to 20 days after rice transplanting and then gradually declined (Khind *et al.*, 1985; Beri *et al.*, 1989a). In wetland rice fields, 40 per cent of the C and 80 per cent of the N of *S. aculeata* got mineralised in the first 10 days of incorporation (Beri *et al.*, 1989b). The N release got its peak around fifth week after incorporation (Becker, 1990), while Singh *et al.* (1991) reported, it was after 2 to 4 weeks. Rate of ammonification attained peak during 35 days after incorporation (Dey and Jain, 1996; Pramanik and Mahapatra, 1997). In general, mineralisation rates from the applied green manure were higher during the first week of its incorporation (Dinesh and Dubey 1998) and it extended till 20 days after transplanting (Clement *et al.*, 1998) in all soils and thereafter the process got slowed down.

2.1.3.2. Fast and slow nitrogen

Bouldin *et al.* (1988) have given a fascinating account on the effect of green manure on soil organic matter and N availability to crops. They reported that green manure contains two N fractions. One which decomposes immediately after incorporation is named as 'Fast N' and the other which decomposes slowly over several years as 'Slow N'. With most of the green manures, 'Fast N' accounts for 50-80 per cent of total N. During the first crop period 65 per cent of the green manure decomposes and it is 14 per cent in the next crop. In the successive crops, it is at 3.3 per cent (Bouldin, 1988).

2.1.3.3. Factors affecting mineralisation

The net N release from green manure is the balance of all N transformation processes occurring in different parts of the green manure. The efficiency of green manure N would depend on the extent of N losses and the rate of supply to the growing crops through mineralisation (Palm *et al.*, 1988) which in turn is influenced by the following factors.

2.1.3.3.1. Green manure species

Among the green manures, *S. aculeata* and *S. speciosa* exhibited higher organic carbon content with wider C-N ratio than *S. rostrata* (Ndoye and Dreyfus, 1988). The total and net N mineralisation were higher in soils applied with *Sesbania*, while they were low with azolla and other organic materials (Dinesh and Dubey, 1998).

2.1.3.3.2. Age of green manure

Incorporation of young green manure ensures adequate mineralisation of N (Bhuiyan and Zaman, 1996). Bharadwaj (1982) suggested incorporation of 45 days old green manure even if the biomass yield was low. Incorporation at this duration (45 days old) was found sufficient to maintain soil fertility (Rajeswari, 1990). Age of the green manure has a definite impact on the N content, with optimal levels at 45 days and declines as the age advances (Yadvinder Singh *et al.*, 1991). *Sesbania aculeata* recorded maximum biomass between 40 and 50 DAS suggesting it to be the ideal time for incorporation into the soil (Kalidurai, 1998). However, with dual cropping of rice and green manure, allowing the latter beyond 30 days resulted in lignification, slow decay upon incorporation and stunting and paling of associate rice crop (Abraham Varughese and Sushama Kumari, 1993).

2.1.3.3.3. Composition of green manure

The water soluble fractions of green manures get metabolised early followed by cellulose and hemi-cellulose. The lignins are more resistant to decomposition and therefore they are more abundant in the residual organic matter (Alexander, 1977).

The net recovery of N from the green manure is correlated directly to its N content and inversely with C-N ratio and lignin content (Buresh and De Datta, 1991). Among the various parameters, lignin content, lignin to N ratio and lignin + polyphenol to N ratio of the green manures accounted for maximum variation in the per cent organic N mineralised and N mineralisation rates in the green manure amended soils (Dinesh and Dubey, 1998).

2.1.3.3.4. Environmental factors

The mineralisation rate is also readily affected by environmental characteristics such as soil texture (Pushpavalli *et al.*, 1993), water (Miki and More, 1968; Brar and Sidhu, 1995; Dey and Jain, 1996), temperature (Ladd *et al.*, 1985) and season (Singh, 1984; Poovardom *et al.*, 1988; Susan John and Alice Abraham, 1995).

2.1.4. Decomposition period of green manure with reference to *Sesbania aculeata*

Classic experiments repeated five times between 1955 and 1958 at Central Rice Research Institute (CRRI), Cuttack showed that an eight week old *S. aculeata* could be incorporated and rice planted on the same day obviating the need for allowing a decomposition period (Vachni and Murthy, 1964). Green manuring has greater manurial potential when rice is planted immediately after burying the green manure (Dargan *et al.*, 1975).

An economy of 60 to 80 kg N ha⁻¹ can be obtained in rice-wheat rotation when dhaincha was incorporated one day prior to transplanting rice (Meelu and Rekhi, 1983). Incorporation of green manure one day before transplanting (DBT) without fertiliser N gave a significantly higher grain yield of rice (by 1.2 – 3.8 t ha⁻¹) which was equivalent to 120 kg N ha⁻¹ urea than its incorporation 7 and 14 DBT (Beri *et al.*, 1989b).

Rice yield was significantly high when the crop was transplanted immediately after the green manure crop was turned in (Bharadwaj, 1982; Bhardwaj and Dev, 1985; Dalel Singh and Hari Om, 1992). The shorter the time gap between green manure incorporation and transplanting, more would be the effectiveness of green manure in terms of rice yield and N uptake. In fact, the best results were obtained when dhaincha was incorporated one day before transplanting (DBT) instead of incorporating 5, 10 and 15 DBT. This was due to the easily decomposable tender plant parts which would supply sufficient amount of available N for the rice seedlings by the time they got established after transplanting (Bhuiyan and Zaman, 1996).

Conversely the reduction in rice yield was more marked when the green matter was allowed to decompose for 20 days particularly at young age of 45 days (Bhardwaj, 1982). The yield was affected even when 55 and 65 days old green manure crop was allowed to decompose for 10 days before transplanting. Regardless of N quantity, the rice yields were seen to be mainly affected by the decomposition period (Bharadwaj and Dev, 1985). Extended period of green manure decomposition did not favour the rice crop principally due to fast decomposing nature of legumes, their low C-N ratio and anaerobic conditions in the tropical climate all leading to extensive loss of ammonia through volatilization (Ghai *et al.*, 1988). A longer time gap would result in loss of some N before the rice seedlings start actively absorbing it. (Bhuiyan and Zaman, 1996).

The foregoing review clearly indicates that it is not only necessary but also wasteful to allow any decomposition period to dhaincha green manure before planting rice.

2.1.5. Present status of green manuring

It is evident that the practice of green manuring has not been widely adopted by rice farmers, although its value for increasing rice production by supplying nutrients and maintaining soil productivity is well established (Abrol and Palaniappan, 1988; Kundu *et al.*, 1993; Ramanathan, 1995).

The following are the constraints which stand in the way of green manuring:

1. In a high intensive cropping system, the situation may not induce the farmers to set apart six to eight weeks exclusively for a green manure with no direct benefit and revenue (Abrol and Palaniappan, 1988; Palaniappan and Siddeswaran, 1999). Want of sufficient irrigation also stands in the way. (Becker *et al.*, 1988).
2. Inadequate availability of quality seeds of preferred green manure species at reduced cost (Abrol and Palaniappan, 1988; Becker *et al.*, 1988; Ramanathan, 1995 ; Palaniappan and Siddeswaran, 1999).

3. Benefits of green manure addition could not be seen very apparently as that of mineral fertiliser N (Abrol and Palaniappan, 1988; Ramanathan, 1995) because from the farmers' point of view, organic sources are only complementary or synergistic to inorganic fertilisers and not essential for crop production (Palaniappan and Siddeswaran, 1999).
4. Incorporation of 5-8 t ha⁻¹ of wet bio-mass with given animal draft power and traditional implements is practically difficult on a large scale (Pandey and Morris, 1983). This point suggests that the practices advocated must be agronomically manageable.
5. Benefits expected from green manure addition may not be always uniform in all the crops because of the variation in the soils, green manure species, environmental conditions *etc.* (Palaniappan and Siddeswaran, 1999).
6. The possibility of using green manure as intercrop has got its own limitations since it is believed that it may compete for nutrients with the main crop (Abraham Varughese and Sushama Kumari, 1993; Palaniappan and Siddeswaran, 1999).
7. Comparatively affordable price of N fertilisers, their ease of application and evenness in distribution in the field and predictable amount of the nutrient (N) availability from them won a place in production systems that will be difficult for the green manures to fill (Mathias Becker, 1996; Peoples *et al.*, 1988).

Although the potential yield increase from leguminous green manures is more, the fact that the practice of green manuring is not widespread evokes cautious and thoughtful research. It appears that fast growing, easily establishable, early nodulating (naturally) green manures capable of fixing abundant N₂ may have more role in the cropping patterns. Once a 'green manure package' is found reliable under experimental conditions, it may then be made acceptable to the farmers by even adjusting the management requirements if need be (Pandey and Morris, 1983). The point which needs attention of the scientists for wider adoption of green manuring technology is evolving a suitable cropping

system for fitting green manures without sacrificing any of the economic crops thereof (Palaniappan and Siddeswaran, 1999).

To overcome the constraints cited and to fulfill the above authors' line of thinking, the apt approach could be intercropping green manure in rice which, if it is simplified, will be more acceptable to the farmers. The research pursued on these lines is therefore reviewed hereunder.

2.1.6. Green manure intercropping in rice

Though intercropping is done from time immemorial, green manure intercropping in rice ecosystem is of recent origin, the main objective of which is to achieve a substantial increase in rice yield with additional yield of green manure for building up the soil fertility (Somasundaram, 1991). The farmers are reluctant to use their land, water and other inputs for raising a crop exclusively for green manuring prior to rice (Ali and Narsico, 1993; Kundu *et al.*, 1993). Under the conditions of intensive agriculture, in which land and time are the major constraints, green manure crops can be accommodated in the cropping calendar when the growth interval is short, or can be grown as an intercrop (Watanabe and Liu, 1992). This in addition to increasing trends of cropping intensity and burgeoning demands formed the basis for switching over to green manure intercropping (Zaman *et al.*, 1991).

2.1.6.1. Earlier reports of green manure intercropping in rice in India

In northern districts of Tamil Nadu, where rice was cultivated, incorporation of green leaf manure was done before or at sowing of semi-dry rice irrigated from tanks. The decomposition of incorporated green manure was non-uniform and incomplete. Under these conditions, simultaneous sowing of sunnhemp and dhaincha was tried along with rice. Trampling of green manure was done after two months when rice started receiving irrigation. This system of green manuring was found to be promising and increased yields upto 42 per cent have been reported. This practice was in vogue in fourteenth century itself (Subramanian and Dorairaj, 1952). Green manuring for the benefit of associate rice is practised in states like Orissa, where rice and dhaincha are sown

simultaneously by the farmers. After about a month and a half, green manure is turned in with a light plough and farmers get beneficial effect out of this dual culture (Subbaiah Mudaliar and Subramania Sarma, 1965).

2.1.6.2. Principles behind green manure intercropping

Leguminous green manure has the greater advantage of transferring N to the main crop (Arunin *et al.*, 1988). When legumes and non-legumes are intercropped, the non-legume species sometimes perform better than it could in monoculture, possibly because of the additional N supplied by the legume. N transfer by excretion from the nodules occurred in a cereal-legume intercropping (Aggarwal *et al.*, 1992).

2.1.6.3. *Sesbania rostrata* as green manure intercrop

Sesbania rostrata can be intercropped with rice to contribute N and increase rice grain yield. It will compete with rice for basally applied N fertiliser but the net result may not be completely negative because the N is re-incorporated at a later date (IRRI, 1986). *S.rostrata* alley cropped with rice produced 3-4 t ha⁻¹ of dry matter in two prunings and improved rice growth, yield and N uptake (Mulongoy, 1986).

Sesbania rostrata seedlings transplanted at 1.5 m interval as intercrop in rice along with the application of 50 and 100 kg N ha⁻¹ gave respectively 7 and 13 per cent more grain yield (Balasubramanian, 1989). Similar transplanting of *S. rostrata* with 100 kg N ha⁻¹ recorded more rice grain yield than that of sole rice (Alagappan, 1990).

Intercropping of *S. rostrata* in rice at 12:1 ratio produced 1.5 t ha⁻¹ of biomass in 45 days without affecting rice growth and incorporating the same at pre-flowering stage recorded the highest rice yield of 6.3 t ha⁻¹ (IRRI 1991; Palaniappan *et al.*, 1991). Somasundaram (1991) on the other hand found 10:1 ratio being optimum for higher biomass and N accumulation and ultimately for higher rice grain yield. At 7:1 ratio, *S. rostrata* contributed 16.3 kg N ha⁻¹ through 2 t biomass ha⁻¹ (Purushothaman and Padmavathy, 1994).

2.1.6.4. *Sesbania aculeata* as green manure intercrop

The benefit of intercropping dhaincha was reported when 30 days old seedlings were transplanted about 30 days after transplanting rice (Lizhi, 1988). Interplanting one row of *S. aculeata* seedlings at a spacing of every 3 m between rice rows with 20 x 15 cm spacing gave more profitable yield than sole crop of rice (Jha *et al.*, 1989).

Sesbania aculeata broadcast at 40 kg seed ha⁻¹ increased the germination of rice by 24 per cent in the encrusted lateritic soils and with its incorporation, the yield of rice was enhanced in upland conditions (Hati, 1987). The highest rice yield was obtained when rice and dhaincha were grown at 2:1 ratio in 20 cm wide rows. The yield was, however, at par with the treatments where rice and dhaincha were grown in alternate rows at 15 cm spacing (Sharma and Das, 1994).

Among the conventional intercrops, dhaincha has wide adaptability to even problem soils and has the ability to produce drymatter ranging from 2.8 to 9.9 t ha⁻¹ accumulating 80-225 kg N ha⁻¹ on 60 DAS (Lauren *et al.*, 1996). The effectiveness of dhaincha in smothering weeds was reported when grown as intercrop in rice (Angadi, 1997). Intercropping dhaincha in between two rows of rice in additive series and incorporating 35 DAS proved superior to sole rice (Joseph, 1998).

2.1.6.5. Effect of green manure intercrop on rice yield

Intercropping *Sesbania* with suitable row (4-6 m) and plant (24-30 cm with 3-4 seedlings per hill) spacings will not affect the associate rice yield (Liu Chungchu, 1988). Intercropping *S.rostrata* did not cause any adverse effect on the yield of transplanted rice (Padmavathy, 1992; Purushothaman and Padmavathy, 1994; Grace *et al.*, 1999) and wet seeded rice (Urkurkar *et al.*, 1994; Jayapaul *et al.*, 1995; Jayachandran and Veerabadran, 1996).

Adverse effects of green manure intercropping have also been reported. The intercropped dhaincha decreased the grain yield of main crop (Aus rice) by 0.9 t ha⁻¹ but can completely substitute fertiliser N for the following Aman rice (Zaman *et al.*, 1996). Solaiappan and Veerabadran (1997) have also reported that

the green manure intercrops had no effect on the yield of associate *kharif* rice but the subsequent *rabi* rice yield got increased.

Thus it is seen from the foregoing review that *S.rostrata* as intercrop in rice performed better and so also *S. aculeata* as reported by different authors. But in the present study, dhaincha (*S. aculeata*) was chosen and its green manure utility is reviewed hereunder.

2.1.7. Dhaincha (*Sesbania aculeata*) the premier green manure

Among all the green manure crops, *S. aculeata* has occupied a prime place in India from early times (Dommergues, 1982).

2.1.7.1. Ecological adaptation of *S. aculeata*

S.bispinosa (Jacq.) W.F is also known as *S. aculeata* (Wild.) Poir and *S. cannabina* (Retz.) Poir. and by the common name as dhaincha. It tolerates a range of climatic and soil conditions for its growth and N fixation (Ghosh *et al.*, 1960; Bharadwaj, 1974). It is adapted to wet areas and heavy soils. It is viewed as a marsh plant and able to produce floating roots with a spongy parenchyma and withstands drought, with rainfall as low as 500 mm in the growing season (Brewbecker and Glover, 1988). *Sesbania* can be grown in saline soil without reduction in total N contribution to the soil (Saradharamani *et al.*, 1989). *Sesbania aculeata* can grow in soils which are saline besides withstanding severe drought also and capable of growing in poorly drained soils (Pandey, 1982).

2.1.7.2. Superiority of *S. aculeata* over *S. rostrata*

For the green manure legumes, the ability to produce a high biomass and the N uptake per unit weight of 'P' applied are the best criteria to determine the efficiency of species. Accordingly the efficiency of legumes was in the following order: *S.cannabina* > *S.rostrata* > *Glycine max* (Mappanoa *et al.*, 1995). Based on this criteria, *S.cannabina* and *S.rostrata* are found to be more promising in soils with low P levels. But the photoperiod sensitivity of *S.rostrata* limited its use to long day period (Becker *et al.*, 1988). Further, the dormancy maintained by the extremely hard seedcoat of *S.rostrata* seeds often prevented the germination

leading to poor stands resulting in low biomass production *i.e.*, 28.5 t ha⁻¹ compared to 32.2 t ha⁻¹ of *S. aculeata* at the time of incorporation (Thamizhvendan and Rajeswari, 1999). *Sesbania aculeata* recorded higher fresh biomass of 51.4 and 73.4 g plant⁻¹ within 40 and 50 DAS respectively than *S.rostrata* due to its fast growth in the early vegetative phase besides recording higher nodule number and nodule dry weight (Kalidurai, 1998). It has already been reported that *S. aculeata* performed better than *S.rostrata* at all the stages of cutting *viz.*, 30, 45 and 60 DAS (Sivabal, 1989). *Sesbania rostrata* seemed to be sensitive to high soil pH (Thamizhvendan and Rajeswari, 1999), whereas *S. aculeata* can be grown in soils which are saline helping in lowering down the alkalinity of soils besides substituting N (Pandey, 1982).

2.1.7.3. Biomass production and N contribution by dhaincha

Sesbania aculeata could produce 21.1 t ha⁻¹ of green biomass and accumulate about 133 kg N ha⁻¹ (Sanyasi Raju, 1952). Thirty days old *S. aculeata* released an equivalent of 38 kg N ha⁻¹, while 45 and 60 days old plants released N equivalent to 60 and 120 kg N ha⁻¹, respectively (Khind *et al.*, 1987). *Sesbania aculeata* at 24, 36 and 48 DAS recorded fresh matter yields of 2.2, 11.5 and 26.3 t ha⁻¹ respectively (Rajabhandari, 1984). It produces about 24 t ha⁻¹ of biomass with 106 kg N ha⁻¹ (Singh *et al.*, 1987) and can produce in general 20 t ha⁻¹ of green matter yield in tropical conditions of Southern India (Abrol and Palaniappan, 1988). *S. aculeata* yields a dry biomass of 3.15 t ha⁻¹ with 1.45 per cent N concentration and accumulates about 42.5 kg N ha⁻¹ (Medhi, 1996) and is capable of contributing 224 kg N ha⁻¹ at 45th day (Thamizhvendan and Rajeswari, 1999).

About eight weeks old dhaincha plants have been found to contain 3 per cent N in addition to K, Ca, Mg, P, S and micronutrients and about 33 kg N, 1 kg P, 14 kg K, 14 kg Ca, 16 kg Mg and 2 kg S are added to the soil if a ton of dhaincha drymatter is applied (Bhuiyan *et al.*, 1988). Besides being a deep rooted crop, dhaincha absorbs nutrients from the sub soil enriching the rice plough layer upon incorporation.

The leaflets of dhaincha degrade rapidly in moist soil and release 50 per cent of their N within four weeks of incorporation (IRRI, 1985).

From the foregoing review, it can be seen that dhaincha is a premier green manure crop since it fulfills the traits of an ideal green manure for lowland ecosystem which is further supported by FAO (1977); IRRI (1988); Ladha *et al.* (1988) and Cosico (1990) as described below.

1. early establishment and high seedling vigour
2. tolerance to flooding and drying
3. early onset of N fixation and efficient sustenance over varied climatic and edaphic conditions.
4. fast growth with an ability to accumulate large biomass and N within four to six weeks of growth.
5. quick decomposability.

2.2. Wet seeding of rice

Wet seeding of rice lends more scope for intercropping green manure without sacrificing any of the economic crops in the cropping systems which was emphasised by Palaniappan and Siddeswaran (1999) for popularisation of green manures. The present study is on these lines and a brief review on wet seeding of rice is made hereunder.

2.2.1. Wet seeding as an alternative

Advances in variety development, pest and disease management and nutrient application have increased the yield potential of rice. Realisation of this potential depends on crop establishment to ensure optimal population. Transplanting of seedlings is the major means of crop establishment in lowland rice (De Datta, 1986). Non-availability of labour in time, higher wages and their lower efficiency are often quoted as constraints in transplanting with manual labour leading to delay in planting and resultant sub-optimal population which ultimately lowers the yield (Khade *et al.*, 1993). The practice of transplanting is being increasingly replaced by direct seeding as labour becomes scarce and cost prohibitive (Erguiza *et al.*, 1990; Madhu and Nanjappa, 1995; Govindarasu *et al.*,

1998; Jayadeva *et al.*, 1998). Constant decline in rice yield and consequent reduction in profit is experienced in irrigated lowlands of Asia because more than 21 per cent of total cost of production is accounted for transplanting alone. Therefore, adoption of alternative rice culture, which requires less input and possible increase in yield is highly desirable (Pingali, 1991).

Expansion of irrigated areas, availability of early maturing and profuse tillering cultivars, use of selective herbicides and improved fertiliser management coupled with reduced cost of production had encouraged many farmers to switch over from transplanting to wet seeding (De Datta, 1986; De Datta and Flinn, 1986).

In command areas, synchronisation of planting is needed for effective pest management and efficient water management but non-cooperation by labourers has been quoted as a constraint for getting optimum population in rice. So the alternatives for manual transplanting will be mechanization of transplanting and direct seeding in puddle (Rangarajan and Veerabadran, 1993).

When there is uncertainty in canal water supply, direct seeding of an early duration culture would be useful (Budhar *et al.*, 1990).

2.2.2. General advantages

Although transplanting is the most popular crop establishment method in the irrigated rice growing areas of Asia, this practice is being increasingly replaced by direct wet seeding which eliminates labour demands for seedbed preparation, pulling seedlings and transportation and is more conducive for mechanisation (Khade *et al.*, 1993; Schnier *et al.*, 1990; Annadurai and Palaniappan, 1999).

Other advantages of wet seeded rice culture include its drought tolerance, less labour requirement for establishment, better weed control and high returns (Bhuiyan *et al.*, 1995). The advantages of direct seeding quoted by Pandey and Velasco (1999) are : i) it saves labour; it can reduce the labour requirement by as much as 50 per cent depending on the nature of the production system, ii) when rainfall at planting is highly variable, direct seeding may help reduce the

population risk, iii) it can facilitate crop intensification and iv) irrigation water can be reduced if dry seeded rice can be established earlier using pre - monsoon showers.

2.2.2.1. Effect on rice growth attributes

Rice dry weight was higher in wet seeded rice (WSR) than in transplanted rice (TPR). Wet seeded rice had higher root density at all soil depths than transplanted one (Nabheerong, 1995 and Pal *et al.*, 1999). The rate of tillering, leaf area expansion, N uptake and dry matter accumulation during the vegetative stage were considerably more rapid in broadcast rice than in TPR (Peng *et al.*, 1996). The growth duration of direct seeded rice was shortened by 7-15 days as compared to transplanted rice (Wang and Sun, 1990).

2.2.2.2. Effect on Water Use Efficiency (WUE)

Recent studies conducted at IRRI, Philippines indicate that wet seeded rice culture is superior to the traditional transplanted rice culture in terms of WUE (Bhuiyan *et al.*, 1995). A saving of 298.8 mm of water under direct sown crop was obtained which was 22.1 per cent less than the amount used by transplanted crop (Kandasamy, 1987). Wet seeded rice was more drought tolerant than transplanted rice (Khan, 1990). Further, the yields of WSR were high in both water sufficient and stress conditions (Sattar, 1992).

2.2.2.3. Effect on Fertiliser Use Efficiency

Fertiliser use efficiency was generally higher in direct sown rice than transplanted rice which may be attributed to lower fertiliser N losses through volatilisation and immobilisation as indicated by ¹⁵N studies (De Datta *et al.*, 1989; Schnier *et al.*, 1990). Under similar N management practices, with applied urea, ¹⁵N recovery was greater in broadcast seeded rice than in transplanted one due to rapid vegetative growth and absence of transplantation shock (De Datta *et al.*, 1989; Peng *et al.*, 1996).

2.2.2.4. Effect on yield attributes and yield

Direct sown rice was advantageous in securing more values of yield attributes *viz.*, number of panicles m^{-2} , number of filled grains panicle^{-1} and test weight (Budhar *et al.*, 1990; Thakur, 1993). Direct seeding on puddled land gave yield comparable to that of transplanting (Rajan and Mahapatra, 1980). Results of most of the field experiments and on farm trials revealed that upon proper management, comparable yields from direct seeded rice could be secured as that of transplanted crop and this might be the reason as to why majority of the rice growing countries are striving hard to make a shift from transplanted to direct seeded rice (Singh *et al.*, 1987; De Datta and Nantasomaran, 1991; Ramasamy *et al.*, 1994; Peng *et al.*, 1996). The direct sown rice by virtue of slightly higher yield stability, makes itself an attractive practice over transplanting (Lantican *et al.*, 1999).

2.2.3. Economics of wet seeding

Input requirement is less for direct sown rice (DSR) than TPR which ultimately results in more gross margin (IRRI, 1995). Although gross margins for both TPR and WSR crops are very similar sometimes, the paid out costs for TPR is higher than that of WSR. The main difference was due to saving in the cost of hired labour. Although the cost of herbicide in WSR is higher, this increased cost was less than savings in labour cost. As the paid out cost associated with transplanting is higher, farmers who have limited access to credit are more likely to adopt WSR as an attempt to save the cash cost of production (Erguiza *et al.*, 1990). The economic incentives for adoption of wet seeding are provided by its labour saving feature. Transplanting typically takes about 20 persons $\text{day}^{-1} \text{ha}^{-1}$ whereas wet seeding requires about 1-2 person $\text{day}^{-1} \text{ha}^{-1}$. With the real price of rice falling over time, increasing adoption of wet seeding can be viewed as a response to the ensuring cost-price squeeze (Pandey, 1995).

The economics of production of DSR should not be judged only from the net return point of view, but other advantages must also be taken into consideration at a time. It reduces the labour needs by more than 20 per cent.

Direct seeding not only provides more turn-around period for double cropping due to reduction in crop duration but also beneficial to maintain the granular crumb structure of the soil (Singh and Bhattacharyya, 1988).

Hitherto, earlier works on various aspects of green manuring including its intercropping in rice, premier position of dhaincha as a green manure in India and rice wet seeding as an alternative to transplanting and its utility were all reviewed. Though these practices were dealt as discrete subjects, they fall within the purview of present study in which dhaincha was intercropped with wet seeded rice using the newly developed rice *cum* green manure seeder of TNAU (Rajendran *et al.*, 1999). Since the seeder was used as a first device in rice + green manure intercropping, earlier works on mechanisation in rice cultivation with particular reference to its establishment would be also looked into and the review hereunder is on this line.

2.3. Need for mechanisation in rice cultivation

Full or partial mechanisation has become a necessity in rice cultivation where manual labour input is very high from planting to harvest (Veerabadran and Pandian, 1999). It is estimated that nearly 145 man days ha⁻¹ are required for rice cultivation. Among the various operations, planting alone accounts for 21 per cent of the total human labour requirement (De Datta, 1981). A study on gender concerns in rice farming quoted that women who constitute a majority of agricultural labour force in India perceive drudgery of work as a major constraint for productive efficiency of labour. They have emphasised the need for light tools and implements for planting and weeding and light machinery for threshing (Singh *et al.*, 1999).

2.3.1. Drum seeder for sowing

Deepa Thomas (1996) evaluated the performance of drum seeder for sowing sprouted seeds in lines onto the puddled soil and reported that two men could cover an area of one hectare in a day.

The advantages of using drum seeder include sowing in lines, optimum plant stand, possibility of growing azolla as a dual crop for incorporation, using

rotary weeder for weed incorporation, urea solution applicator and harvester (Deepa Thomas, 1996). Number of tillers per unit area and leaf area index were also more in row sown rice than in broadcast and transplanted rice (Dingkuhn *et al.*, 1990; Bharathi, 1996). Direct seeding with drum seeder not only helps in maintaining optimum plant population but also reduces the drudgery and duration of crop by seven days and thus helps to avoid water stress at later crop growth stages (DRR, 1999).

Drum seeding method required only eight persons, whereas line sowing of sprouted seeds and transplanting methods required 20 and 40 persons ha⁻¹ respectively. Thus, there is a significant saving of labour in the drum seeding method (Santhi *et al.*, 1998).

The grain and straw yields showed the usefulness of wet seeded rice sown with drum seeder over the other systems *viz.*, semi-dry and transplanting. However, proper land levelling, effective weed and water management are the pre-requisites for WSR (Rachel Sophia Alexander and James Martin, 1995). Bhuvanewari (1998) reported that line sowing of rice by drum seeder gave higher grain yield in both *kharif* and *rabi* seasons. Drum seeding gave a slightly higher grain yield and the yield parameters were not affected by the method of crop establishment *viz.*, transplanting, sowing sprouted seeds in lines manually and drum seeding of sprouted seeds (Santhi *et al.*, 1998). Rice established through drum seeder recorded significantly more number of panicles m⁻² (Narasimman *et al.*, 2000; Subbaiah *et al.*, 2000) and higher yield (Angadi *et al.*, 2000) than broadcast or transplanted rice.

Drum seeding resulted in higher net savings of Rs.1,911/- and Rs.2,233/- ha⁻¹ during *kuruvai* and *thaladi* seasons respectively compared to transplanted rice (Santhi *et al.*, 1998). Direct sowing using drum seeder was reported as the cheapest method of rice establishment and the net return was as good as the transplanted crop (Yashwant Singh, 1999). The highest net return was obtained in transplanting treatment which was closely followed by direct seeding with 3 row paddy seeder and 6 row manual transplanter (DRR, 1999). Among different rice establishment methods, direct seeding using drum seeder recorded the highest

benefit cost ratio of 2.4 as compared to 1.6 for line transplanting and 1.3 for random transplanting method (Narasimman *et al.*, 2000).

Recently, the Tamil Nadu Agricultural University has developed a rice cum green manure seeder. It has a single central wheel with containers on either side for simultaneous sowing of rice and green manure in alternate rows (Rajendran *et al.*, 1999).

Thus, it is seen that direct seeding that too by mechanical means is better than transplanting as viewed and reported by many authors. Feasibility of intercropping green manure is also more in wet seeded rice (as reviewed in the earlier section). Rice wet seeding and intercropping green manure in it all by mechanical means would be a meaningful resource management approach as reviewed from the literatures and the present study is exclusively on this line.

Materials and methods

CHAPTER III

MATERIALS AND METHODS

In order to fulfill the objectives set out in this programme to study the feasibility of green manuring *in situ* in wet seeded rice using single wheel rice cum green manure seeder developed by TNAU, three field experiments (two in *rabi* and one in *kharif*) were carried out. The materials used and methods employed for conducting these field experiments are detailed below.

3.1. Materials

3.1.1. Location

The experiments were conducted in two different locations *viz.*, D block of wetlands of Tamil Nadu Agricultural University (TNAU), Coimbatore (referred to as site I) during *rabi* 1999 and S block of Agricultural Research Station, Bhavanisagar (referred to as site II) during *kharif* and *rabi*, 2000.

Site I is geographically located at 11° N latitude, 77° E longitude and at an altitude of 426.7 m above Mean Sea Level (MSL). Site II is geographically located at 11° 29' N latitude, 77° 08' E longitude and at an altitude of 256 m above MSL.

3.1.2. Weather and Climate

Based on the mean values of 25 years, the climate of site I and site II are briefed hereunder,

Weather parameter	Site I	Site II
Annual rainfall (mm)	640	680
No. of rainy days	43	52
Maximum temperature (°C)	31.5	32.9
Minimum temperature (°C)	27.2	23.0
Relative humidity		
i) Forenoon	95.0	82.4
ii) Afternoon	61.0	46.2
Sunshine (hours day ⁻¹)	7.4	7.5

Weather prevailed during experimentation in site I is presented in Table 1 and Fig. 1. The mean maximum temperature ranged from 26.2 °C to 35.3 °C while the

Table 1. Weather data during the cropping period - rabi 1999 (01.11.1999 to 31.03.2000)

Year & Std Week	Standard Week dates	Temperature (° C)		Rainfall (mm)	Rainy days	Relative humidity		Solar Radiation (cal cm ² day ⁻¹)	Sun Shine hours
		Max.	Min.			07.22 Hrs	14.22 Hrs		
1999									
44	Oct. 29-Nov. 4	30.2	20.2	2.0	-	94	64	389.6	6.9
45	5-11	29.9	19.8	64.2	2.0	91	51	321.4	8.0
46	12-18	29.7	18.4	-	-	88	47	463.2	9.9
47	19-25	27.4	21.0	35.0	3.0	93	71	292.3	3.5
48	Nov. 26-Dec.2	28.4	21.0	6.4	1.0	91	63	373.8	6.3
49	3-9	28.3	19.1	-	-	91	59	388.3	5.6
50	10-16	26.2	19.3	3.0	1.0	91	62	308.1	6.1
51	17-23	27.9	18.3	10.0	1.0	88	57	322.0	5.2
52	24-31	26.8	19.3	8.8	1.0	90	54	416.3	7.6
2000									
1	Jan. 1-7	28.3	19.9	-	-	87	52	281.5	2.9
2	8-14	28.1	20.5	2.0	-	87	62	281.5	2.9
3	15-21	30.5	18.1	-	-	91	39	405.9	9.2
4	22-28	31.6	16.9	-	-	90	35	500.7	9.5
5	Jan.29 - Feb.4	31.0	18.3	-	-	89	40	420.6	6.7
6	5-11	32.0	21.9	-	-	89	48	406.6	7.4
7	12-18	32.2	19.9	-	-	88	37	425.7	9.2
8	19-25	32.7	20.9	18.0	1.0	91	52	366.2	5.7
9	Feb.26 - Mar.3	30.5	19.6	18.9	3.0	90	45	383.7	8.0
10	4-10	33.9	19.8	-	-	86	35	418.0	9.4
11	11-17	35.0	21.9	-	-	86	33	425.7	9.3
12	18-24	35.0	21.9	-	-	85	33	451.9	8.4
13	25-31	35.3	22.3	-	-	87	38	391.8	7.0

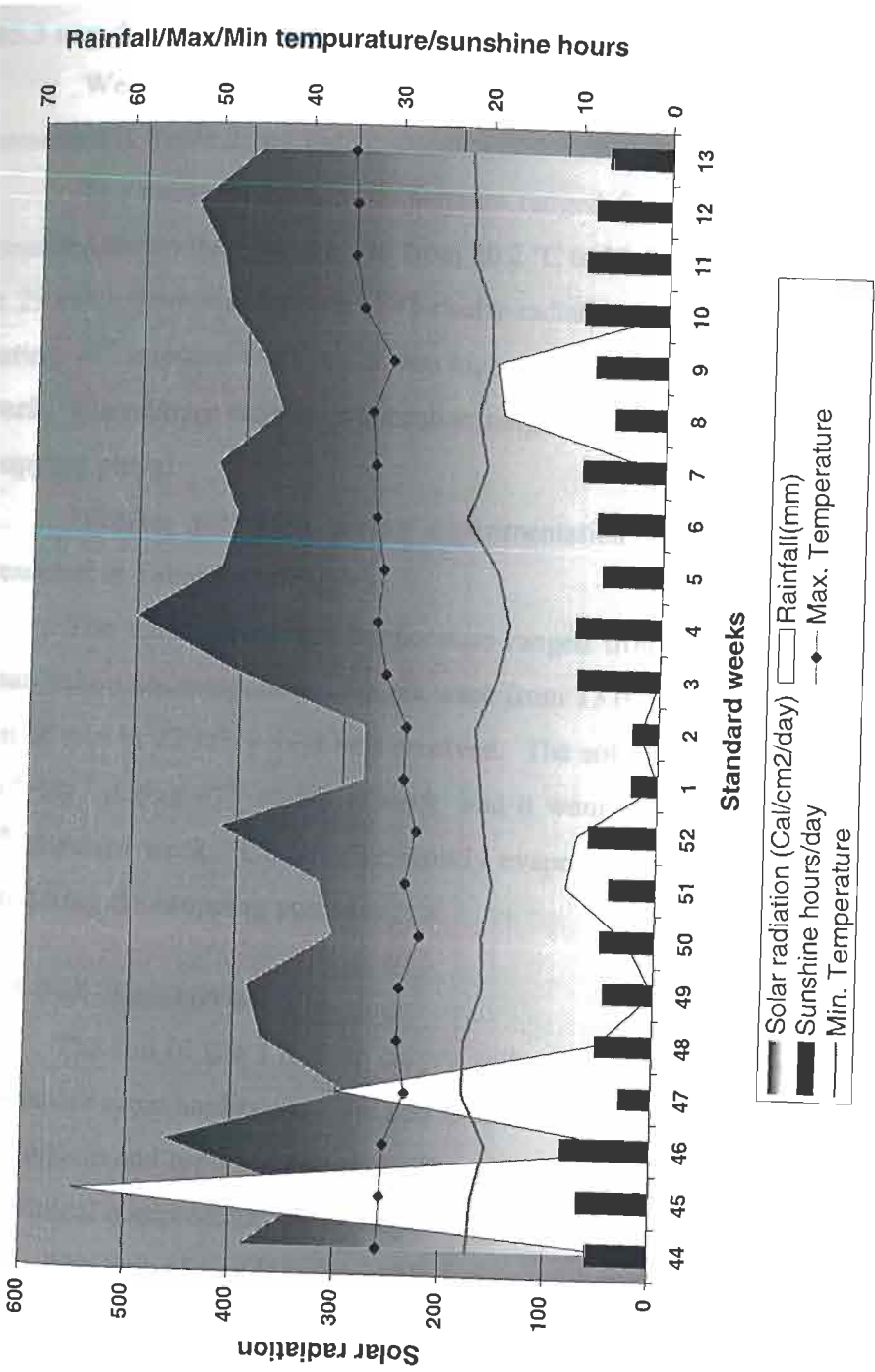


Fig.1 Weather data during rabi 1999

mean minimum temperature ranges were from 18.1 °C to 21.9 °C. A total of 168.3 mm of rain in 13 rainy days was received. The solar radiation was at 281.5 cal cm⁻² day⁻¹ during first and second standard weeks and it was high at 500.7 cal cm⁻² day⁻¹ during fourth standard week. Cumulative weekly evaporation ranged from 7.2 mm to 35.3 mm during the cropping period.

Weather prevailed during experimentation in site II during *kharif* 2000 is presented in Table 2 and Fig. 2.

The mean maximum temperature ranged from 31.3 °C to 35.7 °C while the mean minimum temperature was from 20.2 °C to 23.5 °C. A total of 446.8 mm of rain in 29 rainy days was received. The solar radiation was low at 375.23 cal cm⁻² day⁻¹ during 40th standard week and it was high at 526.29 cal cm⁻² day⁻¹ during 31st standard week. Cumulative weekly evaporation ranged from 11.1 mm to 41.3 mm during the cropping period.

Weather prevailed during experimentation in site II during *rabi* 2000 is presented in Table 3 and Fig.3.

The mean maximum temperature ranged from 29.3 °C to 33.6 °C while the mean minimum temperature ranges were from 13.0 °C to 22.7 °C. A total of 468.6 mm of rain in 22 rainy days was received. The solar radiation was low at 352.04 cal cm⁻² day⁻¹ during 47th standard week and it went upto 592.13 cal cm⁻² day⁻¹ during 50th standard week. Cumulative weekly evaporation ranged from 10.5 mm to 26.2 mm during the cropping period.

3.1.3. Soil characteristics

The soil of site I is deep clayey with moderate drainage and taxonomically it falls under typic haplustalf. The soil available N is low while the available P and K are medium and high respectively. The organic carbon content is 0.68 per cent. The mechanical composition and other particulars of soil are furnished in Table 4.

The soil of site II is gravelly loamy sand to sandy loam with good drainage and taxonomically it falls under Irugur series. The soil available N is low while the available P and K are medium. The organic carbon content is 0.34 per cent. The mechanical composition and other particulars of soil are furnished in Table 4.

Table 2. Weather data during the cropping period - *kharif* 2000 (30.06.2000 to 28.10.2000)

Year & Std Week	Standard Week dates	Temperature (° C)		Rainfall (mm)	Rainy days	Relative humidity		Solar radiation (cal/cm ² /day)	Sun Shine hours
		Max.	Min.			07.22 Hrs	14.22 Hrs		
		2000							
26	June 25-July 1	34.0	22.9	4.9	2	73.7	42.1	444.57	4.9
27	2-8	32.9	23.5	-	-	70.0	43.3	390.31	2.7
28	9-15	34.8	22.4	-	-	71.6	36.7	505.06	7.3
29	16-22	35.4	23.4	-	-	70.4	34.3	484.60	6.3
30	23-29	35.7	22.8	-	-	69.6	33.9	516.27	7.4
31	July 30-Aug. 5	34.3	22.5	125.1	4	79.0	46.9	526.29	6.6
32	6-12	32.3	22.6	49.1	2	79.9	50.9	493.18	5.2
33	13-19	33.4	22.5	26.4	2	87.6	46.7	503.70	5.1
34	20-26	31.5	22.7	1.8	2	77.3	54.0	376.47	2.5
35	Aug. 27-Sep. 2	32.3	22.8	2.0	1	79.1	49.7	459.93	4.8
36	3-9	34.5	23.2	-	-	82.9	43.7	534.23	6.9
37	10-16	34.2	22.8	19.3	2	80.0	46.0	494.54	5.6
38	17-23	33.4	22.3	59.1	4	90.1	53.3	518.63	5.6
39	24-30	31.3	22.2	121.4	4	89.4	65.6	517.27	4.2
40	Oct. 1-7	31.9	22.3	17.5	1	85.9	58.4	375.23	3.6
41	8-14	32.2	22.7	3.2	2	82.7	51.0	519.64	6.5
42	15-21	33.6	22.6	27.5	1	83.6	51.3	458.57	4.7
43	22-28	33.2	20.2	9.5	2	91.0	44.3	520.66	7.4

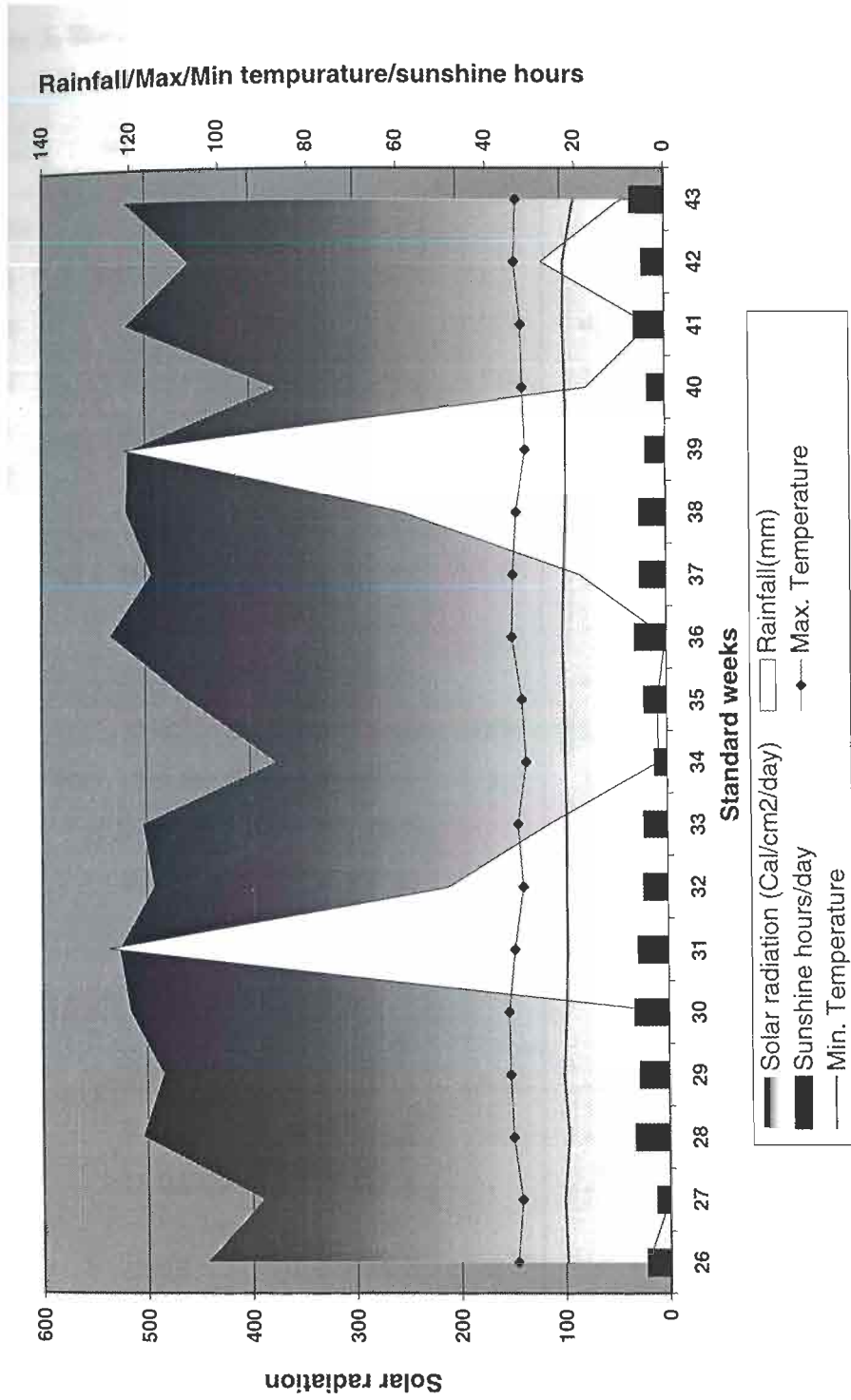


Fig. 2 Weather data during *kharif* 2000

Table 3. Weather data during the cropping period - *rabi* 2000 (22.09.2000 to 9.01.2001)

Year & Std Week	Standard Week dates	Temperature (° C)		Rainfall (mm)	Rainy days	Relative humidity		Solar radiation (cal/cm ² /day)	Sun Shine hours
		Max.	Min.			07.22 Hrs	14.22 Hrs		
2000									
38	Sep. 17-23	33.4	22.3	59.1	4	90.1	53.3	518.63	5.6
39	24-30	31.3	22.2	121.4	4	89.4	65.6	517.27	4.2
40	Oct. 1-7	31.9	22.3	17.5	1	85.9	58.4	375.23	3.6
41	8-14	32.2	22.7	3.2	2	82.7	57.0	519.64	6.5
42	15-21	33.6	22.6	27.5	1	83.6	51.3	458.57	4.7
43	22-28	33.2	20.2	9.5	2	91.0	44.3	520.66	7.4
44	Oct. 29-Nov. 4	31.9	19.9	2.5	1	88.3	51.3	457.22	7.2
45	5-11	31.9	20.1	-	-	89.4	50.3	511.50	8.3
46	12-18	30.7	19.7	-	-	88.0	53.7	446.36	6.7
47	19-25	30.1	20.7	43.9	2	92.9	62.3	352.04	3.4
48	Nov. 26-Dec. 2	29.8	16.8	113.2	3	92.7	55.0	505.47	6.4
49	3-9	29.5	18.0	-	-	90.4	56.6	488.77	7.4
50	10-16	29.3	13.0	-	-	89.1	41.7	592.13	9.1
51	17-23	29.6	14.6	-	-	87.4	44.0	497.59	8.6
52	24-31	30.1	17.7	1.8	1	90.1	51.9	432.93	5.9
2001									
1	Jan. 1-7	30.1	19.1	69.0	-	90.4	58.9	431.77	6.0
2	8-14	30.3	18.2	-	-	92.4	48.0	465.36	6.8
3	15-21	30.7	17.4	-	-	89.1	43.1	520.57	8.4
			0						
4	22-28	31.4	19.4	-	-	87.3	43.6	485.72	6.4
5	Jan. 29-Feb. 4	29.5	19.5	-	-	86.6	54.6	414.47	4.1

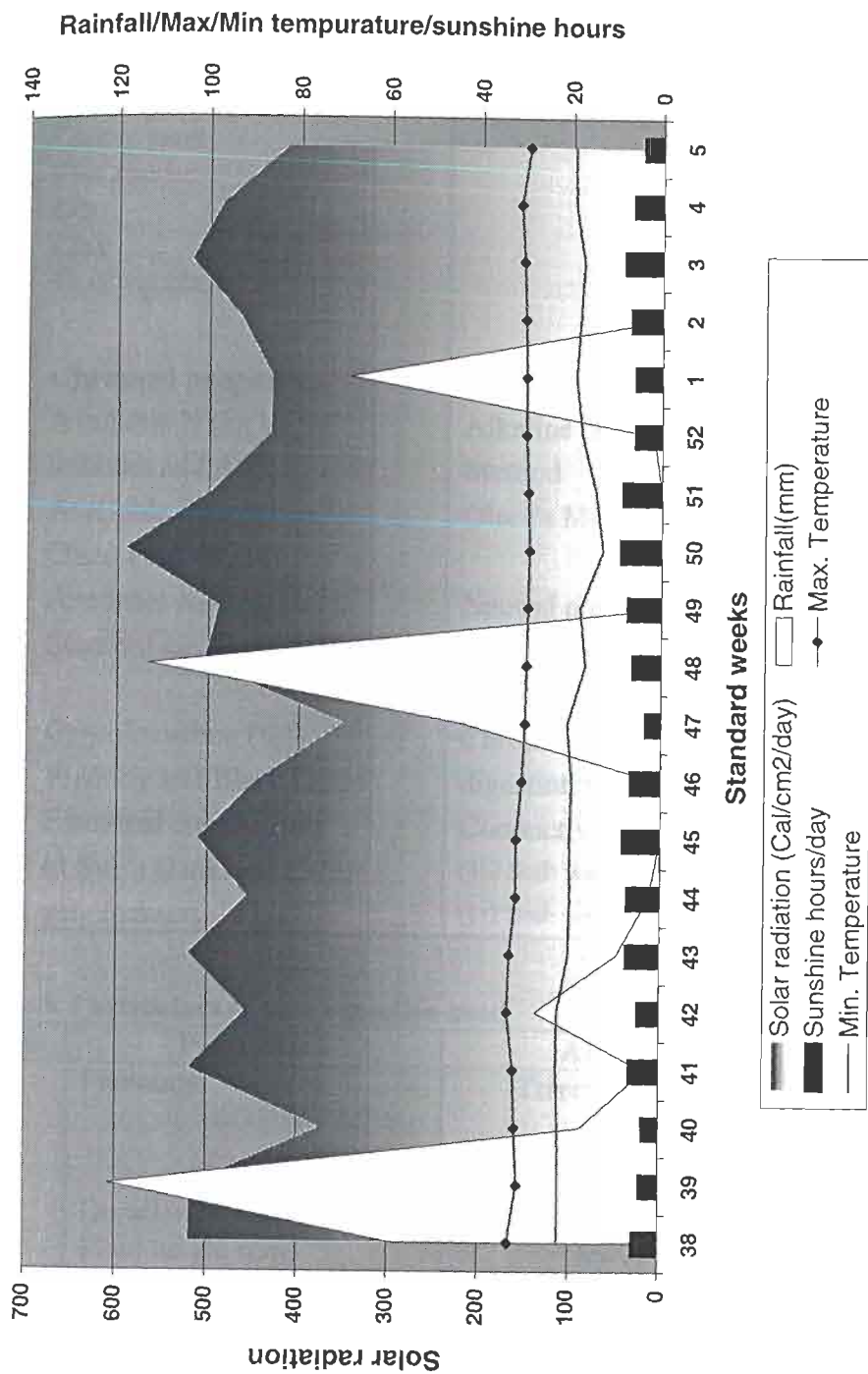


Fig. 3 Weather data during rabi 2000

Table 4. Physico-chemical properties of soil

Sl. No	Constituent	Method employed	Content		
			Expt I	Expt II	Expt III
1.	Mechanical composition (per cent) (Piper, 1966)	International pipette method			
	Coarse sand		15.2	39.9	39.2
	Fine sand		25.2	32.1	33.1
	Silt		19.4	2.1	2.3
	Clay		39.3	24.0	24.8
	Textural class		Clay	Sandy Loam	Sandy Loam
2.	Chemical properties				
	Available N (kg ha ⁻¹) Subbiah and Asija (1956)	Alkaline permanganate Method	214	189	178
	Available P ₂ O ₅ (kg ha ⁻¹) Olsen et al. (1954)	Olsen's Method	16	13.9	12.4
	Available K ₂ O(kg ha ⁻¹) Stanford and English (1949)	Neutral normal Ammonium acetate Method	400	194	18.6
	Organic carbon (%) Walkley and Black (1934)	Chromic acid wet digestion method	0.57	0.34	0.33
	Electrical conductivity (d Sm ⁻¹) (Jackson, 1973)	Conductivity bridge (1:2 Soil: water suspension)	0.4	0.2	0.2
	pH (Jackson, 1973)	(1:2 Soil: water suspension)	7.9	7.2	7.1

Table 5. Particulars of rice varieties used

Sl. No	Particulars	ADT 36	ADT 38
1	Parentage	Triveni x IR 20	IR 1529-680-3-2/ IR 4432-52-6-4/ IR 7963-30-2
2	Duration (days)	105-110	130-135
3	Plant height (cm)	85-90	75-80
4	1000 grain weight (g)	20.60	21.00
5	Grain L/B ratio	3.10	3.20
6	Grain type	Medium	Long slender
7	Habit	Erect	Semi-dwarf
8	Grain yield (kg ha ⁻¹)	6000	6200

3.1.4. Crop and Variety

Short duration rice variety ADT 36 was raised in *kharif* 2000 experiment and medium duration variety ADT 38 was raised in *rabi* season experiments of 1999 and 2000. The details of the varieties grown are given in Table 5. The green manure *Sesbania aculeata* (dhaincha) was raised as intercrop in all the experiments.

3.2. Methods

3.2.1. Design of the experiment

The experiment was laid out in randomised block design with three replications having 15 treatments in experiment I and 16 treatments in experiment II and III.

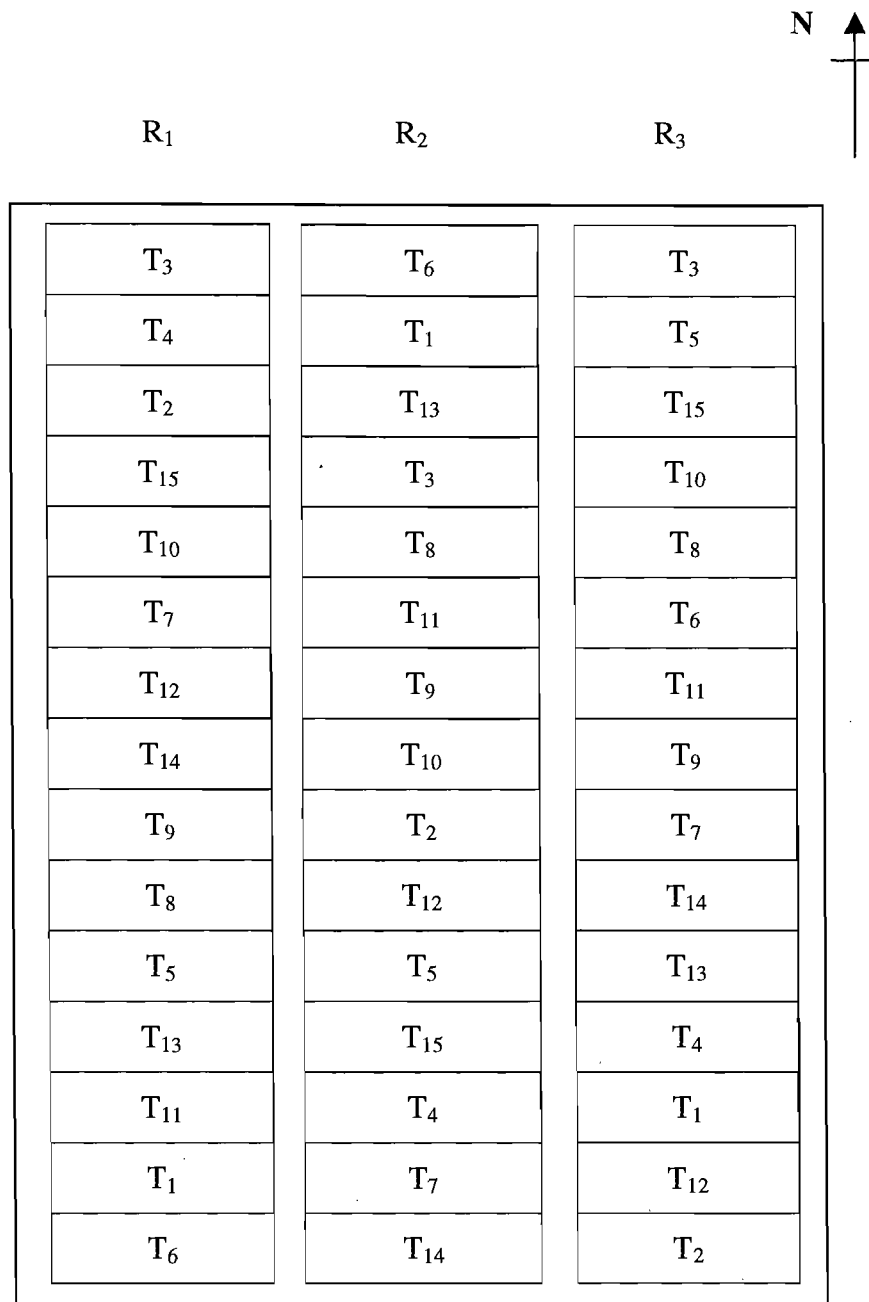
The treatment structure is given below.

- T₁ - Rice + dhaincha incorporation at 40 cm + 100 per cent N
 - T₂ - Rice + dhaincha incorporation at 40 cm + 75 per cent N
 - T₃ - Rice + dhaincha incorporation at 40 cm + 50 per cent N
 - T₄ - Rice + dhaincha incorporation at 50 cm + 100 per cent N
 - T₅ - Rice + dhaincha incorporation at 50 cm + 75 per cent N
 - T₆ - Rice + dhaincha incorporation at 50 cm + 50 per cent N
 - T₇ - Rice + dhaincha incorporation at 60 cm + 100 per cent N
 - T₈ - Rice + dhaincha incorporation at 60 cm + 75 per cent N
 - T₉ - Rice + dhaincha incorporation at 60 cm + 50 per cent N
 - T₁₀ - Rice + dhaincha incorporation at 70 cm + 100 per cent N
 - T₁₁ - Rice + dhaincha incorporation at 70 cm + 75 per cent N
 - T₁₂ - Rice + dhaincha incorporation at 70 cm + 50 per cent N
 - T₁₃ - Sole wet seeded rice + 100 per cent N + basal Incorporation of dhaincha @ 6.25 t/ha
 - T₁₄ - Sole wet seeded rice + 100 per cent N
 - T₁₅ - Transplanted rice + 100 per cent N
 - T₁₆* - Transplanted rice + 100 per cent N + basal incorporation of dhaincha @ 6.25 t/ha
- * Included in *kharif* and *rabi* 2000

The field layout plan is depicted in Fig.4 , 5 and 6.

3.2.2. Field preparation

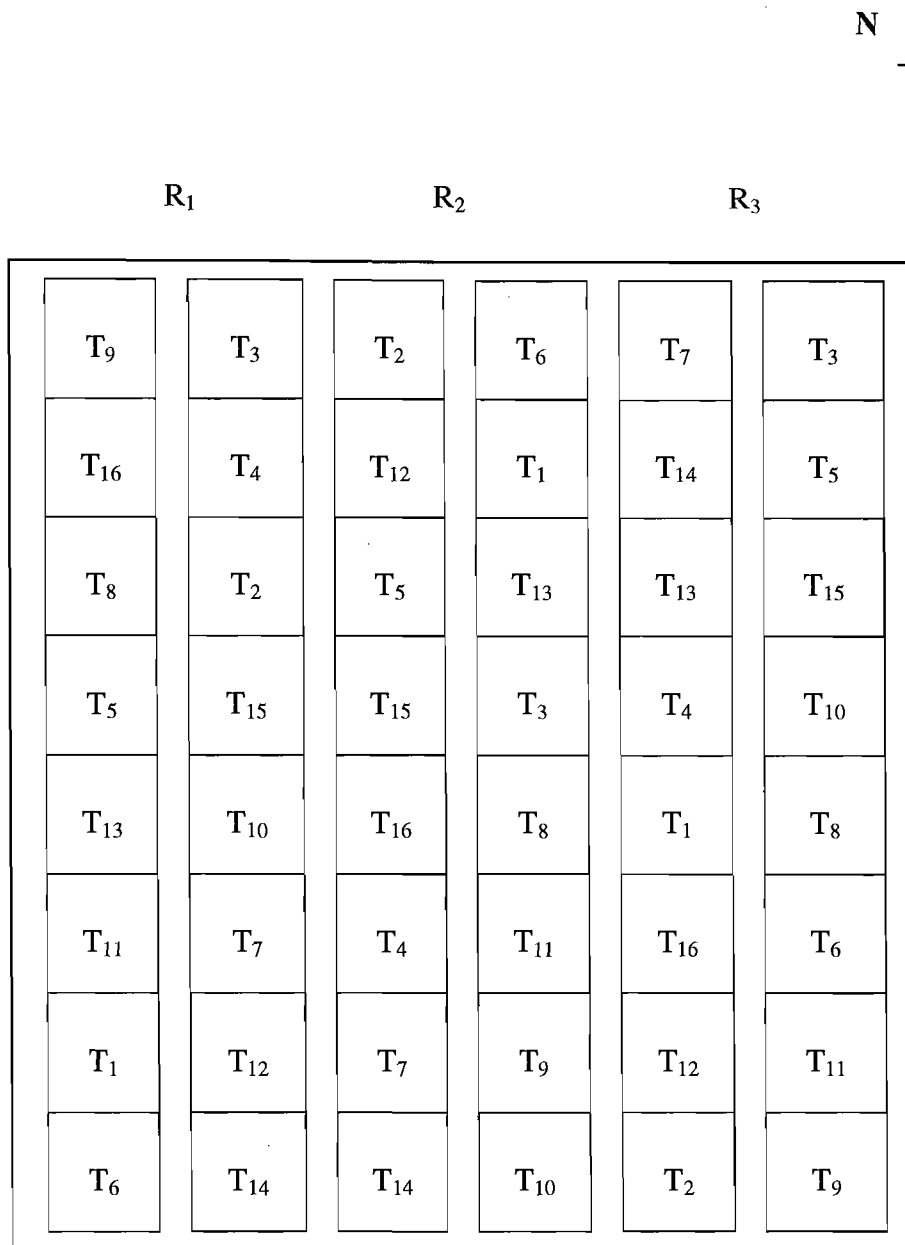
The field was fallow prior to the present experiment in both the sites. It was thoroughly puddled and levelled using bullock drawn wooden plank. Each plot was



PLOT SIZE

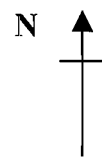
Gross plot : 6.2 X 4.6 m
 Net plot : 5.2 X 4.0 m

Fig. 4. Layout of Experimental field during *rabi* 1999



PLOT SIZE
Gross plot : 4.7 X 4.7 m
Net plot : 4.1 X 3.9 m

Fig. 5. Layout of Experimental field during *kharif* 2000



R ₁	R ₂	R ₃
T ₃	T ₁₆	T ₃
T ₄	T ₆	T ₅
T ₂	T ₁	T ₁₅
T ₁₆	T ₁₃	T ₁₀
T ₁₅	T ₃	T ₈
T ₁₀	T ₈	T ₆
T ₇	T ₁₁	T ₁₁
T ₁₂	T ₉	T ₉
T ₁₄	T ₁₀	T ₇
T ₉	T ₂	T ₁₄
T ₈	T ₁₂	T ₁₃
T ₅	T ₅	T ₄
T ₁₃	T ₁₅	T ₁
T ₁₁	T ₄	T ₁₂
T ₁	T ₇	T ₂
T ₆	T ₁₄	T ₁₆

PLOT SIZE

Gross plot : 4.7 X 4.7 m
 Net plot : 4.1 X 3.9 m

Fig. 6. Layout of Experimental field during *rabi* 2000

delineated by having manually laid small bunds on all the four sides and pathways were provided as shown in the layout plan (Fig. 4, 5 and 6).

3.2.3 Sowing

The newly developed single wheel rice *cum* green manure seeder (Plate 1) developed by TNAU was used for raising the experimental crop (Plate 2). In the treatments involving intercropping (T_1 to T_{14}), rice (pre-germinated) and dhaincha (unsoaked) seeds were sown using the seeder. The rice and dhaincha were alternated at an equidistance of 12.5 cm each. The rice inter row spacing was thus 25 cm with dhaincha in between. In the treatments T_{13} and T_{14} involving sole rice, rice alone was sown closing the green manure rows. In treatments T_{15} and T_{16} , transplanting of the respective rice cultivar was done with the seedlings of the same age as that of the wet seeded rice.

3.2.4 Fertiliser application

The fertiliser N through the source of urea was applied as per the treatment schedule. The recommended dose of 150 kg N ha⁻¹ and 120 kg N ha⁻¹ were followed for the medium (ADT 38) and short (ADT 36) duration rice cultivars. They were taken as 100 per cent of the recommended N for the respective cultivar and in the other treatments, it was proportionately reduced according to the treatments. The entire quantum of N was applied in four equal splits on 20 days after sowing (DAS), on the day of incorporation of green manure, 55 and 70 DAS for wet seeded rice (T_1 to T_{12}); during 20, 40, 55 and 70 DAS for T_{13} and T_{14} and during basal, active tillering (AT), panicle initiation (PI) and flowering stages for transplanted rice (T_{15} and T_{16}).

Phosphorus in the form of single super phosphate @ 38 kg P₂O₅ ha⁻¹ for short duration crop (ADT 36) and @ 50 kg P₂O₅ ha⁻¹ for medium duration crop (ADT 38) was applied basally to all the treatments.

Potassium as muriate of potash was applied @ 38 kg K₂O ha⁻¹ for short duration crop (ADT 36) and @ 50 kg K₂O ha⁻¹ for medium duration crops (ADT 38) in three equal splits on 20 DAS, on the day of incorporation of green manure and 55 DAS for direct seeded crop (T_1 to T_{12}); 20, 40 and 55 DAS for T_{13} and T_{14} and during

basal, AT and PI stages for transplanted crop (T₁₅ and T₁₆) combining with the first three splits of fertiliser nitrogen.

3.2.5. Herbicide application

Butachlor @ 1 kg ha⁻¹ was mixed with sand and broadcast uniformly on 8 DAS in the treatments T₁ to T₁₄ and on 3 DAT in the treatments T₁₅ and T₁₆ maintaining a thin film of water in the field. Later one hand weeding was given after green manure incorporation with IRRI Conoweeder in T₁ to T₁₄ and during AT stage before first top dressing of fertilisers in T₁₅ and T₁₆ treatments.

3.2.6. Irrigation

The field was drained out and sowing was taken up on the moist, saturated soil. Light irrigation was given daily from third to five DAS and the field was drained out immediately following each irrigation. Irrigation was given to a depth of 2 cm thereafter up to 10 DAS and later on, the depth of water was gradually increased to 5 cm. The irrigation was given one day after the disappearance of ponded water.

3.2.7. Green manure incorporation

The intercropped green manure was incorporated using IRRI Conoweeder (Plates 3, 5 and 6) as and when the green manure attained the stipulated height viz., 40, 50, 60 and 70 cm respectively as per the treatment schedule.

3.2.8. Plant protection

Need based plant protection was given uniformly to all the plots. The crop was generally free from any of the major pest and disease.

3.2.9. Harvesting and threshing

The crop was harvested upon full maturity, first the border row on either side and 20cm width of rice crop on the other two sides. The net plot was then harvested, hand threshed plotwise, grains separated, sun dried and weighed. The grain yield was converted to kg ha⁻¹. The straw was also collected plotwise, sun dried, weighed and computed to kg ha⁻¹.

3.3. Biometric observations

3.3.1. Biometric observations on dhaincha

3.3.1.1. Dhaincha population

It was counted for a half metre length at the time of green manure incorporation in randomly selected five places in a plot and converted to plants m^{-2} .

3.3.1.2. Dhaincha height

Height of dhaincha was measured from ground level to the growing point at the time of incorporation in ten randomly selected plants and the mean height plant^{-1} was arrived in cm.

3.3.1.3. Nodules plant^{-1}

Total number of nodules was counted one day before incorporation in ten plants chosen at random in a plot and the mean was arrived as nodules plant^{-1} .

3.3.1.4. Biomass and dry matter production

Whole biomass of the same ten plants chosen for measuring height and nodules plant^{-1} were weighed to estimate fresh biomass and recorded in tonnes ha^{-1} . They were then air and oven dried (oven drying at $60 \pm 5^\circ \text{C}$) to constant weights. Dry matter accumulation was then worked out to tonnes ha^{-1} .

3.3.2. Biometric observations on rice

3.3.2.1. Plant population

It was counted for a half metre length at the time of incorporation of green manure and for 0.25m length during PI, flowering and harvest stages in randomly selected five places in a plot and converted to plants m^{-2} .

3.3.2.2. Plant height

It was measured from ground level to the growing point at the time of green manure incorporation, PI, flowering and harvest stages from randomly selected 10 plants and the average height was calculated in cm.

3.3.2.3. Dry matter production

Ten plants selected at random in a plot were pulled out at the time of green manure incorporation and cut close to the ground level during PI, flowering and

harvest stages, sun dried and later oven dried at $60 \pm 5^\circ \text{C}$ to constant weight. The dry matter values recorded were converted to kg ha^{-1} .

3.4. Light interception, SPAD 502 and LCC values

3.4.1. Light interception

Light intensity was measured using hand held light meter, LI-250 between 9 and 11 AM on the day of recording at different growth stages viz., at the time of green manure incorporation, PI and flowering stages of rice. At the time of green manure incorporation *i.e.*, just before incorporating the green manure, light intensity was measured at the top of the green manure crop which lies in between two rice rows and at the bottom of the green manure crop in randomly chosen five places in a plot. Similarly, during PI and flowering stages, the light intensity was measured at the top and bottom between two rice rows. From the top and bottom level measurements, per cent light interception by the whole canopy was estimated for the five randomly chosen places and the average value was arrived.

3.4.2. Chlorophyll meter (SPAD 502) measurements

SPAD 502 values using SPAD 502 chlorophyll meter were recorded at the time of green manure incorporation and during PI and flowering stages on the third leaf from the top in five randomly chosen rice plants in each plot and the average value was taken.

3.4.3. LCC values

LCC values were recorded using Leaf Colour Chart at the time of green manure incorporation and during PI and flowering stages on the third leaf from the top in five randomly chosen rice plants in each plot and the average values were recorded.

3.5. Yield attributes and yield

3.5.1. Number of panicles m^{-2}

Ear bearing tillers were counted for a length of 0.25 m in randomly chosen five places in each plot and was converted to panicles m^{-2} .

3.5.2. Number of filled and illfilled grains panicle⁻¹

Five panicles in each plot were chosen at random, filled grains in them were counted and the average number of filled grains panicle⁻¹ was worked out. Illfilled grains from the same panicles were counted separately and the average number of illfilled grains panicle⁻¹ was worked out.

3.5.3. Test weight

One thousand grains were counted from each plot and their weight was recorded in gram.

3.5.4. Grain yield and straw yield

Cleaned, sun dried grains from each net plot was weighed and the yield was recorded in kg ha⁻¹ at 14 per cent moisture. Similarly, the straw was sun dried for three days and its yield was recorded plotwise in kg ha⁻¹.

3.6. Soil and plant analyses

3.6.1. Soil chemical analyses

Pre-sowing soil samples to a depth of 20 cm were collected at random from the experimental field, shade dried, sieved through 2mm sieve, samples pooled and the composite sample was analysed for mechanical and chemical properties. In the similar manner, soil samples were collected from each plot at different growth stages viz., just before the incorporation of green manure, PI, flowering and harvest stages, processed and analysed for available macronutrients and organic carbon content. The procedure followed for various analyses are given in Table 4.

3.6.2. Plant analysis

3.6.2.1. Green manure

Nitrogen content of the green manure was estimated at the time of incorporation by Microkjeldahl method (Humphries, 1956).

3.6.2.2. Nutrient uptake by rice

Rice plants sampled for dry matter production during various stages were ground by Willey mill and used for estimating the uptake of nitrogen by

Microkjeldahl method using Kjelplus auto analyzer; phosphorus using triple acid extract by Colorimetry (Jackson, 1973) and potassium using triple acid extract by Flame photometry (Jackson, 1973).

The total nutrient uptake was computed by multiplying the DMP with the corresponding nutrient content in per cent and expressed in kg ha^{-1} .

3.7. Statistical analysis

The data collected during the course of experimentation on various parameters were subject to statistical scrutiny following the methods described by Gomez and Gomez (1984). Treatment differences which were not significant are denoted by NS. Where significant, critical differences were worked out at five per cent probability.

3.8. Economics

The cost of cultivation was worked out by summing up the cost of different inputs and labour for different operations. Gross returns ha^{-1} were calculated with the price prevailed at harvest. Net returns were calculated by subtracting the corresponding cost of cultivation from the respective gross returns. The benefit cost ratio was also worked out by dividing the gross returns by the cost of cultivation.

Results

CHAPTER IV

RESULTS

A field study was undertaken consecutively in three seasons *viz.*, *rabi*, 1999, *kharif*, 2000 and *rabi*, 2000 to find out the feasibility of intercropping dhaincha in wet seeded rice. While *rabi*, 1999 experimental crop was raised at TNAU, Coimbatore, the study was undertaken in the following two seasons at Agricultural Research Station, Bhavanisagar. Rice and dhaincha were sown alternately using the newly developed rice *cum* green manure seeder. The intersown dhaincha was buried at different heights as per the treatment schedule. At each height of incorporation of green manure, three levels of fertiliser N to rice *viz.*, 100, 75 and 50 per cent of recommended dose were tested. Besides, sole rice plus 100 per cent fertiliser nitrogen with or without basal incorporation of green manure and similarly transplanted rice with 100 per cent nitrogen were included for the study. In the second and third crop, transplanted crop plus 100 per cent nitrogen with basal incorporation of green manure at 6.25 t ha⁻¹ was also included as a treatment for effective comparison with the above stated wet seeded rice intercropped with green manure treatments. The results of the study are presented below.

4.1. Dhaincha as an intercrop

4.1.1. Duration of dhaincha

Dhaincha which was sown alternately with rice was incorporated at the pre-determined heights of 40, 50, 60 and 70 cm. The days to attain the above heights were:

During *rabi*, 1999, dhaincha took 36, 39.5, 41.5 and 43.5 days to attain 40, 50, 60 and 70 cm heights respectively (Table 6). Whereas during *kharif*, 2000, within 36 days dhaincha attained 70 cm height. During *rabi*, 2000, the days to attain the respective heights were 32.5, 35, 37.5 and 40.

4.1.2. Weather elements and dhaincha growth

The weather elements *viz.*, temperature (°C), sunshine (hours day⁻¹) and solar radiation (cal cm⁻² day⁻¹) prevalent till incorporation of dhaincha were related with the

days to attain the pre-determined height and the correlation matrix thus obtained is presented in Table 7 seasonwise. Higher temperature reduced the duration to attain the stipulated height recording negative 'r' values of 0.94, 0.19 and 0.76. Sunshine hours and solar radiation had inconsistent relation with the duration (days) to attain various heights.

4.1.3. Plant population

Population of dhaincha varied with the height of incorporation and fertiliser N levels to rice in all the three seasons studied (Tables 8,9 and 10). As dhaincha grew from 40 to 70 cm height at increments of 10 cm, its population got thinned out and this was consistently seen in all the seasons. Reduction in fertiliser N dose to rice reduced the population to some extent but not significantly.

4.1.4. Nodules plant⁻¹

Nodules produced were generally low in *kharif* as compared to *rabi* season (Tables 8, 9 and 10). During *kharif*, 2000, number of nodules ranged from 17.2 to 35.5 plant⁻¹, while it was from 24.5 to 54.5 in *rabi*, 1999 and 26.7 to 45.2 in *rabi*, 2000.

Late incorporation (at 70 cm height) (T₁₀ to T₁₂) were consistently with more number of nodules in all the three seasons. The nodules were conspicuously low when the intercropped green manure was buried at the early stage (40 to 50 cm height) (T₁ to T₆).

As seen from all the three seasons collectively, nodulation was not affected by increasing the fertiliser N to rice from 50 to 100 per cent of the recommended dose regardless of height of incorporation of dhaincha.

4.1.5. Biomass and dry matter production

During the three seasons' study, biomass produced by dhaincha as an intercrop ranged from 7.3 (Rice + dhaincha inc. at 40 cm + 50 per cent N) (T₃ in *rabi*, 1999) to as high as 28.4 t ha⁻¹ in the treatment T₁₀ (Rice + dhaincha inc. at 70 cm + 100 per cent N in *kharif*, 2000) (Table 8, 9 and 10).

Table 6. Duration of dhaincha to attain pre-determined heights

Height (cm)	Days to attain pre-determined heights		
	<i>Rabi 1999</i>	<i>Kharif 2000</i>	<i>Rabi 2000</i>
40	36.0	27.8	32.5
50	39.5	30.7	35.0
60	41.5	33.9	37.5
70	43.5	36.0	40.0

Table 7. Correlation between weather elements and dhaincha growth

Weather parameters	Days to attain pre-determined height	Sunshine hours day ⁻¹	Solar radiation cal cm ⁻² day ⁻¹
<i>rabi 1999</i>			
Sunshine hours	-0.925 ^{NS}	1.000	-
Solar radiation	-0.869 ^{NS}	0.992 ^{**}	1.000
Temperature (° C)	-0.937 [*]	0.747 ^{NS}	0.657 ^{NS}
<i>kharif 2000</i>			
Sunshine hours	0.761 ^{NS}	1.000	-
Solar radiation	0.847 ^{NS}	0.981 ^{**}	1.000
Temperature (° C)	-0.193 ^{NS}	-0.023 ^{NS}	-0.179 ^{NS}
<i>rabi 2000</i>			
Sunshine hours	0.908 ^{NS}	1.000	-
Solar radiation	0.491 ^{NS}	0.785 ^{NS}	1.000
Temperature (° C)	-0.764 ^{NS}	-0.925 ^{NS}	-0.929 [*]

Table 8. Population m⁻², nodules plant⁻¹ and biomass yield t ha⁻¹ of dhaincha at incorporation during *rabi* 1999

Treatments	Dhaincha growth parameters		
	Population m ⁻²	Nodules plant ⁻¹	Biomass (t ha ⁻¹)
T ₁ -R+D(Inc. 40 cm)+100 %N	174 ^{abc}	26.7 ^{bd}	9.7 ^{cd}
T ₂ -R+D(Inc. 40 cm)+75%N	197 ^a	24.5 ^c	8.2 ^d
T ₃ -R+D(Inc. 40 cm)+50%N	178 ^{abc}	25.0 ^c	7.3 ^d
T ₄ -R+D(Inc. 50 cm)+100 %N	168 ^{a-d}	22.7 ^c	8.9 ^d
T ₅ -R+D(Inc. 50 cm)+75%N	122 ^{de}	31.9 ^{bc}	11.2 ^{bcd}
T ₆ -R+D(Inc. 50 cm)+50%N	122 ^{de}	32.5 ^{bc}	8.4 ^{bd}
T ₇ -R+D(Inc. 60 cm)+100 %N	152 ^{b-e}	33.4 ^b	16.9 ^a
T ₈ -R+D(Inc. 60 cm)+75%N	134 ^{b-e}	43.1 ^{ab}	22.5 ^a
T ₉ -R+D(Inc. 60 cm)+50%N	125 ^{cde}	35.0 ^{bc}	16.0 ^{abc}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	116 ^c	43.9 ^{ab}	21.8 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	111 ^c	44.9 ^{ab}	19.4 ^a
T ₁₂ -R+D(Inc. 70 cm)+50%N	100 ^c	54.5 ^a	19.3 ^a
SEd	23.5	7.6	3.3
CD(P=0.05)	48.7	15.7	6.9

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

Table 9. Population m⁻², nodules plant⁻¹ and biomass yield t ha⁻¹ of dhaincha at incorporation during *kharif* 2000

Treatments	Dhaincha growth parameters		
	Population m ⁻²	Nodules plant ⁻¹	Biomass (t ha ⁻¹)
T ₁ -R+D(Inc. 40 cm)+100 %N	206 ^a	18.7 ^{ef}	10.3 ^{ef}
T ₂ -R+D(Inc. 40 cm)+75%N	161 ^{bc}	17.2 ^f	8.1 ^f
T ₃ -R+D(Inc. 40 cm)+50%N	150 ^{bcd}	19.4 ^{ef}	7.5 ^f
T ₄ -R+D(Inc. 50 cm)+100 %N	169 ^b	21.7 ^{de}	20.3 ^{cd}
T ₅ -R+D(Inc. 50 cm)+75%N	157 ^{bc}	23.7 ^d	18.8 ^d
T ₆ -R+D(Inc. 50 cm)+50%N	102 ^f	25.3 ^{cd}	12.2 ^e
T ₇ -R+D(Inc. 60 cm)+100 %N	142 ^{cde}	25.5 ^{cd}	21.3 ^{cd}
T ₈ -R+D(Inc. 60 cm)+75%N	122 ^{ef}	31.5 ^{ab}	18.3 ^d
T ₉ -R+D(Inc. 60 cm)+50%N	120 ^{ef}	32.2 ^{ab}	18.0 ^d
T ₁₀ -R+D(Inc. 70 cm)+100 %N	158 ^{bc}	28.5 ^{bc}	28.4 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	140 ^{cde}	28.9 ^{bc}	25.1 ^b
T ₁₂ -R+D(Inc. 70 cm)+50%N	126 ^{def}	35.5 ^a	22.7 ^{bc}
SEd	12.6	2.02	1.59
CD(P=0.05)	26.2	4.19	3.30

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

Table 10. Population m⁻², nodules plant⁻¹ and biomass yield t ha⁻¹ of dhaincha at incorporation during *rabi* 2000

Treatments	Dhaincha growth parameters		
	Population m ⁻²	Nodules plant ⁻¹	Biomass (t ha ⁻¹)
T ₁ -R+D(Inc. 40 cm)+100 %N	153 ^a	26.7 ^e	11.2 ^f
T ₂ -R+D(Inc. 40 cm)+75%N	145 ^{ab}	27.6 ^e	8.9 ^g
T ₃ -R+D(Inc. 40 cm)+50%N	117 ^c	27.8 ^e	7.9 ^g
T ₄ -R+D(Inc. 50 cm)+100 %N	153 ^a	32.4 ^d	19.8 ^c
T ₅ -R+D(Inc. 50 cm)+75%N	152 ^a	33.8 ^d	17.0 ^d
T ₆ -R+D(Inc. 50 cm)+50%N	129 ^{cde}	32.9 ^d	14.3 ^e
T ₇ -R+D(Inc. 60 cm)+100 %N	149 ^a	37.8 ^c	23.7 ^b
T ₈ -R+D(Inc. 60 cm)+75%N	120 ^{de}	38.2 ^c	19.3 ^c
T ₉ -R+D(Inc. 60 cm)+50%N	119 ^{de}	39.4 ^{bc}	18.7 ^{cd}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	141 ^{abc}	42.4 ^{ab}	26.6 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	131 ^{bc}	44.3 ^a	24.5 ^b
T ₁₂ -R+D(Inc. 70 cm)+50%N	130 ^{cd}	45.2 ^a	23.2 ^b
SEd	6.1	1.9	0.86
CD(P=0.05)	12.7	3.9	1.79

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level



Production of biomass, by and large, got increased with the height of incorporation from 40 to 70 cm height. This trend was seen in all the three seasons.

In *rabi*, 1999 crop raised at Coimbatore with clay soil, reduction in fertiliser N dose to rice did not alter the biomass production at different heights of incorporation (40 to 70 cm height). In the subsequent *kharif* and *rabi*, 2000 experiments in light textured sandy loam soil at Bhavanisagar, biomass from dhaincha was more with 100 per cent N to rice with progressive reduction for lower doses.

The seasonal influence, incorporation at different heights and fertiliser N levels to rice on dhaincha dry matter was similar to its biomass production (Tables 11, 12 and 13).

4.1.6. Nitrogen content and its contribution

Nitrogen content of dhaincha did not vary (2.42 to 2.58 per cent only) due to the influence of seasons, height of incorporation and N levels tested (Tables 11, 12 and 13). The nitrogen accumulation by dhaincha, however, varied due to the influence of treatments. Addition of nitrogen by dhaincha intercropping was relatively low in *rabi*, 1999 crop raised in clay soil at Coimbatore as compared to the subsequent crops (*kharif*, 2000 and *rabi*, 2000) raised at Bhavanisagar in sandy loam soil.

In all the three seasons of study, as the dhaincha was allowed to grow from 40 to 70 cm height, the N accumulation got increased. It was as low as 36.9 kg ha⁻¹ in T₃ (Rice + dhaincha inc. 40 cm + 50 per cent N) to as high as 107.0 kg ha⁻¹ in T₁₀ (Rice + dhaincha inc. 70 cm + 100 per cent N) during *rabi*, 1999. The trend was similar in the subsequent seasons also.

Fertiliser N levels to rice and nitrogen accumulation by dhaincha had inconsistent relations during *rabi*, 1999 (Coimbatore) in clay soil. However, in the subsequent seasons (Bhavanisagar) in sandy loam soil, nitrogen addition by dhaincha got increased when fertiliser N levels to rice was stepped up (50 to 100 per cent of recommended dose). With 100 per cent N, it was conspicuously higher at different heights of incorporation of dhaincha.

Table 11. Dry matter production ($t\ ha^{-1}$), N content (%) and N addition ($kg\ ha^{-1}$) of dhaincha at incorporation during *rabi* 1999

Treatments	Nutrient addition		
	DMP ($kg\ ha^{-1}$)	N content (%)	N addition ($kg\ ha^{-1}$)
T ₁ -R+D(Inc. 40 cm)+100 %N	1.95 ^f	2.49	48.5 ^g
T ₂ -R+D(Inc. 40 cm)+75%N	1.65 ^g	2.55	42.1 ^h
T ₃ -R+D(Inc. 40 cm)+50%N	1.47 ^h	2.50	36.9 ⁱ
T ₄ -R+D(Inc. 50 cm)+100 %N	1.79 ^{fg}	2.51	44.9 ^{gh}
T ₅ -R+D(Inc. 50 cm)+75%N	2.26 ^e	2.50	56.5 ^f
T ₆ -R+D(Inc. 50 cm)+50%N	1.69 ^g	2.46	41.2 ^h
T ₇ -R+D(Inc. 60 cm)+100 %N	3.42 ^c	2.46	84.1 ^d
T ₈ -R+D(Inc. 60 cm)+75%N	4.55 ^a	2.45	111.2 ^a
T ₉ -R+D(Inc. 60 cm)+50%N	3.23 ^b	2.42	78.0 ^e
T ₁₀ -R+D(Inc. 70 cm)+100 %N	4.40 ^a	2.44	107.0 ^b
T ₁₁ -R+D(Inc. 70 cm)+75%N	3.91 ^b	2.40	93.1 ^c
T ₁₂ -R+D(Inc. 70 cm)+50%N	3.89 ^b	2.45	94.9 ^c
SED	0.08	0.06	1.91
CD(P=0.05)	0.16	NS	3.96

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

Table 12. Dry matter production (t ha⁻¹), N content (%) and N addition (kg ha⁻¹) of dhaincha at incorporation during *kharif* 2000

Treatments	Nutrient addition		
	DMP (kg ha ⁻¹)	N content (%)	N addition (kg ha ⁻¹)
T ₁ -R+D(Inc. 40 cm)+100 %N	2.06 ^{ef}	2.52	51.9 ^g
T ₂ -R+D(Inc. 40 cm)+75%N	1.61 ^{ef}	2.58	41.6 ^h
T ₃ -R+D(Inc. 40 cm)+50%N	1.51 ^f	2.53	38.2 ^h
T ₄ -R+D(Inc. 50 cm)+100 %N	4.07 ^{cd}	2.54	103.2 ^d
T ₅ -R+D(Inc. 50 cm)+75%N	3.76 ^{cd}	2.53	94.6 ^e
T ₆ -R+D(Inc. 50 cm)+50%N	2.45 ^e	2.49	61.1 ^f
T ₇ -R+D(Inc. 60 cm)+100 %N	4.24 ^{bcd}	2.49	105.7 ^d
T ₈ -R+D(Inc. 60 cm)+75%N	3.64 ^d	2.48	90.3 ^e
T ₉ -R+D(Inc. 60 cm)+50%N	4.24 ^{bcd}	2.45	103.7 ^d
T ₁₀ -R+D(Inc. 70 cm)+100 %N	5.66 ^a	2.47	139.5 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	5.01 ^{ab}	2.43	121.6 ^b
T ₁₂ -R+D(Inc. 70 cm)+50%N	4.53 ^{bc}	2.48	112.3 ^c
SED	0.41	0.06	2.41
CD(P=0.05)	0.86	NS	4.99

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

Table 13. Dry matter production ($t\ ha^{-1}$), N content (%) and N addition ($kg\ ha^{-1}$) of dhaincha at incorporation during *rabi* 2000

Treatments	Nutrient addition		
	DMP ($kg\ ha^{-1}$)	N content (%)	N addition ($kg\ ha^{-1}$)
T ₁ -R+D(Inc. 40 cm)+100 %N	2.06 ^{fgh}	2.54	52.3 ⁱ
T ₂ -R+D(Inc. 40 cm)+75%N	1.68 ^{gh}	2.58	43.3 ^j
T ₃ -R+D(Inc. 40 cm)+50%N	1.46 ^h	2.53	36.9 ^k
T ₄ -R+D(Inc. 50 cm)+100 %N	3.54 ^{bcd}	2.53	89.6 ^d
T ₅ -R+D(Inc. 50 cm)+75%N	2.94 ^{df}	2.51	73.8 ^g
T ₆ -R+D(Inc. 50 cm)+50%N	2.56 ^{efg}	2.48	63.5 ^h
T ₇ -R+D(Inc. 60 cm)+100 %N	3.97 ^{abc}	2.47	97.9 ^c
T ₈ -R+D(Inc. 60 cm)+75%N	3.46 ^{b-e}	2.46	84.9 ^e
T ₉ -R+D(Inc. 60 cm)+50%N	3.25 ^{cde}	2.44	79.2 ^f
T ₁₀ -R+D(Inc. 70 cm)+100 %N	4.78 ^a	2.48	118.1 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	4.39 ^{ab}	2.45	107.5 ^b
T ₁₂ -R+D(Inc. 70 cm)+50%N	4.16 ^{abc}	2.45	101.8 ^c
SED	0.45	0.06	2.09
CD(P=0.05)	0.93	NS	4.35

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

4.2.2. Rice

4.2.2.1. Plant population

Seasonal effect on the population of rice was not seen during the three seasons of study. The rate of increase in population was more upto panicle initiation (PI) and thereafter it was restricted. This was seen in the green manure intercropped treatments (T₁ to T₁₂), basally green manured treatments (T₁₃ and T₁₆) and also in sole wet seeded rice plots (T₁₄ and T₁₅) (Table 14, 15 and 16).

During all the rice stages *viz.*, dhaincha incorporation, PI and flowering, population difference among treatments was not perceptible during *rabi*, 1999 crop raised in clay soil at Coimbatore. In the transplanted rice + 100 per cent N (T₁₅), the population, was however, markedly low in the above season. The sole wet seeded rice + 100 per cent N (T₁₄) and transplanted rice + 100 per cent N during the above season had a corresponding population of 325 and 259, 770 and 611 and 721 and 594 m⁻² during green manure incorporation, PI and rice flowering respectively.

In the *kharif*, 2000 crop, treatment differences were seen and so also during *rabi*, 2000 crop both of which were raised in sandy loam soil (Bhavanisagar). Late incorporation allowing intercrop dhaincha upto 60 or 70 cm (T₇ to T₉ and T₁₀ to T₁₂) affected the population of rice in both seasons as compared to early incorporation particularly incorporation at 40 cm height. This is the overall trend seen on examination of the data in both seasons collectively.

Recommended dose of N to rice over different heights of incorporation of dhaincha maintained higher population in all the stages during both seasons as compared to lower doses (75 and 50 per cent of recommended N) though statistical difference did not exist. For 100 per cent N at flowering (T₁, T₄, T₇ and T₁₀), the population at 40, 50, 60 and 70 cm dhaincha incorporation was 740, 791, 608 and 679 respectively whereas when the nitrogen was halved (50 per cent N) (T₃, T₆, T₉ and T₁₂), the respective population was 630, 703, 621 and 626 in *kharif*, 2000. Similar trend was seen in *rabi*, 2000 also.

The transplanted rice + 100 per cent N with or without basal incorporation of green manure at 6.25 t ha⁻¹ (T₁₆ and T₁₅ respectively) had, in general lower population in all the rice stages during both *kharif* and *rabi*, 2000 and this was conspicuously

Table 14. Rice plant population m⁻² as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Plant population m ⁻²		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	177	689	726
T ₂ -R+D(Inc. 40 cm)+75%N	240	678	730
T ₃ -R+D(Inc. 40 cm)+50%N	183	642	630
T ₄ -R+D(Inc. 50 cm)+100 %N	246	722	732
T ₅ -R+D(Inc. 50 cm)+75%N	215	644	789
T ₆ -R+D(Inc. 50 cm)+50%N	202	556	677
T ₇ -R+D(Inc. 60 cm)+100 %N	166	624	687
T ₈ -R+D(Inc. 60 cm)+75%N	179	600	694
T ₉ -R+D(Inc. 60 cm)+50%N	135	532	602
T ₁₀ -R+D(Inc. 70 cm)+100 %N	182	691	723
T ₁₁ -R+D(Inc. 70 cm)+75%N	233	568	647
T ₁₂ -R+D(Inc. 70 cm)+50%N	151	590	671
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	317	783	758
T ₁₄ -R+ 100 % N	325	770	721
T ₁₅ -Transplanted rice+100%N	259	611	594
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	58.1	78.6	97.5
CD(P=0.05)	NS	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 15. Rice plant population m⁻² as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Plant population m ⁻²		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	422 ^{b-e}	677 ^a	740 ^{a-d}
T ₂ -R+D(Inc. 40 cm)+75%N	398 ^{c-f}	529 ^{bc}	650 ^{cde}
T ₃ -R+D(Inc. 40 cm)+50%N	354 ^{e-h}	477 ^{bcd}	630 ^{de}
T ₄ -R+D(Inc. 50 cm)+100 %N	403 ^{c-g}	573 ^b	791 ^a
T ₅ -R+D(Inc. 50 cm)+75%N	370 ^{efg}	496 ^{bcd}	772 ^{ab}
T ₆ -R+D(Inc. 50 cm)+50%N	342 ^{fgh}	471 ^{bcd}	703 ^{a-d}
T ₇ -R+D(Inc. 60 cm)+100 %N	498 ^a	543 ^{bc}	608 ^{a-d}
T ₈ -R+D(Inc. 60 cm)+75%N	457 ^{abc}	487 ^{bcd}	670 ^{abc}
T ₉ -R+D(Inc. 60 cm)+50%N	371 ^{d-g}	457 ^{cd}	621 ^{de}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	484 ^{ab}	539 ^{bc}	679 ^{a-d}
T ₁₁ -R+D(Inc. 70 cm)+75%N	439 ^{a-d}	479 ^{bcd}	648 ^{de}
T ₁₂ -R+D(Inc. 70 cm)+50%N	411 ^{c-f}	439 ^d	626 ^{de}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	390 ^{c-g}	543 ^{bc}	740 ^{a-d}
T ₁₄ -R+ 100 % N	354 ^{e-h}	517 ^{bcd}	729 ^{a-d}
T ₁₅ -Transplanted rice+100%N	292 ^h	454 ^{cd}	532 ^e
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	335 ^{gh}	476 ^{bcd}	656 ^{bcd}
SEd	34.2	43.5	58.8
CD(P=0.05)	69.7	88.9	120.2

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 16. Rice plant population m⁻² as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Plant population m ⁻²		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	574 ^{bc}	604 ^{de}	662 ^{abc}
T ₂ -R+D(Inc. 40 cm)+75%N	492 ^e	597 ^{efg}	654 ^{bc}
T ₃ -R+D(Inc. 40 cm)+50%N	491 ^e	578 ^h	632 ^{cd}
T ₄ -R+D(Inc. 50 cm)+100 %N	603 ^b	621 ^{bc}	645 ^{cd}
T ₅ -R+D(Inc. 50 cm)+75%N	475 ^{ef}	602 ^e	642 ^{cd}
T ₆ -R+D(Inc. 50 cm)+50%N	457 ^{fg}	587 ^{fgh}	635 ^{cd}
T ₇ -R+D(Inc. 60 cm)+100 %N	565 ^c	616 ^{cd}	642 ^{cd}
T ₈ -R+D(Inc. 60 cm)+75%N	555 ^{cd}	599 ^{ef}	620 ^d
T ₉ -R+D(Inc. 60 cm)+50%N	434 ^{fg}	529 ⁱ	565 ^{ef}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	531 ^d	631 ^b	680 ^{ab}
T ₁₁ -R+D(Inc. 70 cm)+75%N	499 ^e	609 ^{cde}	662 ^{abc}
T ₁₂ -R+D(Inc. 70 cm)+50%N	409 ^h	586 ^{gh}	646 ^{cd}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	698 ^a	677 ^a	688 ^a
T ₁₄ -R+ 100 % N	553 ^{cd}	618 ^c	649 ^{bcd}
T ₁₅ -Transplanted rice+100%N	431 ^{gh}	482 ^j	537 ^f
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	446 ^{fg}	523 ⁱ	577 ^l
SEd	15.5	6.5	16.0
CD(P=0.05)	31.0	13.0	32.0

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

seen as compared to rice intercropped with dhaincha treatments (T₁ to T₁₂). The sole wet seeded rice + 100 per cent N also had relatively higher population T₁₄).

4.2.2.2. Plant height

In terms of height, rice grew fast upto panicle initiation and thereafter, the height increase was minimum as seen from PI to flowering stage (Tables 17, 18 and 19). From dhaincha incorporation to PI stage, there was approximately three fold increase in the height and it was much less thereafter. Neither the heights of incorporation of intercrop dhaincha (40 to 70 cm height) nor the fertiliser N doses to rice had any significant influence on the rice height and this trend was seen in all the seasons.

4.2.2.3. Dry matter production

In general, rice dry matter production was more in *rabi* (*rabi*, 1999 and *rabi*, 2000) than in *kharif* (*kharif*, 2000) as could be seen clearly at flowering stage (Tables 20, 21 and 22). About 50 per cent of dry matter was produced between PI and flowering stages in *rabi* seasons, while the difference was maximum from dhaincha incorporation to PI stage during *kharif*, 2000.

Increase in the heights of incorporation of dhaincha from 40 to 70cm height (T₁ to T₃, T₄ to T₆, T₇ to T₁₀ and T₁₀ to T₁₂) has not caused any perceptible change in dry matter production in almost all the stages in the three seasons of study. But, consistent and at the same time increased dry matter production was seen with R + D inc. 40 cm + 100 per cent N (T₁) as found from overall observation of three seasons' values. The DMP at flowering in this treatment was 8423, 6482 and 9084 kg ha⁻¹ in the three seasons respectively, whereas in the other intercropped treatments even with 100 per cent N, the dry matter was higher in some years than T₁ and the value was lower in the other years thus lacking consistency as that of the latter.

Dry matter decline, by and large, was little or even inconsistent with reduction in the fertiliser N to rice from 100 to 50 per cent of recommended dose. The mean at 100 per cent of recommended N over three seasons during flowering in rice + green manure intercropping treatments (mean of T₁, T₄, T₇ and T₁₀) was 7930 kg of dry matter, while the respective values were 7833 and 7468 kg for 75 and 50 per cent of

Table 17. Plant height (cm) of rice as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Plant height (cm)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	24.4 ^{bc}	78.9	90.2 ^a
T ₂ -R+D(Inc. 40 cm)+75%N	24.7 ^{bc}	77.2	92.3 ^a
T ₃ -R+D(Inc. 40 cm)+50%N	25.0 ^{bc}	56.8	93.6 ^a
T ₄ -R+D(Inc. 50 cm)+100 %N	25.6 ^{bc}	77.3	94.6 ^a
T ₅ -R+D(Inc. 50 cm)+75%N	26.3 ^b	80.8	97.8 ^a
T ₆ -R+D(Inc. 50 cm)+50%N	25.3 ^{bc}	77.9	90.2 ^a
T ₇ -R+D(Inc. 60 cm)+100 %N	24.9 ^{bc}	74.8	92.3 ^a
T ₈ -R+D(Inc. 60 cm)+75%N	23.9 ^{bcd}	73.4	89.3 ^a
T ₉ -R+D(Inc. 60 cm)+50%N	25.1 ^{bc}	77.3	87.8 ^a
T ₁₀ -R+D(Inc. 70 cm)+100 %N	27.1 ^b	76.7	96.0 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	23.7 ^{bcd}	73.1	92.2 ^a
T ₁₂ -R+D(Inc. 70 cm)+50%N	27.3 ^b	76.4	93.7 ^a
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	22.0 ^{cd}	82.5	94.0 ^a
T ₁₄ -R+ 100 % N	20.4 ^d	79.5	89.7 ^a
T ₁₅ -Transplanted rice+100%N	41.3 ^a	74.5	77.9 ^b
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	1.93	3.81	4.23
CD(P=0.05)	3.97	NS	8.67

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 18. Plant height (cm) of rice as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Plant height (cm)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	50.1 ^{abc}	82.3	91.0
T ₂ -R+D(Inc. 40 cm)+75%N	45.3 ^c	86.1	88.1
T ₃ -R+D(Inc. 40 cm)+50%N	45.5 ^c	82.8	86.1
T ₄ -R+D(Inc. 50 cm)+100 %N	47.1 ^{bc}	82.5	89.3
T ₅ -R+D(Inc. 50 cm)+75%N	51.7 ^{ab}	81.3	89.4
T ₆ -R+D(Inc. 50 cm)+50%N	45.9 ^{bc}	85.6	86.3
T ₇ -R+D(Inc. 60 cm)+100 %N	49.1 ^{abc}	83.4	86.7
T ₈ -R+D(Inc. 60 cm)+75%N	48.8 ^{abc}	80.9	88.8
T ₉ -R+D(Inc. 60 cm)+50%N	51.8 ^{ab}	84.0	88.1
T ₁₀ -R+D(Inc. 70 cm)+100 %N	49.4 ^{abc}	81.4	90.4
T ₁₁ -R+D(Inc. 70 cm)+75%N	50.4 ^{abc}	83.6	87.5
T ₁₂ -R+D(Inc. 70 cm)+50%N	50.4 ^{abc}	83.7	85.7
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	40.7 ^a	81.2	88.9
T ₁₄ -R+ 100 % N	47.6 ^{bc}	84.4	84.4
T ₁₅ -Transplanted rice+100%N	23.3 ^e	83.9	88.4
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	24.6 ^e	86.1	90.2
SEd	2.92	2.17	7.34
CD(P=0.05)	5.97	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 19. Plant height (cm) of rice as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Plant height (cm)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	24.9 ^{hi}	82.5	85.9
T ₂ -R+D(Inc. 40 cm)+75%N	24.7 ⁱ	80.6	84.1
T ₃ -R+D(Inc. 40 cm)+50%N	24.8 ^{hi}	79.6	83.3
T ₄ -R+D(Inc. 50 cm)+100 %N	25.7 ^{gh}	84.2	84.7
T ₅ -R+D(Inc. 50 cm)+75%N	25.1 ^{ghi}	81.3	84.7
T ₆ -R+D(Inc. 50 cm)+50%N	25.7 ^{fg}	77.5	81.8
T ₇ -R+D(Inc. 60 cm)+100 %N	27.2 ^{de}	83.0	82.9
T ₈ -R+D(Inc. 60 cm)+75%N	26.9 ^{ef}	81.1	82.8
T ₉ -R+D(Inc. 60 cm)+50%N	27.3 ^{bcd}	80.4	82.8
T ₁₀ -R+D(Inc. 70 cm)+100 %N	29.8 ^a	84.0	83.4
T ₁₁ -R+D(Inc. 70 cm)+75%N	28.9 ^b	82.7	82.7
T ₁₂ -R+D(Inc. 70 cm)+50%N	28.9 ^b	79.0	81.1
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	27.6 ^{cde}	84.7	85.7
T ₁₄ -R+ 100 % N	26.9 ^{ef}	82.7	84.8
T ₁₅ -Transplanted rice+100%N	20.9 ^j	78.3	80.8
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	21.2 ^h	79.0	83.6
SEd	0.45	6.97	3.24
CD(P=0.05)	0.91	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 20. Dry matter production (kg ha⁻¹) of rice as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Dry matter production (kg ha ⁻¹)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	517 ^g	4739 ^b	8423 ^{bcd}
T ₂ -R+D(Inc. 40 cm)+75%N	693 ^f	4464 ^d	9582 ^{ab}
T ₃ -R+D(Inc. 40 cm)+50%N	490 ^g	4133 ^f	6686 ^{efg}
T ₄ -R+D(Inc. 50 cm)+100 %N	1059 ^c	4734 ^b	8348 ^{bcd}
T ₅ -R+D(Inc. 50 cm)+75%N	908 ^{cde}	4293 ^e	10254 ^a
T ₆ -R+D(Inc. 50 cm)+50%N	781 ^{ef}	3672 ^{hi}	7906 ^{cde}
T ₇ -R+D(Inc. 60 cm)+100 %N	914 ^{cde}	4413 ^d	8261 ^{bcd}
T ₈ -R+D(Inc. 60 cm)+75%N	852 ^{def}	4015 ^g	7637 ^{def}
T ₉ -R+D(Inc. 60 cm)+50%N	769 ^{ef}	3383 ^k	7344 ^{d-g}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	955 ^{cd}	4768 ^b	8590 ^{bcd}
T ₁₁ -R+D(Inc. 70 cm)+75%N	1380 ^b	3626 ^f	6213 ^g
T ₁₂ -R+D(Inc. 70 cm)+50%N	726 ^f	3718 ^h	7874 ^{cde}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	1800 ^a	5394 ^a	8065 ^{cde}
T ₁₄ -R+ 100 % N	1324 ^b	4591 ^c	9201 ^{abc}
T ₁₅ -Transplanted rice+100%N	1038 ^c	3650 ⁱ	6390 ^{fg}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	84	36	686
CD(P=0.05)	172	74	1405

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 21. Dry matter production(kg ha⁻¹) of rice as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Dry matter production (kg ha ⁻¹)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	1621 ^{a-d}	4378 ^{a-d}	6482 ^{a-e}
T ₂ -R+D(Inc. 40 cm)+75%N	1492 ^{cde}	4249 ^{cde}	6353 ^{c-f}
T ₃ -R+D(Inc. 40 cm)+50%N	1443 ^{de}	4200 ^{de}	6304 ^{ef}
T ₄ -R+D(Inc. 50 cm)+100 %N	1673 ^{abc}	4430 ^{abc}	6534 ^{abc}
T ₅ -R+D(Inc. 50 cm)+75%N	1484 ^{cde}	4241 ^{de}	6345 ^{def}
T ₆ -R+D(Inc. 50 cm)+50%N	1398 ^e	4155 ^e	6259 ^f
T ₇ -R+D(Inc. 60 cm)+100 %N	1749 ^a	4506 ^a	6610 ^a
T ₈ -R+D(Inc. 60 cm)+75%N	1694 ^{abc}	4451 ^{ab}	6555 ^{ab}
T ₉ -R+D(Inc. 60 cm)+50%N	1715 ^{ab}	4472 ^{ab}	6576 ^{ab}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	1536 ^{a-e}	4293 ^{b-e}	6397 ^{b-f}
T ₁₁ -R+D(Inc. 70 cm)+75%N	1502 ^{b-e}	4259 ^{cde}	6469 ^{a-e}
T ₁₂ -R+D(Inc. 70 cm)+50%N	1598 ^{a-e}	4355 ^{a-d}	6565 ^{ab}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	817 ^f	3574 ^g	5784 ^g
T ₁₄ -R+ 100 % N	998 ^f	3755 ^f	5965 ^g
T ₁₅ -Transplanted rice+100%N	1545 ^{a-e}	4302 ^{b-e}	6512 ^{a-d}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	1451 ^{de}	3661 ^{fg}	5871 ^g
SEd	104	90	91
CD(P=0.05)	213	184	186

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 22. Dry matter production (kg ha⁻¹) of rice as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Dry matter production (kg ha ⁻¹)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	1056 ^{bc}	4942 ^{bc}	9084 ^a
T ₂ -R+D(Inc. 40 cm)+75%N	892 ^{efg}	4713 ^{cde}	8927 ^{ab}
T ₃ -R+D(Inc. 40 cm)+50%N	736 ^j	4345 ^f	8819 ^{abc}
T ₄ -R+D(Inc. 50 cm)+100 %N	1083 ^{ab}	4986 ^b	8972 ^a
T ₅ -R+D(Inc. 50 cm)+75%N	912 ^{ef}	4579 ^e	8763 ^{a-d}
T ₆ -R+D(Inc. 50 cm)+50%N	879 ^{efg}	4064 ^{gh}	8704 ^{a-d}
T ₇ -R+D(Inc. 60 cm)+100 %N	998 ^d	4718 ^{cde}	8764 ^{a-d}
T ₈ -R+D(Inc. 60 cm)+75%N	859 ^{ghi}	4324 ^f	8518 ^{b-e}
T ₉ -R+D(Inc. 60 cm)+50%N	768 ^j	3776 ^c	8421 ^{cde}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	923 ^e	4826 ^{bcd}	8693 ^{a-d}
T ₁₁ -R+D(Inc. 70 cm)+75%N	869 ^{fg}	4243 ^{fg}	8376 ^{def}
T ₁₂ -R+D(Inc. 70 cm)+50%N	812 ^{hi}	3894 ^{hi}	8152 ^{ef}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	1148 ^a	5648 ^a	8428 ^{cde}
T ₁₄ -R+ 100 % N	1012 ^{cd}	4782 ^{b-e}	8173 ^{ef}
T ₁₅ -Transplanted rice+100%N	978 ^d	4067 ^{gh}	7949 ^f
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	1126 ^d	4671 ^{de}	8244 ^{ef}
SEd	23	115	216
CD(P=0.05)	47	234	442

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

recommended doses. Rice + basal inc. of dhaincha (6.25 t ha^{-1}) + 100 per cent N (T_{13}) had a lower mean value of 7426 kg of dry matter over three seasons as compared to a mean of 7996 kg in Rice + dhaincha inc. 40 cm + 100 per cent N (T_1).

Transplanted rice + 100 per cent N had far less values of dry matter in two (*rabi*, 1999 and *kharif*, 2000) out of three seasons studied. Transplanted rice + 100 per cent N + basal inc. of dhaincha (T_{16}) had lower values of dry matter as compared to rice intercropped with green manure receiving the full dose of N (T_1 , T_4 , T_7 and T_{10}).

4.2.2.4. Light interception

Rice in association with dhaincha (T_1 to T_{12}) intercepted light much higher than unintercropped sole rice (T_{13} and T_{14}) and transplanted treatments (Tables 23, 24 and 25). In the intercropped stands (at incorporation of green manure), the per cent light interception was ranging from 44.3 to 78.0 in *rabi*, 1999, 48.2 to 73.8 in *kharif*, 2000 and 56.8 to 75.6 in *rabi*, 2000 experiments. The corresponding values in unintercropped stands (T_{13} to T_{16}) were 12.3 to 20.0, 16.9 to 23.4 and 18.3 to 24.9. The difference between intercropped (T_1 to T_{12}) and unintercropped stands (T_{13} to T_{16}) was, however, narrowed down in the later stages of rice (after incorporation of green manure) during all the three seasons of study.

Dhaincha intercrop buried at different heights (40 to 70 cm) did not cause any variation with significance on the interception of light by rice. This was seen in almost all the stages over different seasons. Similarly, light interception was not changed due to different levels of fertiliser N also.

Rice row to row spacing was 25 cm in the intercropped stands (T_1 to T_{12}) while it was 12.5 and 20 cm in the transplanted treatments (T_{15} and T_{16}) during *kharif* and *rabi* seasons, respectively. With such wider row spacing of rice after incorporation of intercropped green manure (T_1 to T_{12}) and relatively closely spaced transplanted treatments (T_{15} and T_{16}), there was virtually no difference in the light interception.

4.2.2.5. SPAD 502 and Leaf Colour Chart (LCC) values

These are the indices for indirect estimation of leaf chlorophyll and in turn leaf

Table 23. Light interception (%) of rice as influenced by treatments at different growth stages during rabi 1999

Treatments	Light interception (%)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	73.9 ^a	62.2	87.2
T ₂ -R+D(Inc. 40 cm)+75%N	61.5 ^{abc}	70.4	92.2
T ₃ -R+D(Inc. 40 cm)+50%N	76.6 ^a	57.6	84.4
T ₄ -R+D(Inc. 50 cm)+100 %N	63.8 ^{abc}	71.5	93.2
T ₅ -R+D(Inc. 50 cm)+75%N	58.3 ^{abc}	65.7	91.1
T ₆ -R+D(Inc. 50 cm)+50%N	52.8 ^{bc}	58.6	83.7
T ₇ -R+D(Inc. 60 cm)+100 %N	66.9 ^{ab}	60.0	89.8
T ₈ -R+D(Inc. 60 cm)+75%N	78.0 ^a	52.4	86.8
T ₉ -R+D(Inc. 60 cm)+50%N	68.4 ^{ab}	52.4	87.4
T ₁₀ -R+D(Inc. 70 cm)+100 %N	67.5 ^{ab}	69.1	91.1
T ₁₁ -R+D(Inc. 70 cm)+75%N	57.3 ^{abc}	53.8	88.8
T ₁₂ -R+D(Inc. 70 cm)+50%N	44.3 ^c	66.5	88.7
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	20.0 ^d	69.5	89.6
T ₁₄ -R+ 100 % N	15.8 ^d	71.4	92.3
T ₁₅ -Transplanted rice+100%N	12.3 ^d	67.6	90.2
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	10.2	8.3	3.4
CD(P=0.05)	20.9	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 24. Light interception (%) of rice as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Light interception (%)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	51.3 ^{ef}	73.5	93.2
T ₂ -R+D(Inc. 40 cm)+75%N	50.0 ^f	72.2	89.3
T ₃ -R+D(Inc. 40 cm)+50%N	48.2 ^f	72.0	87.4
T ₄ -R+D(Inc. 50 cm)+100 %N	59.0 ^{cde}	84.3	92.2
T ₅ -R+D(Inc. 50 cm)+75%N	56.0 ^{def}	78.9	88.8
T ₆ -R+D(Inc. 50 cm)+50%N	55.1 ^{def}	82.2	86.8
T ₇ -R+D(Inc. 60 cm)+100 %N	62.1 ^{a-d}	78.2	91.1
T ₈ -R+D(Inc. 60 cm)+75%N	61.7 ^{bcd}	76.4	87.4
T ₉ -R+D(Inc. 60 cm)+50%N	60.8 ^{cd}	77.3	84.4
T ₁₀ -R+D(Inc. 70 cm)+100 %N	73.8 ^{abc}	82.2	91.1
T ₁₁ -R+D(Inc. 70 cm)+75%N	71.1 ^a	80.1	89.6
T ₁₂ -R+D(Inc. 70 cm)+50%N	69.8 ^{ab}	79.8	83.7
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	25.5 ^g	77.9	92.3
T ₁₄ -R+ 100 % N	23.4 ^g	78.2	91.8
T ₁₅ -Transplanted rice+100%N	17.8 ^g	76.3	90.0
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	16.9 ^g	75.9	89.2
SEd	4.4	6.6	7.5
CD(P=0.05)	80.9	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rab* i2000

Table 25. Light interception (%) of rice as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Light interception (%)		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	58.4 ^{efg}	71.1	93.3
T ₂ -R+D(Inc. 40 cm)+75%N	57.5 ^{fgh}	70.9	88.5
T ₃ -R+D(Inc. 40 cm)+50%N	56.7 ^h	70.7	87.6
T ₄ -R+D(Inc. 50 cm)+100 %N	59.7 ^e	72.5	94.2
T ₅ -R+D(Inc. 50 cm)+75%N	58.5 ^{ef}	73.5	90.3
T ₆ -R+D(Inc. 50 cm)+50%N	56.8 ^{gh}	72.8	88.5
T ₇ -R+D(Inc. 60 cm)+100 %N	65.9 ^d	72.6	89.8
T ₈ -R+D(Inc. 60 cm)+75%N	64.6 ^d	73.6	88.7
T ₉ -R+D(Inc. 60 cm)+50%N	64.8 ^d	73.5	87.6
T ₁₀ -R+D(Inc. 70 cm)+100 %N	75.5 ^a	72.8	92.8
T ₁₁ -R+D(Inc. 70 cm)+75%N	72.7 ^b	71.9	89.7
T ₁₂ -R+D(Inc. 70 cm)+50%N	70.7 ^c	71.6	89.0
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	26.8 ⁱ	73.5	91.7
T ₁₄ -R+ 100 % N	24.9 ^j	74.3	91.0
T ₁₅ -Transplanted rice+100%N	18.4 ^k	72.8	91.5
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	18.3 ^k	72.0	92.2
SEd	0.8	4.2	6.3
CD(P=0.05)	1.7	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

N status. There was no variation in the values of these indices in rice due to incorporation of intercropped dhaincha at different heights. Similarly N levels to rice did not alter the SPAD 502 and LCC values (Tables 26 to 31). The trend was alike during all the three seasons of study.

4.2.2.6. Nitrogen uptake

Nitrogen uptake got increased at every stage till harvest (Tables 32, 33 and 34). During *rabi*, 1999 (Coimbatore) and in the subsequent *kharif*, 2000 (Bhavanisagar), the values of mean uptake difference between flowering and harvest stages were 9.3 and 31.8 kg ha⁻¹, respectively. Whereas, during *rabi*, 2000, it was as high as 43.5 kg ha⁻¹.

Incorporation of dhaincha at different heights had its influence on the N uptake during *rabi*, 1999 and 2000 whereas during *kharif*, 2000, the effect was inconsistent. Incorporation at 40 cm height had an average uptake of 76.1 and 108.1 kg ha⁻¹ at harvest during *rabi*, 1999 and 2000, while at 70 cm height, the corresponding uptake values were 68.8 and 107.8 kg ha⁻¹.

The nitrogen uptake got increased with fertiliser N doses from 50 to 100 per cent during all the three seasons of study.

The uptake at harvest in the intercropped stands (T₁ to T₁₂) was relatively more promoted in Rice + dhaincha inc. 40 cm + 100 per cent N than other intercropped treatments. To clarify further, trampling in green manure early (40 cm height) with full dose of N to rice had higher uptake. This trend was seen in two out of three seasons. It was followed by sole rice + 100 per cent N + basal incorporation of green manure at 6.25 t ha⁻¹ (T₁₃). The treatments which did not receive green manure either basally or as a source of intercrop (T₁₄ and T₁₅) had significantly lower values. This was inspite of full dose of N (100 per cent) applied to these treatments. The transplanted rice + 100 per cent N + basal incorporation of green manure (T₁₆) had only comparable values as that of Rice + dhaincha inc. 40 cm + 100 per cent N (T₁).

Table 26. SPAD 502 values as influenced by treatments at different growth stages during *rabi* 1999

Treatments	SPAD 502 values		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	28.8	40.6	38.0
T ₂ -R+D(Inc. 40 cm)+75%N	28.7	42.7	44.7
T ₃ -R+D(Inc. 40 cm)+50%N	24.5	41.3	42.6
T ₄ -R+D(Inc. 50 cm)+100 %N	31.2	41.9	46.5
T ₅ -R+D(Inc. 50 cm)+75%N	31.1	43.7	36.4
T ₆ -R+D(Inc. 50 cm)+50%N	27.7	39.1	39.7
T ₇ -R+D(Inc. 60 cm)+100 %N	26.8	40.6	44.3
T ₈ -R+D(Inc. 60 cm)+75%N	28.0	39.5	37.7
T ₉ -R+D(Inc. 60 cm)+50%N	26.9	41.7	39.1
T ₁₀ -R+D(Inc. 70 cm)+100 %N	28.4	43.7	42.1
T ₁₁ -R+D(Inc. 70 cm)+75%N	29.4	43.2	40.1
T ₁₂ -R+D(Inc. 70 cm)+50%N	29.8	39.6	45.6
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	29.4	40.4	37.2
T ₁₄ -R+ 100 % N	30.6	37.2	37.2
T ₁₅ -Transplanted rice+100%N	30.9	44.5	46.3
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	3.1	2.0	5.9
CD(P=0.05)	NS	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 27. SPAD 502 values as influenced by treatments at different growth stages during *kharif* 2000

Treatments	SPAD 502 values		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	37.9 ^{ab}	40.6	42.3
T ₂ -R+D(Inc. 40 cm)+75%N	38.6 ^{ab}	38.4	42.5
T ₃ -R+D(Inc. 40 cm)+50%N	33.1 ^{bcd}	39.7	40.4
T ₄ -R+D(Inc. 50 cm)+100 %N	38.6 ^{ab}	40.2	42.9
T ₅ -R+D(Inc. 50 cm)+75%N	36.0 ^{ab}	37.2	42.7
T ₆ -R+D(Inc. 50 cm)+50%N	38.2 ^{ab}	36.7	42.4
T ₇ -R+D(Inc. 60 cm)+100 %N	39.0 ^a	40.5	43.0
T ₈ -R+D(Inc. 60 cm)+75%N	26.3 ^d	38.0	41.4
T ₉ -R+D(Inc. 60 cm)+50%N	38.6 ^{ab}	36.8	41.5
T ₁₀ -R+D(Inc. 70 cm)+100 %N	29.4 ^{cd}	40.6	43.5
T ₁₁ -R+D(Inc. 70 cm)+75%N	33.3 ^{abc}	38.9	39.4
T ₁₂ -R+D(Inc. 70 cm)+50%N	38.4 ^{ab}	38.8	42.7
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	38.4 ^{ab}	38.5	42.7
T ₁₄ -R+ 100 % N	41.2 ^{ab}	39.2	43.5
T ₁₅ -Transplanted rice+100%N	33.3 ^{abc}	35.4	40.2
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	35.2 ^{abc}	36.6	43.4
SEd	2.9	1.7	1.8
CD(P=0.05)	5.9	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 28. SPAD 502 values as influenced by treatments at different growth stages during rabi 2000

Treatments	SPAD 502 values		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	28.2 ^{ef}	39.6	41.5
T ₂ -R+D(Inc. 40 cm)+75%N	27.6 ^f	39.5	41.8
T ₃ -R+D(Inc. 40 cm)+50%N	27.5 ^f	39.4	40.6
T ₄ -R+D(Inc. 50 cm)+100 %N	30.7 ^{bcd}	40.8	40.9
T ₅ -R+D(Inc. 50 cm)+75%N	30.6 ^{bcd}	41.0	40.9
T ₆ -R+D(Inc. 50 cm)+50%N	28.1 ^{ef}	38.8	41.1
T ₇ -R+D(Inc. 60 cm)+100 %N	31.2 ^{ab}	41.4	42.2
T ₈ -R+D(Inc. 60 cm)+75%N	30.8 ^{bc}	40.5	41.9
T ₉ -R+D(Inc. 60 cm)+50%N	29.4 ^{cde}	41.5	41.0
T ₁₀ -R+D(Inc. 70 cm)+100 %N	29.3 ^{de}	41.8	41.9
T ₁₁ -R+D(Inc. 70 cm)+75%N	27.8 ^f	41.8	41.8
T ₁₂ -R+D(Inc. 70 cm)+50%N	26.9 ^f	41.5	41.8
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	29.9 ^{bcd}	39.5	41.9
T ₁₄ -R+ 100 % N	30.6 ^{bcd}	39.0	42.4
T ₁₅ -Transplanted rice+100%N	30.9 ^{ab}	41.9	42.4
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	32.3 ^a	42.3	42.5
SEd	0.73	2.0	0.9
CD(P=0.05)	1.49	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

*T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 29. Leaf colour chart values of rice as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Leaf colour values		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	2.87	3.64	4.27
T ₂ -R+D(Inc. 40 cm)+75%N	2.93	3.60	4.57
T ₃ -R+D(Inc. 40 cm)+50%N	2.70	3.80	4.53
T ₄ -R+D(Inc. 50 cm)+100 %N	2.96	3.40	4.63
T ₅ -R+D(Inc. 50 cm)+75%N	3.33	3.64	4.30
T ₆ -R+D(Inc. 50 cm)+50%N	2.77	3.50	3.80
T ₇ -R+D(Inc. 60 cm)+100 %N	2.90	3.60	4.77
T ₈ -R+D(Inc. 60 cm)+75%N	3.10	3.60	4.00
T ₉ -R+D(Inc. 60 cm)+50%N	3.03	3.57	3.93
T ₁₀ -R+D(Inc. 70 cm)+100 %N	2.83	3.64	4.57
T ₁₁ -R+D(Inc. 70 cm)+75%N	3.00	3.57	4.30
T ₁₂ -R+D(Inc. 70 cm)+50%N	2.97	3.43	3.97
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	2.83	3.60	4.10
T ₁₄ -R+ 100 % N	2.67	3.53	4.33
T ₁₅ -Transplanted rice+100%N	3.10	3.74	4.63
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	2.34	0.11	0.34
CD(P=0.05)	NS	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rab i*2000

Table 30. Leaf colour chart values of rice as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Leaf colour values		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	3.23	4.10	4.80
T ₂ -R+D(Inc. 40 cm)+75%N	3.47	4.17	4.34
T ₃ -R+D(Inc. 40 cm)+50%N	3.23	3.34	3.20
T ₄ -R+D(Inc. 50 cm)+100 %N	3.87	3.67	5.00
T ₅ -R+D(Inc. 50 cm)+75%N	3.47	3.84	5.07
T ₆ -R+D(Inc. 50 cm)+50%N	3.47	4.54	4.37
T ₇ -R+D(Inc. 60 cm)+100 %N	3.47	3.84	5.00
T ₈ -R+D(Inc. 60 cm)+75%N	3.20	4.00	4.70
T ₉ -R+D(Inc. 60 cm)+50%N	3.47	3.67	4.67
T ₁₀ -R+D(Inc. 70 cm)+100 %N	3.00	3.67	5.04
T ₁₁ -R+D(Inc. 70 cm)+75%N	3.40	4.00	4.47
T ₁₂ -R+D(Inc. 70 cm)+50%N	4.03	3.97	4.57
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	3.30	3.87	4.80
T ₁₄ -R+ 100 % N	3.60	4.14	5.07
T ₁₅ -Transplanted rice+100%N	4.07	3.57	5.00
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	3.90	4.17	5.07
SEd	0.35	0.34	0.42
CD(P=0.05)	NS	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 31. Leaf colour chart values of rice as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Leaf colour values		
	At incorporation of dhaincha	At panicle initiation	At flowering
T ₁ -R+D(Inc. 40 cm)+100 %N	2.89	3.71	4.54
T ₂ -R+D(Inc. 40 cm)+75%N	2.94	3.64	4.32
T ₃ -R+D(Inc. 40 cm)+50%N	2.78	3.60	4.31
T ₄ -R+D(Inc. 50 cm)+100 %N	2.99	3.75	4.68
T ₅ -R+D(Inc. 50 cm)+75%N	2.85	3.68	4.59
T ₆ -R+D(Inc. 50 cm)+50%N	2.81	3.62	4.56
T ₇ -R+D(Inc. 60 cm)+100 %N	3.10	3.84	4.78
T ₈ -R+D(Inc. 60 cm)+75%N	2.98	3.78	4.42
T ₉ -R+D(Inc. 60 cm)+50%N	2.94	3.74	4.39
T ₁₀ -R+D(Inc. 70 cm)+100 %N	3.11	3.76	4.73
T ₁₁ -R+D(Inc. 70 cm)+75%N	2.99	3.73	4.58
T ₁₂ -R+D(Inc. 70 cm)+50%N	2.96	3.73	4.56
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	2.71	3.62	4.69
T ₁₄ -R+ 100 % N	2.68	3.64	4.57
T ₁₅ -Transplanted rice+100%N	3.20	3.71	4.74
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	3.30	3.73	4.72
SEd	0.47	0.28	0.41
CD(P=0.05)	NS	NS	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 32. Nitrogen uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Nitrogen uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	29.3 ^a	64.3 ^b	79.2 ^a
T ₂ -R+D(Inc. 40 cm)+75%N	28.2 ^a	60.4 ^d	76.3 ^{ab}
T ₃ -R+D(Inc. 40 cm)+50%N	27.6 ^a	60.6 ^{cd}	72.9 ^{b-e}
T ₄ -R+D(Inc. 50 cm)+100 %N	28.7 ^a	64.1 ^b	76.4 ^{ab}
T ₅ -R+D(Inc. 50 cm)+75%N	27.4 ^a	64.0 ^b	74.3 ^{a-d}
T ₆ -R+D(Inc. 50 cm)+50%N	26.5 ^a	63.6 ^b	71.8 ^{b-e}
T ₇ -R+D(Inc. 60 cm)+100 %N	27.8 ^a	63.9 ^b	73.5 ^{b-e}
T ₈ -R+D(Inc. 60 cm)+75%N	27.2 ^a	63.2 ^{bcd}	70.2 ^{c-f}
T ₉ -R+D(Inc. 60 cm)+50%N	27.1 ^a	62.6 ^{bcd}	69.3 ^{def}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	27.0 ^a	63.4 ^{bc}	69.7 ^{c-f}
T ₁₁ -R+D(Inc. 70 cm)+75%N	26.8 ^a	62.6 ^{bcd}	68.4 ^{ef}
T ₁₂ -R+D(Inc. 70 cm)+50%N	26.4 ^a	62.3 ^{bcd}	68.2 ^{ef}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	30.3 ^a	70.4 ^a	75.3 ^{abc}
T ₁₄ -R+ 100 % N	28.4 ^a	56.8 ^c	65.9 ^f
T ₁₅ -Transplanted rice+100%N	12.3 ^b	54.9 ^e	64.6 ^f
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	2.29	1.41	2.78
CD(P=0.05)	4.68	2.89	5.70

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 33. Nitrogen uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Nitrogen uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	31.2 ^{cd}	67.6 ^a	98.7 ^{bc}
T ₂ -R+D(Inc. 40 cm)+75%N	27.2 ^{fg}	62.4 ^{def}	91.2 ^{fg}
T ₃ -R+D(Inc. 40 cm)+50%N	25.9 ^{gh}	61.2 ^{def}	89.3 ^{fg}
T ₄ -R+D(Inc. 50 cm)+100 %N	32.9 ^b	68.2 ^a	100.4 ^{bc}
T ₅ -R+D(Inc. 50 cm)+75%N	26.7 ^{fgh}	62.6 ^{de}	92.5 ^{efg}
T ₆ -R+D(Inc. 50 cm)+50%N	25.6 ^{hi}	60.2 ^{ef}	90.4 ^f
T ₇ -R+D(Inc. 60 cm)+100 %N	35.2 ^a	69.4 ^a	112.6 ^a
T ₈ -R+D(Inc. 60 cm)+75%N	32.4 ^{bc}	67.1 ^{ab}	99.8 ^{bc}
T ₉ -R+D(Inc. 60 cm)+50%N	30.1 ^{de}	66.4 ^{abc}	96.7 ^{cde}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	30.8 ^d	64.3 ^{bcd}	102.9 ^b
T ₁₁ -R+D(Inc. 70 cm)+75%N	29.2 ^e	63.4 ^{cde}	93.7 ^{def}
T ₁₂ -R+D(Inc. 70 cm)+50%N	27.6 ^f	62.2 ^{def}	92.6 ^{ef}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	30.9 ^d	68.2 ^a	97.6 ^{cd}
T ₁₄ -R+ 100 % N	21.2 ^j	59.2 ^f	86.4 ^g
T ₁₅ -Transplanted rice+100%N	24.3 ⁱ	61.3 ^{def}	90.7 ^{fg}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	32.8 ^b	63.4 ^{cde}	100.7 ^{bc}
SEd	0.73	1.61	2.42
CD(P=0.05)	1.50	3.30	4.95

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 34. Nitrogen uptake (kg ha⁻¹) of rice as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Nitrogen uptake (kg ha ⁻¹)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	30.9 ^{ab}	68.2 ^{ab}	117.4 ^a
T ₂ -R+D(Inc. 40 cm)+75%N	26.7 ^{cde}	64.3 ^{cd}	111.7 ^{bcd}
T ₃ -R+D(Inc. 40 cm)+50%N	25.2 ^{def}	62.5 ^{def}	95.3 ^f
T ₄ -R+D(Inc. 50 cm)+100 %N	29.8 ^b	69.8 ^{ab}	114.6 ^{abc}
T ₅ -R+D(Inc. 50 cm)+75%N	26.3 ^{cde}	63.2 ^{def}	110.5 ^{bcd}
T ₆ -R+D(Inc. 50 cm)+50%N	24.7 ^{c-f}	60.9 ^{ef}	93.2 ^f
T ₇ -R+D(Inc. 60 cm)+100 %N	28.6 ^c	63.8 ^{de}	113.4 ^{abc}
T ₈ -R+D(Inc. 60 cm)+75%N	25.2 ^{def}	61.7 ^{def}	109.8 ^{cd}
T ₉ -R+D(Inc. 60 cm)+50%N	23.9 ^{fg}	57.6 ^{gh}	104.1 ^e
T ₁₀ -R+D(Inc. 70 cm)+100 %N	27.1 ^{cd}	67.2 ^{bc}	112.7 ^{a-d}
T ₁₁ -R+D(Inc. 70 cm)+75%N	26.4 ^{cde}	60.8 ^{efg}	107.4 ^{de}
T ₁₂ -R+D(Inc. 70 cm)+50%N	22.2 ^g	56.8 ^h	103.3 ^e
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	32.1 ^a	71.3 ^a	115.9 ^{ab}
T ₁₄ -R+ 100 % N	27.4 ^c	63.5 ^{de}	94.8 ^f
T ₁₅ -Transplanted rice+100%N	24.8 ^{ef}	60.2 ^{fg}	96.3 ^f
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	26.2 ^{cde}	64.2 ^{cd}	112.1 ^{a-d}
SEd	0.93	1.59	2.70
CD(P=0.05)	1.91	3.25	5.51

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

4.2.2.7. Phosphorus uptake

There was progressive increase in the uptake of phosphorus till harvest (Tables 35, 36 and 37). As in N uptake, during *rabi*, 2000, the uptake difference between flowering and harvest was relatively larger than in the earlier two seasons. The mean difference between flowering and harvest was 9.3 kg ha⁻¹ during *rabi*, 2000, while it was 9.95 and 7.2 kg ha⁻¹ during *rabi*, 1999 and *kharif*, 2000 seasons respectively.

Incorporation of dhaincha at different heights had no perceptible influence on the phosphorus uptake of rice, while the levels of fertiliser N to rice had concomitant changes in the uptake of phosphorus. There was, by and large, progressive increase in the uptake of phosphorus when the fertiliser N was increased from 50 to 100 per cent.

When the uptake at different stages over three seasons was examined in the intercropped stands (T₁ to T₁₂), Rice + dhaincha inc. 40 cm + 100 per cent N had relatively more uptake during *rabi* seasons. As in N uptake, reduction in P uptake was clearly pronounced in sole rice + 100 per cent N (T₁₄) and transplanted rice + 100 per cent N (T₁₅) both not receiving green manure either basally or by intercrop green manuring. The intercropped stands (T₁ to T₁₂) had an average uptake of 28.3, 25.7 and 28.9 kg ha⁻¹ at harvest during *rabi*, 1999, *kharif*, 2000 and *rabi*, 2000 seasons, respectively. The corresponding uptake values were 26.3, 20.8 and 23.8 kg ha⁻¹ for sole rice + 100 per cent N (T₁₄) and 25.6, 22.3 and 24.5 kg ha⁻¹ for transplanted rice + 100 per cent N (T₁₅).

4.2.2.8. Potassium uptake

Potassium uptake was higher in *rabi*, 1999 than in the other seasons particularly during flowering and harvest stages (Table 38, 39 and 40). As observed in both *rabi* seasons, early dhaincha incorporation at 40 cm height had higher uptake of potassium and it got decreased with height increments. During *rabi*, 1999, the uptake was 136.3 kg ha⁻¹ with Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) at harvest stage, while it was as low as 119.0 kg ha⁻¹ with Rice + dhaincha inc. 70 cm + 50 per cent N (T₁₂) thus showing declining trend when dhaincha was allowed to grow taller and buried. Similarly, during *rabi*, 2000, the corresponding values were 105.7

Table 35. Phosphorus uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Phosphorus uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	5.9	18.8 ^{abc}	29.0 ^{ab}
T ₂ -R+D(Inc. 40 cm)+75%N	5.8	19.1 ^a	28.5 ^{a-d}
T ₃ -R+D(Inc. 40 cm)+50%N	5.7	17.9 ^{de}	28.3 ^{b-f}
T ₄ -R+D(Inc. 50 cm)+100 %N	5.9	18.9 ^{ab}	29.0 ^a
T ₅ -R+D(Inc. 50 cm)+75%N	4.9	18.5 ^{a-d}	28.1 ^{c-f}
T ₆ -R+D(Inc. 50 cm)+50%N	4.6	17.7 ^{ef}	27.6 ^{ef}
T ₇ -R+D(Inc. 60 cm)+100 %N	5.7	18.8 ^{abc}	28.7 ^{abc}
T ₈ -R+D(Inc. 60 cm)+75%N	5.4	18.1 ^{b-e}	28.3 ^{a-e}
T ₉ -R+D(Inc. 60 cm)+50%N	5.2	17.6 ^{ef}	27.5 ^f
T ₁₀ -R+D(Inc. 70 cm)+100 %N	5.2	18.0 ^{cde}	28.6 ^{abc}
T ₁₁ -R+D(Inc. 70 cm)+75%N	5.0	17.6 ^{ef}	28.4 ^{a-e}
T ₁₂ -R+D(Inc. 70 cm)+50%N	4.8	16.9 ^{fg}	27.7 ^{def}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	5.8	19.3 ^a	28.4 ^{a-e}
T ₁₄ -R+ 100 % N	5.0	16.5 ^g	26.3 ^g
T ₁₅ -Transplanted rice+100%N	5.2	17.0 ^{fg}	25.6 ^g
T ₁₆ -Transplanted rice+100%N + basal 2Inc. D(6.25 t/ha)*	-	-	-
SEd	0.5	0.41	0.39
CD(P=0.05)	NS	0.82	0.81

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 36. Phosphorus uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Phosphorus uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	6.8 ^c	19.2 ^b	26.9 ^{de}
T ₂ -R+D(Inc. 40 cm)+75%N	5.7 ^e	19.1 ^b	23.2 ^h
T ₃ -R+D(Inc. 40 cm)+50%N	4.2 ^h	18.7 ^{bc}	21.3 ^{ij}
T ₄ -R+D(Inc. 50 cm)+100 %N	7.2 ^b	19.0 ^b	28.0 ^{cd}
T ₅ -R+D(Inc. 50 cm)+75%N	5.8 ^e	19.0 ^b	23.1 ^h
T ₆ -R+D(Inc. 50 cm)+50%N	4.6 ^g	18.2 ^{bcd}	22.7 ^h
T ₇ -R+D(Inc. 60 cm)+100 %N	8.1 ^a	18.6 ^{bc}	31.7 ^a
T ₈ -R+D(Inc. 60 cm)+75%N	6.9 ^{bc}	17.4 ^{bcd}	27.3 ^{cde}
T ₉ -R+D(Inc. 60 cm)+50%N	5.7 ^e	17.2 ^{bcd}	25.4 ^{fg}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	5.3 ^f	18.3 ^{bcd}	30.2 ^b
T ₁₁ -R+D(Inc. 70 cm)+75%N	5.3 ^f	17.4 ^{bcd}	24.8 ^g
T ₁₂ -R+D(Inc. 70 cm)+50%N	5.2 ^f	16.8 ^{bcd}	23.2 ^h
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	6.6 ^{cd}	22.4 ^a	26.2 ^{ef}
T ₁₄ -R+ 100 % N	4.1 ^h	17.3 ^{bcd}	20.8 ⁱ
T ₁₅ -Transplanted rice+100%N	5.2 ^f	15.7 ^d	22.3 ^{hi}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	6.3 ^d	16.2 ^{cd}	28.6 ^c
SEd	0.16	1.29	0.64
CD(P=0.05)	0.32	2.64	1.31

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 37. Phosphorus uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Phosphorus uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	6.2 ^b	21.8 ^{bc}	34.2 ^a
T ₂ -R+D(Inc. 40 cm)+75%N	4.9 ^c	20.4 ^d	30.6 ^{cd}
T ₃ -R+D(Inc. 40 cm)+50%N	4.4 ^{fg}	19.0 ^{ef}	24.0 ^h
T ₄ -R+D(Inc. 50 cm)+100 %N	5.9 ^c	22.6 ^b	32.9 ^{ab}
T ₅ -R+D(Inc. 50 cm)+75%N	4.7 ^f	19.8 ^{de}	29.4 ^{de}
T ₆ -R+D(Inc. 50 cm)+50%N	4.1 ^{hi}	17.5 ^{gh}	23.8 ^h
T ₇ -R+D(Inc. 60 cm)+100 %N	5.2 ^d	19.4 ^e	32.9 ^{ab}
T ₈ -R+D(Inc. 60 cm)+75%N	4.4 ^{fgh}	18.2 ^{fg}	28.7 ^e
T ₉ -R+D(Inc. 60 cm)+50%N	4.2 ^{gh}	15.6 ⁱ	26.4 ^{fg}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	4.9 ^e	23.7 ^a	31.3 ^{bc}
T ₁₁ -R+D(Inc. 70 cm)+75%N	4.5 ^{fg}	17.3 ^{gh}	26.9 ^f
T ₁₂ -R+D(Inc. 70 cm)+50%N	3.9 ⁱ	14.9 ⁱ	25.1 ^{gh}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	7.3 ^a	24.3 ^a	33.7 ^a
T ₁₄ -R+ 100 % N	5.2 ^d	19.4 ^e	23.8 ^h
T ₁₅ -Transplanted rice+100%N	4.0 ⁱ	17.0 ^h	24.5 ^h
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	5.1 ^{dc}	21.6 ^c	31.9 ^{bc}
SEd	0.12	0.50	0.72
CD(P=0.05)	0.24	1.00	1.46

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 38. Potassium uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Potassium uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	25.2 ^b	85.5 ^a	136.3 ^a
T ₂ -R+D(Inc. 40 cm)+75%N	24.5 ^{bc}	84.8 ^b	134.0 ^{ab}
T ₃ -R+D(Inc. 40 cm)+50%N	23.6 ^{de}	83.6 ^d	130.0 ^{cd}
T ₄ -R+D(Inc. 50 cm)+100 %N	25.0 ^b	84.3 ^{bc}	134.0 ^{ab}
T ₅ -R+D(Inc. 50 cm)+75%N	24.1 ^{cd}	83.5 ^d	130.0 ^{cd}
T ₆ -R+D(Inc. 50 cm)+50%N	23.5 ^{de}	82.3 ^e	126.0 ^{fg}
T ₇ -R+D(Inc. 60 cm)+100 %N	23.9 ^{cd}	83.9 ^{cd}	131.0 ^{bcd}
T ₈ -R+D(Inc. 60 cm)+75%N	23.6 ^{de}	82.4 ^e	126.3 ^{ef}
T ₉ -R+D(Inc. 60 cm)+50%N	23.0 ^e	81.2 ^f	121.7 ^{hi}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	23.8 ^d	82.2 ^e	129.3 ^{de}
T ₁₁ -R+D(Inc. 70 cm)+75%N	22.0 ^f	81.1 ^f	123.0 ^{gh}
T ₁₂ -R+D(Inc. 70 cm)+50%N	21.5 ^f	79.4 ^g	119.0 ⁱ
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	26.9 ^a	85.8 ^a	133.0 ^{bc}
T ₁₄ -R+ 100 % N	14.0 ^h	76.6 ^h	128.7 ^{def}
T ₁₅ -Transplanted rice+100%N	15.5 ^g	74.9 ⁱ	122.7 ^h
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	0.33	0.31	1.55
CD(P=0.05)	0.68	0.63	3.17

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 39. Potassium uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Potassium uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	26.3 ^c	62.7 ^{ab}	89.6 ^{bcd}
T ₂ -R+D(Inc. 40 cm)+75%N	25.2 ^{cd}	56.6 ^{f-i}	83.4 ^{fg}
T ₃ -R+D(Inc. 40 cm)+50%N	24.8 ^d	56.2 ^{ghi}	80.7 ^{gh}
T ₄ -R+D(Inc. 50 cm)+100 %N	27.7 ^b	63.4 ^a	91.5 ^{bcd}
T ₅ -R+D(Inc. 50 cm)+75%N	24.6 ^{de}	56.8 ^{e-i}	83.6 ^{fg}
T ₆ -R+D(Inc. 50 cm)+50%N	23.5 ^{ef}	55.7 ^{hi}	81.3 ^{gh}
T ₇ -R+D(Inc. 60 cm)+100 %N	31.4 ^a	64.6 ^a	102.8 ^a
T ₈ -R+D(Inc. 60 cm)+75%N	27.9 ^b	62.2 ^{ab}	92.6 ^{bc}
T ₉ -R+D(Inc. 60 cm)+50%N	25.7 ^b	61.7 ^{ab}	87.5 ^{def}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	25.2 ^{cd}	59.8 ^{a-d}	93.8 ^b
T ₁₁ -R+D(Inc. 70 cm)+75%N	24.8 ^d	59.3 ^{c-f}	84.6 ^{efg}
T ₁₂ -R+D(Inc. 70 cm)+50%N	23.1 ^f	57.4 ^{e-h}	83.1 ^{fg}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	26.2 ^c	63.5 ^a	88.7 ^{cde}
T ₁₄ -R+ 100 % N	17.4 ^g	54.1 ⁱ	77.8 ^{gh}
T ₁₅ -Transplanted rice+100%N	18.9 ^h	57.4 ^{e-h}	80.9 ^h
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	27.6 ^b	58.8 ^{d-g}	92.6 ^{bc}
SEd	0.63	1.50	2.19
CD(P=0.05)	1.28	3.07	4.48

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 40. Potassium uptake (kg ha^{-1}) of rice as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Potassium uptake (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	27.8 ^b	63.4 ^{bc}	105.7 ^a
T ₂ -R+D(Inc. 40 cm)+75%N	24.6 ^{de}	61.2 ^{cde}	99.8 ^{bcd}
T ₃ -R+D(Inc. 40 cm)+50%N	22.7 ^{hi}	58.3 ^{efg}	87.9 ^{fg}
T ₄ -R+D(Inc. 50 cm)+100 %N	26.4 ^c	64.7 ^{ab}	103.5 ^{ab}
T ₅ -R+D(Inc. 50 cm)+75%N	22.1 ^{hi}	58.4 ^{efg}	99.8 ^{a-d}
T ₆ -R+D(Inc. 50 cm)+50%N	21.8 ⁱ	55.9 ^{fg}	81.8 ^h
T ₇ -R+D(Inc. 60 cm)+100 %N	25.7 ^{cd}	58.7 ^{ef}	101.7 ^{abc}
T ₈ -R+D(Inc. 60 cm)+75%N	23.1 ^{gh}	56.6 ^{fg}	98.4 ^{cd}
T ₉ -R+D(Inc. 60 cm)+50%N	19.9 ^j	52.9 ^{hi}	92.9 ^e
T ₁₀ -R+D(Inc. 70 cm)+100 %N	24.3 ^{efg}	62.3 ^{bcd}	100.4 ^{bcd}
T ₁₁ -R+D(Inc. 70 cm)+75%N	23.2 ^{gh}	55.7 ^{gh}	96.7 ^{de}
T ₁₂ -R+D(Inc. 70 cm)+50%N	19.3 ^j	51.9 ⁱ	92.4 ^{ef}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	29.2 ^a	66.7 ^a	103.6 ^{ab}
T ₁₄ -R+ 100 % N	24.5 ^{def}	58.4 ^{efg}	82.8 ^h
T ₁₅ -Transplanted rice+100%N	21.6 ⁱ	55.6 ^{gh}	84.7 ^{gh}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	23.3 ^{fgh}	59.7 ^{dc}	101.2 ^{a-d}
SEd	0.60	1.46	2.36
CD(P=0.05)	1.23	2.98	4.82

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

and 92.4 kg ha⁻¹. The relation between height of incorporation of green manure and potassium uptake was not, however, clear during *kharif*, 2000.

The uptake of potassium got decreased with reduction in the fertiliser N levels from 100 to 50 per cent of the recommended dose and this was uniformly seen during all the seasons of study.

The uptake, by and large, was higher when the intercropped green manure was trampled in at tender state with full recommended dose of fertiliser N to rice [Rice + dhaincha inc. 40 cm + 100 per cent N (T₁)]. Further, this treatment had comparable uptake as that of sole rice + 100 per cent N with basally green manure applied treatment, T₁₃.

Absence of green manuring either basally or by intercropping resulted in lower potassium uptake (T₁₄ and T₁₅). Such reduced uptake was seen invariably during all the three seasons.

4.2.3. Yield attributes of rice

The data on yield attributes *viz.*, panicles m⁻², filled and illfilled grains panicle⁻¹ and test weight are furnished seasonwise in tables 41, 42 and 43.

4.2.3.1. Panicles m⁻²

In the green manure intercropped treatments, there was wider variation in the number of panicles produced which ranged from 461 (T₁₁) to 569 (T₁), 398 (T₉) to 509 (T₄) and 517 (T₁₂) to 582 (T₁) during *rabi*, 1999, *kharif*, 2000 and *rabi*, 2000 seasons, respectively. Incorporation of green manure at different heights affected the panicle production. The mean of three seasons' panicle m⁻² for 40, 50, 60 and 70 cm height of incorporation of dhaincha were 519, 507, 497 and 484 respectively. Thus when dhaincha was allowed to grow taller and buried, particularly at 60 and 70 cm height, the effect was found detrimental reducing the panicle production.

Panicle production came down more so at increased height of incorporation of dhaincha with reduction in fertiliser N to rice from 100 to 50 per cent of the recommended dose.

Wet seeded rice + basal incorporation of green manure + 100 per cent N to rice (T₁₃) resulted in higher production of panicles (563, 475 and 559 during *rabi*,

1999, *kharif*, 2000 and *rabi*, 2000 respectively). Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) produced similar number of panicles as that of T₁₃ during *rabi*, 1999 and *kharif*, 2000 and outscored considerably during *rabi*, 2000 (582 for T₁ and 559 for T₁₃).

There was considerable fall in panicle production in the absence of green manuring whether the rice was wet seeded (T₁₄) or transplanted (T₁₅) even with full dose of N (100 per cent). While the mean number of panicles of three seasons' green manured treatments either by intercropping (T₁ to T₁₂) or by basal application (T₁₃ and T₁₆) stood at 501 m⁻², it was as low as 464 m⁻² in the absence of green manuring (T₁₄ and T₁₅). Transplanting rice with basal application of dhaincha (T₁₆) produced less number of panicles as compared to green manure intercropped, wet seeded rice (T₁ to T₁₂).

4.2.3.2. Filled grains panicle⁻¹

Number of filled grains panicle⁻¹ varied among intercropped green manure treatments (T₁ to T₁₂) during all the three seasons of study. Grain filling was influenced depending upon the growth of intercropped dhaincha. When it was allowed to grow taller particularly at 60 or 70 cm, the filled grains panicle⁻¹ generally got reduced. At each height of incorporation, reduction in filled grains was significant with reduced dose of fertiliser N to rice. The mean of three seasons for 100, 75 and 50 per cent N were 147, 136 and 131 filled grains panicle⁻¹ respectively. The detrimental effect of reduced dose of nitrogen was relatively more than trampling in taller (60 or 70 cm) dhaincha, as observed from the data collectively.

Filled grains were considerably reduced in the absence of green manuring (T₁₄ and T₁₅). Transplanted rice + 100 per cent N + basal incorporation of dhaincha at 6.25 t ha⁻¹ (T₁₆) had 167 and 143 number of filled grains panicle⁻¹ and it was not better than green manure intercropped treatments such as T₁, T₁₀ etc.,

4.2.3.3. Illfilled grains panicle⁻¹

Between two main variables tested in combinations viz., dhaincha incorporation height and levels of fertiliser N to rice, it was the height at which the green manure was buried caused more variation on the grain illfilling (Tables 41, 42

and 43). At 40, 50, 60 and 70 cm heights, the average illfilled grains over different N levels and seasons were 15.8, 12.3, 10.3 and 8.3 panicle⁻¹, whereas the corresponding values for 100, 75 and 50 per cent N were 9.5, 11.8 and 13.8 panicle⁻¹. In other words, more the green manure biomass addition, lesser were the illfilled grains. In the absence of green manuring [sole wet seeded rice + 100 per cent N (T₁₄) and transplanted rice + 100 per cent N (T₁₅)], the illfilled grains were relatively much higher.

4.2.3.4. 1000 grain weight

There was no significant variation in the test weight of rice grain either due to green manuring or by varying the dose of fertiliser N to rice (Tables 41, 42 and 43). This was seen in all the three seasons of study.

4.2.3.5. Grain and straw yield

The data on rice grain and straw yield are furnished in tables 44, 45 and 46. The increase in the incorporation height of intercropped green manure (at the increments of 10 cm) from 40 to 70 cm gave an average yield of 5135, 4830, 5207 and 5083 kg ha⁻¹, respectively. Thus the impact of incorporation height could not be ascertained clearly. However, in two out of three seasons *i.e.*, in both *rabi* seasons, incorporation at 40 cm height gave relatively higher yield than all other heights of incorporation

Reduction in N to rice from 100 to 50 per cent of recommended dose led to decline in rice yield. The average grain yield over different dhaincha heights and seasons for 100, 75 and 50 per cent were 5484, 5016 and 4691 kg ha⁻¹ respectively.

In combinations of intercropped green manure height and N levels to rice, the treatment rice + dhaincha inc. 40 cm + 100 per cent N (T₁), performed better from the point of consistency and comparability than all other intercropped treatments (T₁ to T₁₂) as observed from three seasons of study. The average yield of this treatment for three seasons was 5540 kg ha⁻¹ and its yield was comparable to that of sole wet seeded rice + basal incorporation of green manure + 100 per cent N (T₁₃) which gave on an average 5700 kg ha⁻¹. Thus, given 100 per cent N to both treatments, what was achieved by basal incorporation of green manure was almost realised by intercropping

Table 41. Yield attributes of rice as influenced by treatments during *rabi* 1999

Treatments	Yield attributes			
	Panicles m ⁻²	Filled grains panicle ⁻¹	Illfilled grains panicle ⁻¹	1000 grain weight
T ₁ -R+D(Inc. 40 cm)+100 %N	569	128.4	15.0 ^e	21.04
T ₂ -R+D(Inc. 40 cm)+75%N	569	114.0	16.3 ^d	20.85
T ₃ -R+D(Inc. 40 cm)+50%N	534	101.5	19.4 ^c	20.82
T ₄ -R+D(Inc. 50 cm)+100 %N	467	97.6	7.0 ^k	20.98
T ₅ -R+D(Inc. 50 cm)+75%N	469	103.8	11.2 ^g	20.51
T ₆ -R+D(Inc. 50 cm)+50%N	463	106.2	14.3 ^e	21.41
T ₇ -R+D(Inc. 60 cm)+100 %N	533	94.9	4.5 ^l	20.92
T ₈ -R+D(Inc. 60 cm)+75%N	530	104.6	8.1 ^{ij}	20.53
T ₉ -R+D(Inc. 60 cm)+50%N	481	102.5	12.3 ^f	20.62
T ₁₀ -R+D(Inc. 70 cm)+100 %N	529	137.6	5.4 ^l	21.85
T ₁₁ -R+D(Inc. 70 cm)+75%N	461	101.1	7.2 ^{jk}	21.26
T ₁₂ -R+D(Inc. 70 cm)+50%N	493	110.2	9.7 ^h	20.35
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	563	120.2	8.6 ⁱ	20.21
T ₁₄ -R+ 100 % N	476	88.3	22.1 ^b	20.58
T ₁₅ -Transplanted rice+100%N	570	114.5	26.3 ^a	22.10
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-	-
SEd	44.1	19.5	0.49	0.76
CD(P=0.05)	NS	NS	1.01	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 42. Yield attributes of rice as influenced by treatments during *kharif* 2000

Treatments	Yield attributes			
	Panicles m ⁻²	Filled grains panicle ⁻¹	Illfilled grains panicle ⁻¹	1000 grain weight
T ₁ -R+D(Inc. 40 cm)+100 %N	475 ^c	175 ^{ab}	17.3 ^c	20.9
T ₂ -R+D(Inc. 40 cm)+75%N	417 ^f	155 ^{fgh}	18.2 ^{de}	20.9
T ₃ -R+D(Inc. 40 cm)+50%N	404 ^g	147 ^{hi}	19.8 ^c	20.8
T ₄ -R+D(Inc. 50 cm)+100 %N	509 ^a	174 ^{abc}	14.3 ^g	21.1
T ₅ -R+D(Inc. 50 cm)+75%N	497 ^b	151 ^{gh}	16.2 ^f	20.3
T ₆ -R+D(Inc. 50 cm)+50%N	452 ^d	141 ^j	17.4 ^c	20.1
T ₇ -R+D(Inc. 60 cm)+100 %N	448 ^d	171 ^{bcd}	12.4 ^h	21.2
T ₈ -R+D(Inc. 60 cm)+75%N	430 ^e	158 ^{efg}	14.6 ^g	20.5
T ₉ -R+D(Inc. 60 cm)+50%N	398 ^g	148 ^{hi}	15.2 ^{fg}	20.4
T ₁₀ -R+D(Inc. 70 cm)+100 %N	436 ^e	180 ^a	8.2 ^j	20.3
T ₁₁ -R+D(Inc. 70 cm)+75%N	416 ^f	165 ^{cde}	10.3 ⁱ	20.7
T ₁₂ -R+D(Inc. 70 cm)+50%N	402 ^g	149 ^{hi}	11.4 ^h	21.2
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	475 ^c	164 ^{def}	15.3 ^{fg}	20.8
T ₁₄ -R+ 100 % N	471 ^c	160 ^{efg}	28.2 ^b	20.0
T ₁₅ -Transplanted rice+100%N	341 ^h	147 ^{hi}	30.4 ^a	21.9
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	421 ^f	167 ^{b-e}	18.5 ^{cd}	21.5
SEd	3.51	4.55	0.51	1.70
CD(P=0.05)	7.20	9.90	1.04	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 43. Yield attributes of rice as influenced by treatments during *rabi* 2000

Treatments	Yield attributes			
	Panicles m ⁻²	Filled grains panicle ⁻¹	Illfilled grains panicle ⁻¹	1000 grain weight
T ₁ -R+D(Inc. 40 cm)+100 %N	c	154 ^a	9.8 ^{ef}	21.2
T ₂ -R+D(Inc. 40 cm)+75%N	571 ^b	147 ^{b-e}	12.0 ^d	21.2
T ₃ -R+D(Inc. 40 cm)+50%N	554 ^e	146 ^{c-f}	14.2 ^c	21.1
T ₄ -R+D(Inc. 50 cm)+100 %N	579 ^a	151 ^{abc}	8.3 ^{gh}	20.9
T ₅ -R+D(Inc. 50 cm)+75%N	564 ^c	145 ^{def}	10.4 ^e	20.6
T ₆ -R+D(Inc. 50 cm)+50%N	561 ^{cd}	138 ^{ghi}	11.8 ^d	20.7
T ₇ -R+D(Inc. 60 cm)+100 %N	572 ^b	152 ^{ab}	6.2 ⁱ	21.0
T ₈ -R+D(Inc. 60 cm)+75%N	546 ^f	139 ^{ghi}	8.9 ^g	20.9
T ₉ -R+D(Inc. 60 cm)+50%N	532 ^h	136 ^{hi}	10.2 ^{ef}	20.8
T ₁₀ -R+D(Inc. 70 cm)+100 %N	563 ^{cd}	149 ^{a-d}	5.3 ^j	20.7
T ₁₁ -R+D(Inc. 70 cm)+75%N	538 ^g	143 ^{efg}	7.8 ^h	20.6
T ₁₂ -R+D(Inc. 70 cm)+50%N	517 ⁱ	141 ^{fgh}	9.7 ^f	20.6
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	559 ^d	147 ^{b-e}	12.2 ^d	20.8
T ₁₄ -R+ 100 % N	482 ^j	134 ⁱ	16.3 ^b	20.6
T ₁₅ -Transplanted rice+100%N	442 ^l	142 ^{efg}	18.3 ^a	20.5
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	469 ^k	143 ^{efg}	13.8 ^c	20.6
SEd	5.5	2.57	0.30	0.82
CD(P=0.05)	11.0	5.05	0.61	NS

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

dhaincha and burying it at tender state (at 40 cm height) (T₁). Further, it (T₁) has given far higher yield than transplanted rice + 100 per cent N (T₁₅), the average yield of the latter being 4512 kg ha⁻¹.

The fall in grain yield was sharp in the absence of green manuring either by intercropping or by its basal application (T₁₄ and T₁₅). The average yield of three seasons by green manuring was 5150 kg ha⁻¹, while in its absence and even with 100 per cent fertiliser N (T₁₄ and T₁₅), it was 4515 kg ha⁻¹.

Thus green manure intercropping in wet seeded rice and burying it at tender state of 40 cm height was advantageous and secured comparable yield as that of basally green manure incorporated treatment in the same wet seeded rice both receiving full dose of N (T₁ vs T₁₃). Again such intercropping outscored transplanted rice received with full dose of N and basal incorporation of green manure (T₁₆). Absence of green manuring reflected on the grain yield of rice.

The rice straw yield due to treatment effects was similar to its grain yield.

4.2.4. Economics of rice establishment and N levels

In the experiment repeated for three seasons, rice was wet seeded with or without intercropping green manure and they were subject to different levels of N (100 to 50 per cent of recommended dose) (T₁ to T₁₄). These treatment combinations were compared in the present study with transplanted rice, again with or without green manuring (T₁₅ and T₁₆). The costs and returns for different establishment techniques with different levels of N are presented in Tables 44, 45 and 46.

4.2.4.1. Gross returns

The gross returns varied from Rs. 22933 [Rice + dhaincha inc. 50 cm + 50 per cent N] (T₆) to Rs.34358 [Sole wet seeded rice + basal inc. dhaincha at 6.25 + ha⁻¹ + 100 per cent N] (T₁₃) during *rabi*, 1999, Rs.24921 [Sole wet seeded rice + 100 per cent N] (T₁₄) to Rs.38660 [Rice + dhaincha inc. 60 cm + 100 per cent N] (T₇) during *kharif*, 2000 and Rs.33750 [Rice + dhaincha inc. 70 cm + 50 per cent N] (T₁₂) to Rs.40667 [Rice + dhaincha inc. 40 cm + 100 per cent N] (T₁), during *rabi*, 2000. Thus consistency in the performance of treatments in giving returns is lacking. It is

known from the above comparison that full dose of N led to higher returns, while reduction in N (50 per cent) minimised it.

The mean returns of three seasons were maximum at Rs.37509 ha⁻¹ in the transplanted rice + 100 per cent N + basal incorporation of green manure at 6.25 t ha⁻¹ (T₁₆) and it was followed by Rice + basal incorporation of dhaincha at 6.25 t ha⁻¹ + 100 per cent N (T₁₃) at Rs.36354 ha⁻¹. The mean return in Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) was close enough to T₁₃ securing Rs.35318 ha⁻¹.

4.2.4.2. Net returns

As in gross returns, there is wider variation in the net returns among the treatments imposed and such variation is seen in all the three different seasons. It varied from Rs.10320 ha⁻¹ secured by Rice + dhaincha inc. 50 cm + 75 per cent N (T₅) to Rs.19663 ha⁻¹ obtained by Rice + basal inc. dhaincha at 6.25 t ha⁻¹ + 100 per cent N (T₁₃) during *rabi*, 1999. During *kharif*, 2000, it was from Rs.12228 ha⁻¹ netted by transplanted rice + 100 per cent N (T₁₅) to Rs.25518 ha⁻¹ realised by Rice + dhaincha inc. 60 cm + 100 per cent N (T₇). In *rabi*, 2000, it was Rs.18846 ha⁻¹ in Rice + dhaincha inc. at 50 cm + 50 per cent N (T₆) to as high as Rs.27160 ha⁻¹ in Rice + dhaincha inc. 40 cm + 100 per cent N (T₁).

The average returns, in the absence of consistency in any of the treatments, were in the order of Rice + dhaincha inc. at 40 cm + 100 per cent N (T₁) (Rs.22240 ha⁻¹) > Rice + dhaincha inc. 60 cm + 100 per cent N (T₇) (Rs.21592 ha⁻¹) > Rice + dhaincha basal inc. at 6.25 t ha⁻¹ + 100 per cent N (T₁₃) (Rs.21469). It was followed by transplanted rice with basal incorporation of green manure + 100 per cent N (T₁₆) (Rs.21396 ha⁻¹). The returns were reduced conspicuously in the absence of green manuring (T₁₄ and T₁₅) (Rs.15563 ha⁻¹ on an average) as compared to a mean of Rs.19640 ha⁻¹ secured by all the green manured treatments over three seasons (T₁ to T₁₃ and T₁₆).

The seasonwise variation in returns and the mean returns furnished above also clearly indicates that with 100 per cent N to rice only, the treatments, by and large, secured higher returns.

Both transplanted rice treatments (T₁₅ and T₁₆) received with 100 per cent N to rice had average net returns of Rs.17612 ha⁻¹, while from all the wet seeded rice treatments with or without green manuring and the fertiliser N application ranging from 50 to 100 per cent, it was Rs.19549 ha⁻¹. Thus wet seeding with all variations in N dose secured higher returns, while transplanted rice with 100 per cent N realised comparatively lower profit.

4.2.4.3. Benefit Cost Ratio (BCR)

The BCR also varied widely among the treatments. The treatments' performance are not the same over seasons. The mean ratio of three seasons for individual treatment showed similar trend as that of net returns with Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) securing a higher value of 2.70. It was followed by Rice + dhaincha inc. 60 cm + 100 per cent N (T₇) (2.62), Rice + dhaincha inc. 70 cm + 100 per cent N (T₁₀) (2.59) and the transplanted rice + basal inc. of green manure at 6.25 t ha⁻¹ + 100 per cent N (T₁₆) had a ratio of 2.33 positioning itself to fifth place among the best performing treatments. In the treatments which did not receive green manuring (T₁₄ and T₁₅), the average value of the ratio over different seasons stood at 2.16, while it was 2.48 in the green manured treatments (T₁ to T₁₃ and T₁₆).

4.2.5. Yield and soil fertility status

One of the key purposes of the present study is to find out the influence of intercropping and *in situ* incorporation of green manuring on the yield of wet seeded rice through the changes in soil fertility status. The periodical organic carbon status and nitrogen availability in the soil, nitrogen uptake at different stages were, therefore correlated with the yield to give an explanation as to how the rice yield was influenced ultimately. The seasonwise correlation matrix is furnished in the table 47.

A close observation of the 'r' values under different seasons showed that it was the organic carbon status in the soil (oci) on the day of incorporation of green manure (but prior to turning in green manure) that had consistent and positive association with the yield. Similarly, soil available nitrogen at flowering (nf) had consistent positive association with the yield with 'r' values being 0.65**, 0.65** and 0.47* during *rabi*, 1999, *kharif*, 2000 and *rabi*, 2000 respectively.

Table 44. Yield (kg ha⁻¹) and economics (Rs. ha⁻¹) of rice as influenced by treatments during *rabi* 1999

Treatments	Yield (kg ha ⁻¹) and economics (Rs ha ⁻¹)				
	Grain yield	Straw yield	Gross returns	Net returns	B:C ratio
T ₁ -R+D(Inc. 40 cm)+100 %N	4650 ^{ab}	7440 ^{ab}	29714	16841	2.31
T ₂ -R+D(Inc. 40 cm)+75%N	4660 ^{ab}	7540 ^{ab}	29811	17313	2.39
T ₃ -R+D(Inc. 40 cm)+50%N	4500 ^{abc}	7200 ^{abc}	28755	16631	2.37
T ₄ -R+D(Inc. 50 cm)+100 %N	4500 ^{abc}	7290 ^{abc}	28781	15908	2.24
T ₅ -R+D(Inc. 50 cm)+75%N	3560 ^c	5870 ^c	22818	10320	1.83
T ₆ -R+D(Inc. 50 cm)+50%N	3580 ^c	5870 ^c	22933	10809	1.89
T ₇ -R+D(Inc. 60 cm)+100 %N	4360 ^{bc}	7110 ^{bc}	27914	14843	2.14
T ₈ -R+D(Inc. 60 cm)+75%N	4200 ^{bc}	6800 ^{bc}	26870	14174	2.12
T ₉ -R+D(Inc. 60 cm)+50%N	3690 ^c	5900 ^c	23578	11256	1.91
T ₁₀ -R+D(Inc. 70 cm)+100 %N	4650 ^{ab}	7530 ^{ab}	29750	16481	2.24
T ₁₁ -R+D(Inc. 70 cm)+75%N	4090 ^{bc}	6630 ^{bc}	26170	13276	2.03
T ₁₂ -R+D(Inc. 70 cm)+50%N	4370 ^{bc}	6920 ^{bc}	27896	15376	2.23
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	5370 ^a	8700 ^a	34358	19663	2.34
T ₁₄ -R+ 100 % N	4390 ^{bc}	7110 ^{bc}	28087	15392	2.21
T ₁₅ -Transplanted rice+100%N	3790 ^{bc}	6140 ^{bc}	24249	11182	1.86
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-	-	-
SEd	470	760	-	-	-
CD(P=0.05)	960	1550	-	-	-

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rab i*2000

Table 45. Yield (kg ha⁻¹) and economics (Rs. ha⁻¹) of rice as influenced by treatments during *kharif* 2000

Treatments	Yield (kg ha ⁻¹) and economics (Rs ha ⁻¹)				
	Grain yield	Straw yield	Gross returns	Net returns	B:C ratio
T ₁ -R+D(Inc. 40 cm)+100 %N	5570 ^{a-d}	8910 ^{a-d}	35592	22720	2.77
T ₂ -R+D(Inc. 40 cm)+75%N	4770 ^{d-h}	7630 ^{d-h}	30480	17907	2.42
T ₃ -R+D(Inc. 40 cm)+50%N	4480 ^{gh}	7170 ^{gh}	28628	16354	2.33
T ₄ -R+D(Inc. 50 cm)+100 %N	5630 ^{a-d}	9010 ^{a-d}	35977	23106	2.80
T ₅ -R+D(Inc. 50 cm)+75%N	4670 ^{e-h}	7470 ^{e-h}	29841	17268	2.38
T ₆ -R+D(Inc. 50 cm)+50%N	4510 ^{fgh}	7220 ^{fgh}	28821	16547	2.35
T ₇ -R+D(Inc. 60 cm)+100 %N	6050 ^a	9680 ^a	38660	25518	2.94
T ₈ -R+D(Inc. 60 cm)+75%N	5680 ^{abc}	9080 ^{abc}	36292	23449	2.83
T ₉ -R+D(Inc. 60 cm)+50%N	5390 ^{a-f}	8620 ^{a-f}	34441	21897	2.75
T ₁₀ -R+D(Inc. 70 cm)+100 %N	5850 ^{ab}	9360 ^{ab}	37382	23970	2.79
T ₁₁ -R+D(Inc. 70 cm)+75%N	5020 ^{b-g}	8030 ^{c-g}	32077	18964	2.45
T ₁₂ -R+D(Inc. 70 cm)+50%N	4820 ^{c-g}	7710 ^{c-g}	30799	17985	2.40
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	5470 ^{a-c}	8750 ^{a-c}	34953	20260	2.38
T ₁₄ -R+ 100 % N	3900 ^h	6240 ^h	24921	12228	1.96
T ₁₅ -Transplanted rice+100%N	4400 ^{gh}	7040 ^{gh}	28346	14459	2.04
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	5700 ^{abc}	9120 ^{ab}	36423	20536	2.29
SEd	430	690	-	-	-
CD(P=0.05)	880	1410	-	-	-

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rab* 2000

Table 46. Yield (kg ha⁻¹) and economics(Rs. ha⁻¹) of rice as influenced by treatments during *rabi* 2000

Treatments	Yield (kg ha ⁻¹) and economics (Rs ha ⁻¹)				
	Grain yield	Straw yield	Gross returns	Net returns	B:C ratio
T ₁ -R+D(Inc. 40 cm)+100 %N	6401 ^a	9602 ^a	40647	27160	3.01
T ₂ -R+D(Inc. 40 cm)+75%N	5985 ^{bcd}	8978 ^{bcd}	38005	24892	2.90
T ₃ -R+D(Inc. 40 cm)+50%N	5202 ^{gh}	7803 ^{gh}	33033	20294	2.59
T ₄ -R+D(Inc. 50 cm)+100 %N	6106 ^{abc}	9157 ^{abc}	38772	25285	2.87
T ₅ -R+D(Inc. 50 cm)+75%N	5937 ^{cd}	8907 ^{cd}	37700	24587	2.88
T ₆ -R+D(Inc. 50 cm)+50%N	4974 ^h	7461 ^h	31585	18846	2.48
T ₇ -R+D(Inc. 60 cm)+100 %N	6016 ^{bc}	9024 ^{bc}	38202	24445	2.78
T ₈ -R+D(Inc. 60 cm)+75%N	5912 ^{cd}	8868 ^{cd}	37341	23958	2.79
T ₉ -R+D(Inc. 60 cm)+50%N	5562 ^{ef}	8343 ^{ef}	35319	22310	2.71
T ₁₀ -R+D(Inc. 70 cm)+100 %N	6024 ^{bc}	9036 ^{bc}	38252	24225	2.73
T ₁₁ -R+D(Inc. 70 cm)+75%N	5704 ^{de}	8556 ^{de}	36220	22597	2.66
T ₁₂ -R+D(Inc. 70 cm)+50%N	5315 ^{fg}	7973 ^{fg}	33750	20491	2.54
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	6260 ^{ab}	9390 ^{ab}	39751	24485	2.60
T ₁₄ -R+ 100 % N	5256 ^h	7884 ^h	33756	20490	2.54
T ₁₅ -Transplanted rice+100%N	5349 ^{fg}	8024 ^{fg}	33966	19626	2.37
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	6078 ^{bc}	9117 ^{bc}	38595	22255	2.36
SEd	145	218	-	-	-
CD(P=0.05)	296	446	-	-	-

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rab i*2000

Table 47. Correlation between yield and soil fertility status

	Yield	oci	ocf	och	ni	nf	Nh	ui	uf	uh
<i>rabi 1999</i>										
Yield	1.00									
oci	0.71	1.00								
ocf	0.19	0.56	1.00							
och	0.41	0.80	0.80	1.00						
ni	0.47	0.38	0.27	0.24	1.00					
nf	0.65	0.54	-0.08	0.37	0.48	1.00				
nh	-0.03	0.47	0.60	0.65	0.22	0.21	1.00			
ui	-0.38	-0.05	-0.08	-0.01	-0.27	-0.04	0.16	1.00		
uf	0.41	0.75	0.55	0.85	0.40	0.58	0.66	0.16	1.00	
uh	0.42	0.69	0.16	0.63	0.06	0.72	0.49	0.21	0.63	1.00
t (P=0.05) : 0.44										
<i>kharif 2000</i>										
Yield	1.00									
oci	0.64	1.00								
ocf	0.54	0.79	1.00							
och	0.53	0.61	0.87	1.00						
ni	0.41	0.37	0.01	-0.15	1.00					
nf	0.65	0.44	0.01	-0.08	0.51	1.00				
nh	0.38	0.62	0.82	0.75	-0.22	-0.01	1.00			
ui	0.72	0.45	0.26	0.31	0.34	0.71	0.06	1.00		
uf	0.71	0.46	0.23	0.32	0.31	0.76	0.07	0.93	1.00	
uh	0.97	0.71	0.65	0.62	0.32	0.57	0.56	0.64	0.63	1.00
t (P=0.05) : 0.43										
<i>rabi 2000</i>										
Yield	1.00									
oci	0.60	1.00								
ocf	0.77	0.61	1.00							
och	0.71	0.42	0.87	1.00						
ni	0.21	0.57	-0.06	-0.14	1.00					
nf	0.47	0.64	0.19	0.03	0.79	1.00				
nh	0.79	0.63	0.83	0.65	0.10	0.42	1.00			
ui	0.98	0.56	0.74	0.66	0.17	0.49	0.80	1.00		
uf	0.87	0.57	0.63	0.58	0.17	0.44	0.64	0.88	1.00	
uh	0.93	0.52	0.73	0.73	0.11	0.35	0.63	0.92	0.82	1.00
t (P= 0.05) : 0.43										

oci- Organic carbon at incorporation
ocf- Organic carbon at flowering
och- Organic carbon at harvest
ni- Soil available nitrogen at incorporation
nf- Soil available nitrogen at flowering

nh- Soil available nitrogen at harvest
ui- Nitrogen uptake at incorporation
uf- Nitrogen uptake at flowering
uh- Nitrogen uptake at harvest

From the observation between independent variables, it is seen that higher soil organic carbon content at flowering (ocf) led to its higher content at rice harvest stage (och) also (ocf vs och). Similarly, if nitrogen uptake was higher at flowering (uf), its uptake at harvest was also more (uf vs uh). So also, when soil available nitrogen at flowering was higher (nf), its uptake at harvest (uh) was also higher (nf vs uh) in two of the three seasons studied. Thus, soil available nitrogen at flowering (nf) has positive association with its uptake at harvest (uh) and also on rice yield (yld).

4.2.6. Soil available nitrogen at harvest and rice maturity

The rice maturity was earlier by 17, 4 and 5 days in transplanted rice (T₁₅ and T₁₆) as compared to wet seeded rice (T₁ to T₁₄) (Table 48) in the three seasons respectively. The rice maturity days were correlated with soil available nitrogen at harvest (Table 49). As soil available nitrogen at harvest was more, the days to maturity also increased having significant positive association in two of three seasons studied (0.68**, - 0.31^{NS} and 0.57**).

4.2.7. Soil fertility status at harvest

4.2.7.1. Soil organic carbon

During the three seasons of study, soil organic carbon, by and large, built up with advancement of rice growth and development. This was more clearly seen in the last two seasons (*kharif*, 2000 and *rabi*, 2000) (Tables 50, 51 and 52). Similarly increase in the fertiliser N dose to rice from 50 to 100 per cent increased the organic carbon content over different heights of incorporation. The average values of soil organic carbon content of three seasons at harvest were 0.78, 0.70 and 0.69 per cent for 100, 75 and 50 per cent recommended dose of fertiliser N. Sole rice + 100 per cent N + basal incorporation of green manure at 6.25 t ha⁻¹ (T₁₃) had maintained, by and large, higher levels of carbon right from the early stage of rice to till it was harvested (T₁₃). Similarly the transplanted rice + 100 per cent N + basal inc. dhaincha at 6.25 t ha⁻¹ (T₁₆) built up the organic carbon content.

Soil organic carbon was significantly low in all the rice stages over three seasons of study in the treatments *viz.*, sole rice + 100 per cent N (T₁₄) and



Table 48. Rice duration to maturity as influenced by soil available nitrogen at harvest

Treatment	Days to attain maturity		
	<i>rabi</i> 1999	<i>kharif</i> 2000	<i>rabi</i> 2000
T ₁ to T ₁₄	150	121	133
T ₁₅ and T ₁₆	133	117	128

Table 49. Correlation between soil available nitrogen at harvest and days to maturity

	Correlation coefficient (r)
<i>rabi</i> 1999	0.684 ^{**}
<i>kharif</i> 2000	-0.312 ^{NS}
<i>rabi</i> 2000	0.572 ^{**}

Table 50. Soil organic carbon content (%) as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Soil organic carbon content (%)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	1.15 ^{ab}	0.80 ^{fg}	1.09 ^{ab}
T ₂ -R+D(Inc. 40 cm)+75%N	1.04 ^{bcd}	0.81 ^{fg}	0.86 ^{ef}
T ₃ -R+D(Inc. 40 cm)+50%N	0.72 ^{gh}	0.66 ^{gh}	0.79 ^f
T ₄ -R+D(Inc. 50 cm)+100 %N	1.03 ^{cd}	0.97 ^{cde}	1.06 ^{a-d}
T ₅ -R+D(Inc. 50 cm)+75%N	0.81 ^{fgh}	0.81 ^{fgh}	0.90 ^{df}
T ₆ -R+D(Inc. 50 cm)+50%N	0.70 ^g	0.71 ^g	0.89 ^{ef}
T ₇ -R+D(Inc. 60 cm)+100 %N	0.95 ^{de}	1.26 ^a	1.17 ^{ac}
T ₈ -R+D(Inc. 60 cm)+75%N	0.80 ^{fg}	1.09 ^{bcd}	1.00 ^{b-e}
T ₉ -R+D(Inc. 60 cm)+50%N	0.79 ^{fgh}	0.98 ^{cde}	0.92 ^{def}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	1.10 ^{abc}	1.16 ^{ab}	1.07 ^{abc}
T ₁₁ -R+D(Inc. 70 cm)+75%N	0.97 ^d	1.09 ^{bc}	0.90 ^{def}
T ₁₂ -R+D(Inc. 70 cm)+50%N	0.84 ^{cf}	0.93 ^{def}	0.95 ^{b-f}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	1.21 ^a	0.92 ^{ef}	1.10 ^{ab}
T ₁₄ -R+ 100 % N	0.68 ^h	0.57 ^h	0.61 ^g
T ₁₅ -Transplanted rice+100%N	0.46 ⁱ	0.56 ^h	0.58 ^g
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	0.06	0.07	0.08
CD(P=0.05)	0.12	0.16	0.16

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 51. Soil organic carbon content (%) as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Soil organic carbon content (%)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	0.39 ^{de}	0.59 ^{de}	0.62 ^d
T ₂ -R+D(Inc. 40 cm)+75%N	0.38 ^e	0.58 ^{ef}	0.60 ^{ef}
T ₃ -R+D(Inc. 40 cm)+50%N	0.38 ^e	0.56 ^g	0.59 ^{fg}
T ₄ -R+D(Inc. 50 cm)+100 %N	0.40 ^{cd}	0.60 ^{cd}	0.64 ^c
T ₅ -R+D(Inc. 50 cm)+75%N	0.39 ^{de}	0.59 ^{de}	0.61 ^{de}
T ₆ -R+D(Inc. 50 cm)+50%N	0.38 ^e	0.58 ^{ef}	0.58 ^{gh}
T ₇ -R+D(Inc. 60 cm)+100 %N	0.41 ^{bc}	0.62 ^{ab}	0.66 ^b
T ₈ -R+D(Inc. 60 cm)+75%N	0.40 ^{cd}	0.61 ^{bc}	0.62 ^d
T ₉ -R+D(Inc. 60 cm)+50%N	0.39 ^{de}	0.60 ^{cd}	0.60 ^{ef}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	0.42 ^b	0.63 ^a	0.68 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	0.41 ^{bc}	0.62 ^{ab}	0.64 ^a
T ₁₂ -R+D(Inc. 70 cm)+50%N	0.40 ^{cd}	0.59 ^{de}	0.61 ^{de}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	0.46 ^a	0.60 ^{cd}	0.60 ^{ef}
T ₁₄ -R+ 100 % N	0.38 ^e	0.57 ^{fg}	0.58 ^{gh}
T ₁₅ -Transplanted rice+100%N	0.38 ^f	0.55 ^g	0.57 ^h
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	0.41 ^{bc}	0.59 ^{cd}	0.59 ^{fg}
SEd	0.008	0.008	0.008
CD(P=0.05)	0.017	0.017	0.017

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 52. Soil organic carbon content (%) as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Soil organic carbon content (%)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	0.40 ^{ef}	0.52 ^{ghi}	0.54 ^{efg}
T ₂ -R+D(Inc. 40 cm)+75%N	0.37 ^g	0.51 ^{hij}	0.53 ^{fg}
T ₃ -R+D(Inc. 40 cm)+50%N	0.37 ^g	0.48 ^k	0.52 ^g
T ₄ -R+D(Inc. 50 cm)+100 %N	0.42 ^{cde}	0.56 ^{de}	0.59 ^{cd}
T ₅ -R+D(Inc. 50 cm)+75%N	0.40 ^{ef}	0.54 ^{efg}	0.57 ^{de}
T ₆ -R+D(Inc. 50 cm)+50%N	0.38 ^{fg}	0.53 ^{fgh}	0.56 ^{def}
T ₇ -R+D(Inc. 60 cm)+100 %N	0.44 ^{bc}	0.57 ^{cd}	0.61 ^{bc}
T ₈ -R+D(Inc. 60 cm)+75%N	0.42 ^{cde}	0.56 ^{de}	0.59 ^{cd}
T ₉ -R+D(Inc. 60 cm)+50%N	0.40 ^{ef}	0.55 ^{def}	0.59 ^{cd}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	0.45 ^b	0.61 ^b	0.63 ^b
T ₁₁ -R+D(Inc. 70 cm)+75%N	0.43 ^{bcd}	0.59 ^{bc}	0.61 ^{bc}
T ₁₂ -R+D(Inc. 70 cm)+50%N	0.41 ^{de}	0.60 ^b	0.62 ^{bc}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	0.48 ^a	0.65 ^a	0.68 ^a
T ₁₄ -R+ 100 % N	0.36 ^g	0.50 ^{ijk}	0.52 ^g
T ₁₅ -Transplanted rice+100%N	0.36 ^g	0.49 ^{jk}	0.54 ^{efg}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	0.44 ^{bc}	0.59 ^{bc}	0.63 ^b
SEd	0.013	0.014	0.016
CD(P=0.05)	0.027	0.029	0.033

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

transplanted rice + 100 per cent N (T₁₅) not received with green manure either basally or by intercropping and *in situ* green manuring.

4.2.7.2. Soil available nitrogen

Soil available nitrogen got built up as the crop advanced to different stages in all the green manure intercropped treatments (Tables 53, 54 and 55). In the treatments where there was no green manuring either basally or by intercropping [Rice + 100 per cent N (T₁₄) and transplanted rice + 100 per cent N (T₁₅)], its status remained almost same till harvest. The average soil nitrogen of three seasons at incorporation of green manure, rice flowering and at rice harvest were 247.7, 250.7 and 242.7 kg ha⁻¹ for T₁₄ and 246.3, 244 and 236.7 kg ha⁻¹ for T₁₅ respectively.

In the basally green manured treatments both in wet seeded (T₁₃) and transplanted rice (T₁₆) with 100 per cent, the available N got increased to some extent upto flowering and thereafter it declined.

There was a distinguishing difference between rice flowering and harvest stages regarding the influence of dhaincha incorporation at different heights. With increase in the incorporation height, the availability got down at flowering, while it was the other way at harvest. This trend was seen during all the three seasons of study: At flowering, as compared to intercropped green manure treatments (T₁ to T₁₂), the available soil N was higher in the basally green manured, wet seeded rice with 100 per cent N (T₁₃). It was followed by transplanted rice + 100 per cent N + basal incorporation of dhaincha (T₁₆).

At rice harvest, on the other hand, with increase in the height of incorporation of intercropped dhaincha (40 to 70 cm), the soil available N got built up surpassing even basally green manured treatment (T₁₃) (in two out of three seasons) (*rabi*, 1999 and 2000 seasons) which showed higher value at flowering.

Reduction in the dose of fertiliser N to rice from 100 to 50 per cent of recommended level resulted in slight decrease in soil available nitrogen by and large.

During rice flowering stage, among the intercropped treatments, incorporation of dhaincha at tender state (40 cm) with 100 per cent N to rice (T₁) showed higher values than when it was trampled in at increased height (70 cm). On 100 per cent N

Table 53. Soil available nitrogen (kg ha⁻¹) as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Soil available nitrogen (kg ha ⁻¹)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	257 ^{bcd}	295 ^b	304 ^{efg}
T ₂ -R+D(Inc. 40 cm)+75%N	270 ^{abc}	291 ^{bc}	293 ^g
T ₃ -R+D(Inc. 40 cm)+50%N	251 ^{bcd}	282 ^{bcd}	303 ^{fg}
T ₄ -R+D(Inc. 50 cm)+100 %N	229 ^d	282 ^{bcd}	319 ^{b-e}
T ₅ -R+D(Inc. 50 cm)+75%N	241 ^{cd}	257 ^{d-g}	316 ^{c-f}
T ₆ -R+D(Inc. 50 cm)+50%N	247 ^{bcd}	257 ^{d-g}	327 ^{abc}
T ₇ -R+D(Inc. 60 cm)+100 %N	258 ^{bcd}	269 ^{cde}	317 ^{b-f}
T ₈ -R+D(Inc. 60 cm)+75%N	275 ^{ab}	253 ^{efg}	333 ^{ab}
T ₉ -R+D(Inc. 60 cm)+50%N	269 ^{abc}	258 ^{def}	324 ^{bc}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	262 ^{bc}	232 ^{fg}	321 ^{bcd}
T ₁₁ -R+D(Inc. 70 cm)+75%N	262 ^{bc}	231 ^{fg}	327 ^{abc}
T ₁₂ -R+D(Inc. 70 cm)+50%N	245 ^{bcd}	232 ^g	342 ^a
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	298 ^a	353 ^a	309 ^{def}
T ₁₄ -R+ 100 % N	249 ^{bcd}	250 ^{efg}	246 ^h
T ₁₅ -Transplanted rice+100%N	254 ^{bcd}	239 ^{fg}	232 ^h
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	14.8	13.1	7.96
CD(P=0.05)	30.4	26.9	16.3

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 54. Soil available nitrogen (kg ha^{-1}) as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Soil available nitrogen (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	263 ^c	286 ^b	296 ^{cde}
T ₂ -R+D(Inc. 40 cm)+75%N	260 ^{cd}	284 ^b	284 ^{fg}
T ₃ -R+D(Inc. 40 cm)+50%N	249 ^{ef}	263 ^{def}	276 ^g
T ₄ -R+D(Inc. 50 cm)+100 %N	231 ^{hij}	277 ^{bc}	298 ^{bcd}
T ₅ -R+D(Inc. 50 cm)+75%N	225 ^{jk}	267 ^{cde}	290 ^{def}
T ₆ -R+D(Inc. 50 cm)+50%N	220 ^k	260 ^{d-g}	287 ^{ef}
T ₇ -R+D(Inc. 60 cm)+100 %N	240 ^{fgh}	270 ^{cd}	302 ^{abc}
T ₈ -R+D(Inc. 60 cm)+75%N	238 ^{ghi}	267 ^{cde}	300 ^{a-d}
T ₉ -R+D(Inc. 60 cm)+50%N	230 ^{ij}	254 ^{fg}	300 ^{a-d}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	250 ^e	268 ^{cde}	310 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	238 ^{ghi}	260 ^{d-g}	308 ^{ab}
T ₁₂ -R+D(Inc. 70 cm)+50%N	246 ^{efg}	248 ^g	300 ^{a-d}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	295 ^a	321 ^a	308 ^{ab}
T ₁₄ -R+ 100 % N	251 ^{de}	256 ^{efg}	244 ^h
T ₁₅ -Transplanted rice+100%N	246 ^{efg}	248 ^g	242 ^h
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	281 ^b	310 ^a	302 ^{abc}
SEd	4.41	5.9	5.4
CD(P=0.05)	9.01	12.1	11.0

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 55. Soil available nitrogen (kg ha^{-1}) as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Soil available nitrogen (kg ha^{-1})		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	248 ^b	273 ^{bc}	285 ^{cd}
T ₂ -R+D(Inc. 40 cm)+75%N	244 ^{bc}	266 ^{cd}	276 ^{de}
T ₃ -R+D(Inc. 40 cm)+50%N	237 ^{cde}	261 ^{de}	269 ^e
T ₄ -R+D(Inc. 50 cm)+100 %N	219 ^{ghi}	265 ^{de}	290 ^{abc}
T ₅ -R+D(Inc. 50 cm)+75%N	216 ^{hi}	262 ^{de}	286 ^{bcd}
T ₆ -R+D(Inc. 50 cm)+50%N	203 ^j	254 ^{e-h}	282 ^{cd}
T ₇ -R+D(Inc. 60 cm)+100 %N	227 ^{efg}	258 ^{def}	294 ^{abc}
T ₈ -R+D(Inc. 60 cm)+75%N	226 ^{fg}	256 ^{d-g}	291 ^{abc}
T ₉ -R+D(Inc. 60 cm)+50%N	251 ^{hi}	248 ^{f-i}	287 ^{bcd}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	242 ^{bcd}	250 ^{f-i}	302 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	235 ^{c-f}	241 ^{ij}	300 ^a
T ₁₂ -R+D(Inc. 70 cm)+50%N	232 ^{def}	237 ^j	298 ^{ab}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	276 ^a	294 ^a	282 ^{cd}
T ₁₄ -R+ 100 % N	243 ^{bc}	246 ^{g-i}	238 ^f
T ₁₅ -Transplanted rice+100%N	239 ^{bcd}	245 ^{hij}	236 ^f
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	269 ^a	279 ^b	267 ^e
SEd	5.31	5.27	6.28
CD(P=0.05)	10.84	10.76	12.82

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

application, the respective values of soil available N at 40 and 70 cm height of incorporation of dhaincha were 295 and 232 kg ha⁻¹ during *rabi*, 1999 and they were 286 and 268 during *kharif*, 2000 and 273 and 250 kg ha⁻¹ during *rabi*, 2000.

4.2.7.3. Soil available nitrogen and its uptake by rice

Soil available N status was correlated with the uptake of nitrogen by rice during different stages. The stagewise relation during different years are furnished in the table 56. Soil available N had no relation with the N uptake of rice during incorporation of green manure in all the three years of study. Whereas, available N in the soil was positively associated with its uptake by rice during flowering stage in all the three years (the 'r' values being 0.58**, 0.44* and 0.76** during *rabi*, 1999, *kharif*, 2000 and *rabi*, 2000 respectively). Subsequently, at harvest stage, the available N in the soil did not influence the uptake in two out of three years.

4.2.7.4. Soil available phosphorus

Soil available phosphorus got increased from the stage of incorporation of green manure to rice flowering and thereafter it declined perceptibly (Tables 57, 58 and 59). Different heights of incorporation of dhaincha did not influence the soil available phosphorus in any of the stages. However, at rice harvest stage during *kharif* and *rabi*, 2000, the available phosphorus was pronounced at higher side with 100 per cent N to rice at 60 and 70 cm heights of incorporation (T₇ and T₁₀). With reduction in fertiliser N to rice, there was, by and large, considerable decrease in the available phosphorus during flowering and harvest stages in *kharif* and *rabi*, 2000.

In the basally green manured, wet seeded rice with 100 per cent N (T₁₃), the soil available phosphorus was invariably high at incorporation stage than all the green manure intercropped treatments (T₁ to T₁₂), but later, the amount got decreased at flowering and harvest stages of rice. This trend was seen in all the three seasons of study.

In the transplanted rice treatments (T₁₅ and T₁₆), the initial soil available phosphorus was rather high and later, the decrease was sharp in T₁₅ than the basally green manured transplanted treatment T₁₆. The respective values at green manure incorporation, rice flowering and harvest stages were 29.6, 19.8 and 16.2 kg ha⁻¹ for

Table 56. Correlation between soil available nitrogen and its uptake during different rice growth stages

	Correlation coefficient (r)
Soil available nitrogen Vs Nitrogen uptake at incorporation	
<i>rabi</i> 1999	0.154 ^{NS}
<i>kharif</i> 2000	0.174 ^{NS}
<i>rabi</i> 2000	0.339 ^{NS}
Soil available nitrogen Vs Nitrogen uptake at flowering	
<i>rabi</i> 1999	0.582 ^{**}
<i>kharif</i> 2000	0.442 [*]
<i>rabi</i> 2000	0.756 ^{**}
Soil available nitrogen Vs Nitrogen uptake at harvest	
<i>Rabi</i> 1999	0.339 ^{NS}
<i>Kharif</i> 2000	0.633 ^{**}
<i>rabi</i> 2000	0.021 ^{NS}

Table 57. Soil available phosphorus (kg ha⁻¹) as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Soil available phosphorus (kg ha ⁻¹)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	20.5 ^b	30.2 ^{ab}	19.0 ^{b-e}
T ₂ -R+D(Inc. 40 cm)+75%N	20.7 ^b	31.5 ^{ab}	19.8 ^{cde}
T ₃ -R+D(Inc. 40 cm)+50%N	21.0 ^b	32.5 ^{ab}	21.0 ^{b-e}
T ₄ -R+D(Inc. 50 cm)+100 %N	21.0 ^b	28.7 ^{bc}	22.0 ^{ab}
T ₅ -R+D(Inc. 50 cm)+75%N	21.7 ^b	31.3 ^{ab}	23.6 ^{a-d}
T ₆ -R+D(Inc. 50 cm)+50%N	21.9 ^b	31.8 ^{ab}	23.7 ^{a-d}
T ₇ -R+D(Inc. 60 cm)+100 %N	20.8 ^b	28.2 ^{bc}	21.8 ^{ab}
T ₈ -R+D(Inc. 60 cm)+75%N	22.2 ^b	32.2 ^{ab}	24.2 ^{abc}
T ₉ -R+D(Inc. 60 cm)+50%N	22.9 ^b	33.0 ^{ab}	24.8 ^{abc}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	22.6 ^b	29.6 ^{ab}	24.0 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	24.0 ^b	33.0 ^{ab}	25.2 ^{ab}
T ₁₂ -R+D(Inc. 70 cm)+50%N	23.5 ^b	34.0 ^a	26.0 ^{a-d}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	30.0 ^a	24.0 ^{cd}	18.6 ^{de}
T ₁₄ -R+ 100 % N	23.6 ^b	21.3 ^d	16.5 ^e
T ₁₅ -Transplanted rice+100%N	29.8 ^a	23.8 ^{cd}	18.0 ^e
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	1.93	2.52	2.11
CD(P=0.05)	3.95	5.16	4.33

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 58. Soil available phosphorus (kg ha⁻¹) as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Soil available phosphorus (kg ha ⁻¹)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	19.8 ^{bc}	28.4 ^{de}	22.6 ^{ef}
T ₂ -R+D(Inc. 40 cm)+75%N	19.2 ^c	25.6 ^f	19.8 ^h
T ₃ -R+D(Inc. 40 cm)+50%N	20.3 ^{bc}	21.2 ^h	18.2 ⁱ
T ₄ -R+D(Inc. 50 cm)+100 %N	19.6 ^{bc}	27.2 ^e	21.3 ^g
T ₅ -R+D(Inc. 50 cm)+75%N	20.4 ^{bc}	23.6 ^g	18.6 ⁱ
T ₆ -R+D(Inc. 50 cm)+50%N	20.3 ^{bc}	20.4 ^{hi}	18.2 ⁱ
T ₇ -R+D(Inc. 60 cm)+100 %N	21.2 ^{bc}	30.8 ^b	24.9 ^{bc}
T ₈ -R+D(Inc. 60 cm)+75%N	19.4 ^c	28.9 ^{cd}	22.6 ^{ef}
T ₉ -R+D(Inc. 60 cm)+50%N	21.8 ^{bc}	27.3 ^e	21.5 ^{fg}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	22.4 ^b	33.6 ^a	26.3 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	21.6 ^{bc}	30.4 ^b	24.1 ^{cd}
T ₁₂ -R+D(Inc. 70 cm)+50%N	21.4 ^{bc}	29.8 ^{bc}	23.6 ^{de}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	30.2 ^a	28.4 ^{de}	22.1 ^{fg}
T ₁₄ -R+ 100 % N	20.6 ^{bc}	21.3 ^h	15.9 ^j
T ₁₅ -Transplanted rice+100%N	29.6 ^a	19.8 ⁱ	16.2 ^j
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	30.8 ^a	30.2 ^{bc}	25.7 ^{ab}
SEd	1.38	0.68	0.54
CD(P=0.05)	2.81	1.38	1.10

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 59. Soil available phosphorus (kg ha⁻¹) as influenced by treatments at different growth stages during rabi 2000

Treatments	Soil available phosphorus (kg ha ⁻¹)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	18.9 ^{hi}	27.6 ^{bc}	21.4 ^{ef}
T ₂ -R+D(Inc. 40 cm)+75%N	18.3 ^{ij}	24.9 ^e	18.6 ^{hi}
T ₃ -R+D(Inc. 40 cm)+50%N	17.6 ^{jk}	21.8 ^f	16.7 ^{jk}
T ₄ -R+D(Inc. 50 cm)+100 %N	19.5 ^{fgh}	28.4 ^b	23.6 ^c
T ₅ -R+D(Inc. 50 cm)+75%N	19.0 ^{ghi}	26.3 ^{b-e}	20.1 ^g
T ₆ -R+D(Inc. 50 cm)+50%N	18.0 ^{ijk}	24.6 ^c	19.5 ^{gh}
T ₇ -R+D(Inc. 60 cm)+100 %N	20.8 ^{de}	30.2 ^{b-e}	25.2 ^b
T ₈ -R+D(Inc. 60 cm)+75%N	18.8 ^{hi}	26.4 ^{b-e}	21.7 ^{dc}
T ₉ -R+D(Inc. 60 cm)+50%N	17.0 ^k	25.1 ^{de}	20.4 ^{fg}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	21.5 ^d	31.9 ^a	26.7 ^a
T ₁₁ -R+D(Inc. 70 cm)+75%N	20.2 ^{ef}	27.5 ^{bcd}	22.8 ^{cd}
T ₁₂ -R+D(Inc. 70 cm)+50%N	20.0 ^{efg}	25.4 ^{cde}	21.9 ^{de}
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	27.2 ^a	24.7 ^c	20.3 ^{fg}
T ₁₄ -R+ 100 % N	24.3 ^c	20.7 ^{fg}	17.6 ^{ij}
T ₁₅ -Transplanted rice+100%N	25.6 ^b	18.6 ^g	15.9 ^k
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	26.7 ^a	27.9 ^b	22.4 ^{de}
SEd	0.53	1.21	0.54
CD(P=0.05)	1.08	2.47	1.10

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

T₁₅ and they were 30.8, 30.2 and 25.7 kg ha⁻¹ for T₁₆ during *kharif*, 2000. During *rabi*, 2000, the corresponding values were 25.6, 18.6 and 15.4 kg ha⁻¹ for T₁₅ and 26.7, 27.9 and 22.4 for T₁₆.

4.2.7.5. Soil available potassium

Soil available potassium, unlike other two major nutrients, got decreased from the stage of green manure incorporation to rice harvest (Tables 60, 61 and 62). A close look at the alphabets assigned to different treatment showed that as the height of incorporation of green manure increased from 40 to 70 cm, the potassium status was also found more at flowering and so also at rice harvest stage in all the three seasons of study. Reduction in N from 100 to 50 per cent of the recommended dose led to general increase of soil available potassium at flowering and at harvest of rice. Likewise, transplanted rice both with 100 per cent N (T₁₅) 100 per cent N + basal incorporation of green manure at 6.25 t ha⁻¹ (T₁₆) had, in general higher potassium status except in the first season (*rabi*, 1999). Wet seeded rice + dhaincha inc. 40 cm + 100 per cent N (T₁) had lower soil available potassium status during rice flowering and harvest stages in two of three seasons as compared to other intercropped treatments, basally green manured treatment (T₁₃) and transplanted treatments (T₁₅ and T₁₆).

Table 60. Soil available potassium (kg ha⁻¹) as influenced by treatments at different growth stages during *rabi* 1999

Treatments	Soil available potassium (kg ha ⁻¹)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	515	495 ^g	485 ⁱ
T ₂ -R+D(Inc. 40 cm)+75%N	521	504 ^{efg}	486 ^{hi}
T ₃ -R+D(Inc. 40 cm)+50%N	532	510 ^{cde}	467 ^j
T ₄ -R+D(Inc. 50 cm)+100 %N	526	506 ^{d-g}	492 ^{gh}
T ₅ -R+D(Inc. 50 cm)+75%N	538	508 ^{c-f}	510 ^f
T ₆ -R+D(Inc. 50 cm)+50%N	540	511 ^{b-e}	523 ^{cd}
T ₇ -R+D(Inc. 60 cm)+100 %N	527	512 ^{cde}	517 ^{de}
T ₈ -R+D(Inc. 60 cm)+75%N	529	520 ^{bc}	523 ^{cd}
T ₉ -R+D(Inc. 60 cm)+50%N	543	520 ^{bc}	540 ^a
T ₁₀ -R+D(Inc. 70 cm)+100 %N	536	516 ^{cd}	525 ^{bc}
T ₁₁ -R+D(Inc. 70 cm)+75%N	539	521 ^b	530 ^b
T ₁₂ -R+D(Inc. 70 cm)+50%N	543	540 ^a	541 ^a
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	486	416 ^h	496 ^g
T ₁₄ -R+ 100 % N	526	508 ^{def}	514 ^{ef}
T ₁₅ -Transplanted rice+100%N	476	498 ^{fg}	468 ^j
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	-	-	-
SEd	44.4	5.76	3.41
CD(P=0.05)	NS	11.8	6.98

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 61. Soil available potassium (kg ha⁻¹) as influenced by treatments at different growth stages during *kharif* 2000

Treatments	Soil available potassium (kg ha ⁻¹)		
	At incorporation of dhaincha	At lowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	264 ^j	242 ^j	220 ^j
T ₂ -R+D(Inc. 40 cm)+75%N	271 ^{g-j}	249 ^{hij}	227 ^{hi}
T ₃ -R+D(Inc. 40 cm)+50%N	280 ^{cde}	256 ^{e-h}	231 ^{gh}
T ₄ -R+D(Inc. 50 cm)+100 %N	271 ^{hij}	251 ^{ghi}	228 ^{hi}
T ₅ -R+D(Inc. 50 cm)+75%N	278 ^{d-h}	256 ^{e-h}	235 ^{efg}
T ₆ -R+D(Inc. 50 cm)+50%N	286 ^{bcd}	263 ^{cde}	242 ^{cd}
T ₇ -R+D(Inc. 60 cm)+100 %N	274 ^{f-i}	253 ^{f-i}	234 ^{efg}
T ₈ -R+D(Inc. 60 cm)+75%N	281 ^{c-f}	259 ^{def}	238 ^{def}
T ₉ -R+D(Inc. 60 cm)+50%N	293 ^{bc}	269 ^{bc}	247 ^{bc}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	279 ^{d-g}	257 ^{efg}	235 ^{efg}
T ₁₁ -R+D(Inc. 70 cm)+75%N	286 ^{bcd}	265 ^{cd}	242 ^{cd}
T ₁₂ -R+D(Inc. 70 cm)+50%N	302 ^a	278 ^a	255 ^a
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	269 ^{ij}	247 ^{ij}	224 ^{ij}
T ₁₄ -R+ 100 % N	276 ^{e-i}	254 ^{f-i}	231 ^{gh}
T ₁₅ -Transplanted rice+100%N	281 ^{c-f}	263 ^{cde}	240 ^{de}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	292 ^b	274 ^{ab}	252 ^{ab}
SEd	3.98	3.64	2.78
CD(P=0.05)	8.13	7.42	5.68

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

Table 62. Soil available potassium (kg ha⁻¹) as influenced by treatments at different growth stages during *rabi* 2000

Treatments	Soil available potassium (kg ha ⁻¹)		
	At incorporation of dhaincha	At flowering	At harvest
T ₁ -R+D(Inc. 40 cm)+100 %N	259 ^j	237 ^h	211 ^g
T ₂ -R+D(Inc. 40 cm)+75%N	265 ^{ghi}	243 ^{fg}	219 ^f
T ₃ -R+D(Inc. 40 cm)+50%N	273 ^{d-g}	249 ^{de}	227 ^{de}
T ₄ -R+D(Inc. 50 cm)+100 %N	264 ^{hi}	242 ^g	217 ^f
T ₅ -R+D(Inc. 50 cm)+75%N	271 ^{d-h}	247 ^{ef}	223 ^{ef}
T ₆ -R+D(Inc. 50 cm)+50%N	278 ^{bcd}	256 ^c	232 ^e
T ₇ -R+D(Inc. 60 cm)+100 %N	269 ^{e-i}	247 ^{ef}	226 ^{de}
T ₈ -R+D(Inc. 60 cm)+75%N	277 ^{cde}	255 ^c	232 ^c
T ₉ -R+D(Inc. 60 cm)+50%N	285 ^b	266 ^b	241 ^{ab}
T ₁₀ -R+D(Inc. 70 cm)+100 %N	274 ^{def}	252 ^{cd}	229 ^{cd}
T ₁₁ -R+D(Inc. 70 cm)+75%N	286 ^{ab}	265 ^b	238 ^b
T ₁₂ -R+D(Inc. 70 cm)+50%N	294 ^a	272 ^a	246 ^a
T ₁₃ -R+ basal Inc. D(6.25 t/ha)+100%N	263 ^{f-i}	241 ^{gh}	219 ^f
T ₁₄ -R+ 100 % N	271 ^{d-h}	248 ^{de}	227 ^{cde}
T ₁₅ -Transplanted rice+100%N	278 ^{bcd}	254 ^c	231 ^{cd}
T ₁₆ -Transplanted rice+100%N + basal Inc. D(6.25 t/ha)*	286 ^{bc}	262 ^b	239 ^b
SEd	4.06	2.27	2.80
CD(P=0.05)	8.29	4.63	5.71

R- Rice; D- Daincha; Inc.- Incorporation at; N – Nitrogen

Means followed by a common letter are not significantly different at 5% level

* T₁₆ included in *Kharif* 2000 and *Rabi* 2000

***D*iscussion**

CHAPTER V

DISCUSSION

'Sustainability' is a byword of resource management researchers and research is geared up on this line in many field crops. But sustainability is not that much easy task as it involves the protection of resources, more importantly the soil health and stepping up the production from such protected resources. Thus, crop sustainability stems from soil sustainability and the statement of Summer and Farina (1986) that crops do not respond to fertiliser application *per se* but rather to the soil's response to its application is more relevant in this context.

Promotion of organic manuring could be a viable and effective solution for soil sustainability. However, unavailability and bulkiness of organic sources stand in the way of regular and sufficient organic manuring.

Cereal crops like rice and wheat do not raise upto commercial status like oilseeds, as the profits from them are low. In such crops, due to the lack of incentives, promotion of organic manuring is still more difficult. In these crops enough organic manuring and simultaneous cost reduction might lead to enhancement of profit margin and also soil health.

Switch over from rice transplanting to wet seeding saves 20 per cent of the labour cost (Singh and Bhattacharyya, 1988). Green manure intercropping in such wet seeded rice could aid for better soil health and it would be a feasible approach provided sowing and trampling all done by tools. With the development of rice *cum* green manure seeder by TNAU (Rajendran *et al.*, 1999), the objective of soil sustainability and ultimately the crop sustainability is pursued in the present study with simultaneous reduction in the cost of production.

Sesbania aculeata, the premier green manure of our country was tested as intercrop in wet seeded rice in the present study. The experiment with same set of treatments was conducted in three seasons *viz.*, *rabi*, 1999 at TNAU, Coimbatore in heavy textured clayey soil and *kharif* and *rabi*, 2000 at Agricultural Research Station, Bhavanisagar in light textured, low fertile soil.

Dhaincha was allowed to grow to pre-determined heights of 40 to 70 cm at 10 cm increment and at each height, three different levels of N to rice were tested with the aim of finding out optimum dhaincha growth in conjunction with maximum substitution of fertiliser N (T_1 to T_{12}). Besides, sole and transplanted rice were included in the set of treatments for effective comparison.

Using the seeder, the rice and green manure were sown alternately at an equidistance of 12.5 cm with rice interrow spacing of 25 cm.

There is deviation in the formulation of treatments contravening the convention. In the present study, instead of duration, the height was used as an index for optimisation of dhaincha growth as an intercrop. It is first explained below.

5.1. Height as an index for optimisation of dhaincha growth

To optimise the growth of dhaincha, conventionally different duration periods are fixed and the ideal duration is found out. But in the earlier studies (Joseph, 1998) as an intercrop in rice, dhaincha growth in relation to duration was found quite asymmetrical. Its growth was 32-38 cm during the first 35 days and in another 15 days, its height got increased manifold to 83-92 cm on an average as observed by him. Further, the phenology is altered by the weather elements. In the present study, the dhaincha growth was rapid during *kharif*, 2000 season, attained the pre-determined heights (40 to 70 cm) earlier by a week as compared to other seasons. On relating with weather elements (Table 7), it was seen that temperature had relatively more influence on the growth of dhaincha. Lower temperature led to slow growth taking more days to attain the specified heights as the 'r' values indicate. Thus for the optimisation of dhaincha growth under intercropping, height instead of duration might be an appropriate basis and the same was therefore followed in the present study.

Hereagain, the maximum height was fixed at 70 cm on the basis of previous work by Joseph (1998) who found the associate rice yield got affected when dhaincha intercrop was allowed to grow about 90 cm.

5.2. Biometrical and analytical studies in dhaincha (intercrop)

Research information is abundant regarding dhaincha as a green manure crop in pure stands but dhaincha as an intercrop in wet seeded rice has only few studies so far and the establishment of rice and dhaincha in alternate rows using the seeder in the present experiment is first of its kind in fact. Every information therefore needs its interpretation and utility.

5.2.1. Dhaincha population

Since the seeder was used in this experiment, the dhaincha population was expected to be uniform at the time of incorporation in all intercropped treatments (Plate 4). However, the population, in fact, got decreased as the dhaincha grew taller from 40 to 70 cm height in between rice rows (Tables 8, 9 and 10; Fig. 7, 8 and 9). At 40 cm height, the mean population was 183, 172 and 138 m⁻² during *rabi*, 1999; *kharif*, 2000 and *rabi*, 2000 respectively. At 70 cm, the corresponding populations were 109, 141 and 134 m⁻². Sizeable reduction in the population of dhaincha as it grew is obvious and advantageous.

The population due to seeder sowing was high enough to have crowding effect and self-mortality in due course of time as the results indicate. This is advantageous to smother the weeds in direct seeded rice where weed menace is usually a problem. Weed suppression due to intercropping dhaincha and cowpea in rice was earlier reported by Gracy Mathew and Alexander (1995) and the present observation of intra species (dhaincha) competition and mortality is evidently supportive of their findings.

5.2.2. Dhaincha nodulation

Considering waterlogged situation, the level of nodulation in dhaincha in the present study is satisfactory (Fig. 7, 8 and 9). The least that was observed was 17.2 nodules plant⁻¹ (*kharif*, 2000; Table 9) and it was as high as 54.9 nodules plant⁻¹ (*rabi*, 1999; Table 8). Nodule number got increased, as the dhaincha grew taller. It is obviously due to growth factor.

5.2.3. Biomass addition

The biomass production of dhaincha (intercrop) ranged from a minimum of 7.3 t ha⁻¹ to as high as 28.4 t ha⁻¹ (Tables 8, 9 and 10; Fig. 7, 8 and 9) as against the normal basal recommendation of 6.25 t ha⁻¹ of green manure to rice. The present study thus shifts our attention from the constraints for green manuring such as non-availability of green manures voiced so far to the concern of overproduction due to intercropping. Biomass also got increased with belated incorporation of dhaincha obviously due to growth factor.

The level of nodulation and biomass addition indicate further that dhaincha is able to tolerate water stagnation along with rice. Brewbaker and Glover (1988) viewing dhaincha as a marshy plant is in accordance with the present finding.

5.2.4. Nitrogen contribution from dhaincha

Nitrogen contribution from dhaincha ranged from 36.9 kg ha⁻¹ to as high as 139.5 kg ha⁻¹ (Tables 11, 12 and 13; Fig. 10). Usually with the stepping up of inorganic nitrogen, the biological fixation of nitrogen would be lower and literature evidences on these are many (Brady, 1999; Herridge *et al.*, 1984). In the present study, on the other hand, nitrogen addition by dhaincha got increased from the N level of 50 to 100 per cent of recommended dose to rice. The insensitivity of dhaincha to the external source of nitrogen strengthens the feasibility of its intercropping in wet seeded rice.

The quantum of biomass addition, nodulation and nitrogen addition all collectively looked into indicate clearly that dhaincha could be grown as an intercrop in wet seeded rice with greater feasibility using the new seeder.

5.3. Biometric observation in rice

5.3.1. Plant population

Rice population did not vary among treatments during *rabi*, 1999. But during *kharif* and *rabi*, 2000, it varied significantly (Tables 14, 15 and 16; Fig. 11). In Rice + dhaincha intercropping treatments (T₁ to T₁₂), over different levels of fertiliser N, the population variation was not wide enough to reason out the difference. Lacking appreciable at the same time consistent increase or decrease

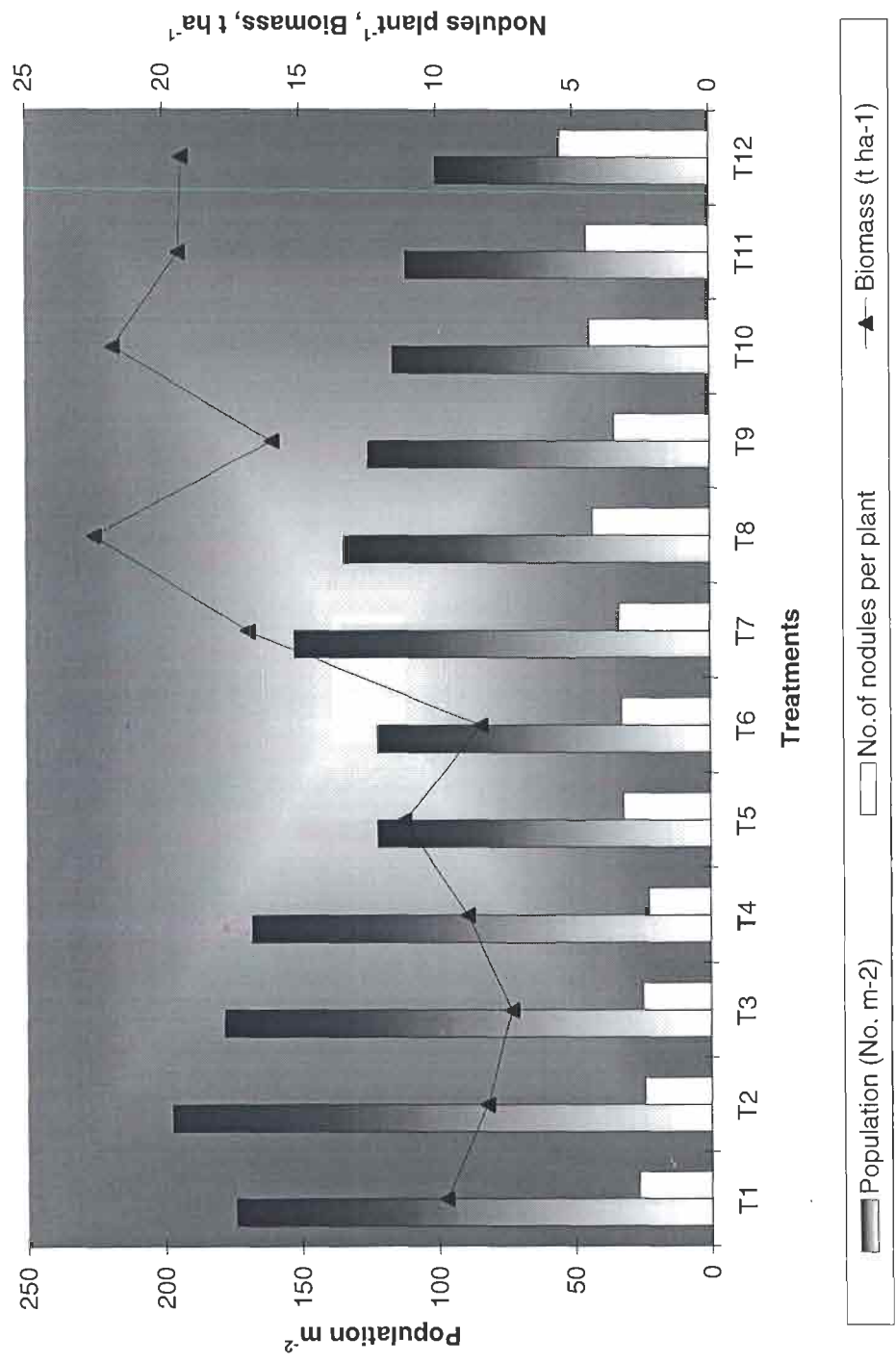


Fig. 7 Population, nodules plant⁻¹ and biomass of dhaincha at incorporation during *rabi* 1999

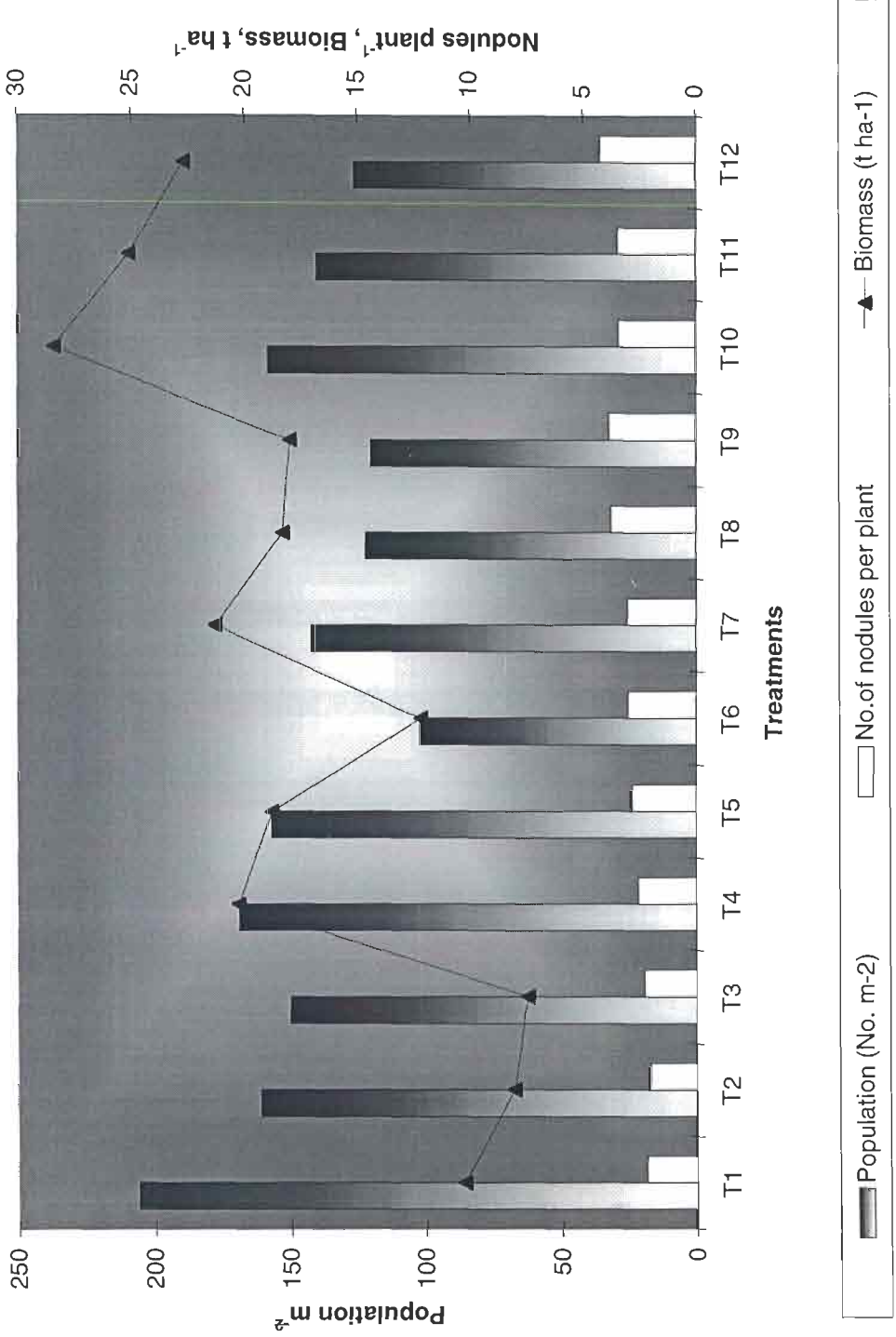


Fig. 8 Population, nodules plant⁻¹ and biomass of dhaincha at incorporation during *kharif* 2000

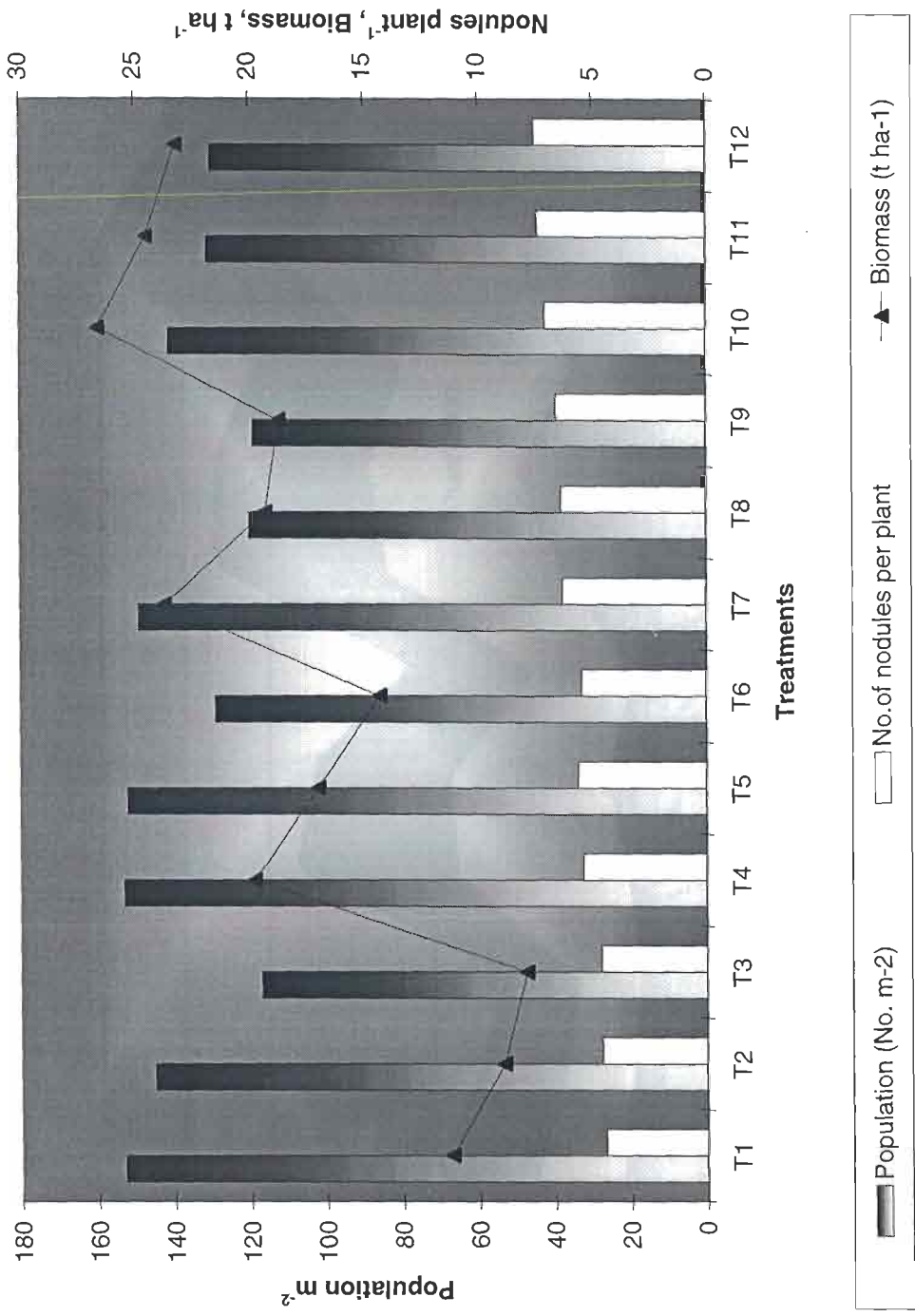


Fig. 9 Population, nodules plant⁻¹ and biomass of dhaincha at incorporation during rabi 2000

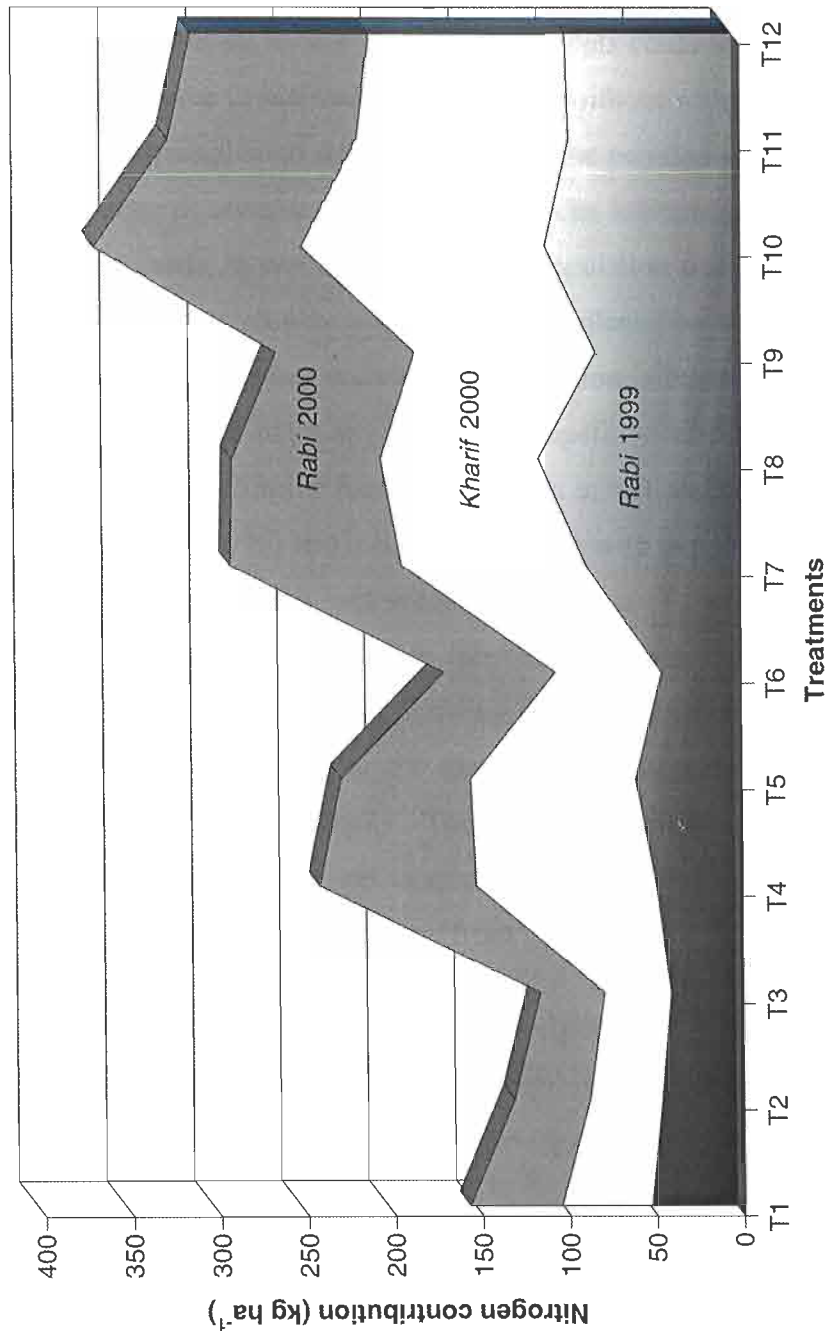


Fig. 10 Nitrogen contribution from dhaincha at incorporation

of population in any of the intercropped treatments over three seasons might be due to the fact that population ends up by and large with active tillering stage having thus a limited period to visualise the full impact of mineralisation from the intercropped green manures. Further, integration of green manure intercropping and N levels in all Rice + dhaincha treatments could have compensatory effect to a greater degree in maintaining population without wider variation.

In transplanted rice (T₁₅ and T₁₆), the population was invariably low in all the seasons as compared to Rice + dhaincha intercropped treatments (T₁ to T₁₂). In other words, in wet seeded rice, the population was higher due to higher seed rate, continuous growth without any transplantation stock and the added green manure effect. Further such higher population indicated clearly that the intercrop dhaincha did not have any adverse competitive effect while both were grown simultaneously. Similar higher population in wet seeded rice was earlier recorded by Peng *et al.* (1996) and it is in consonance with the present finding.

Further, all the wet seeding treatments (T₁ to T₁₃) had 25 cm interrow spacing. Even with such wide inter row spacing, the population was, in fact, higher than transplanted rice showing the flexibility of rice crop in adjusting the population while giving at the same time an opportunity to accommodate the intercrop dhaincha (Plate 7). Thus, wider interrow spacing is not a limitation contrary to the normal expectations that such spacing might affect the population. This is a valid information drawn from the study.

5.3.2. Plant height and Dry matter production

Height of rice is mainly a genetic factor and possibly that might be the reason for more or less uniform height regardless of treatments (Table 17, 18 and 19).

Dry matter production at the stage of rice flowering requires more consideration than the earlier stages as the expression of intercropped and *in situ* incorporated green manures could be seen more likely only at or after this stage. Further, DMP at this stage could have more bearing on the ultimate rice

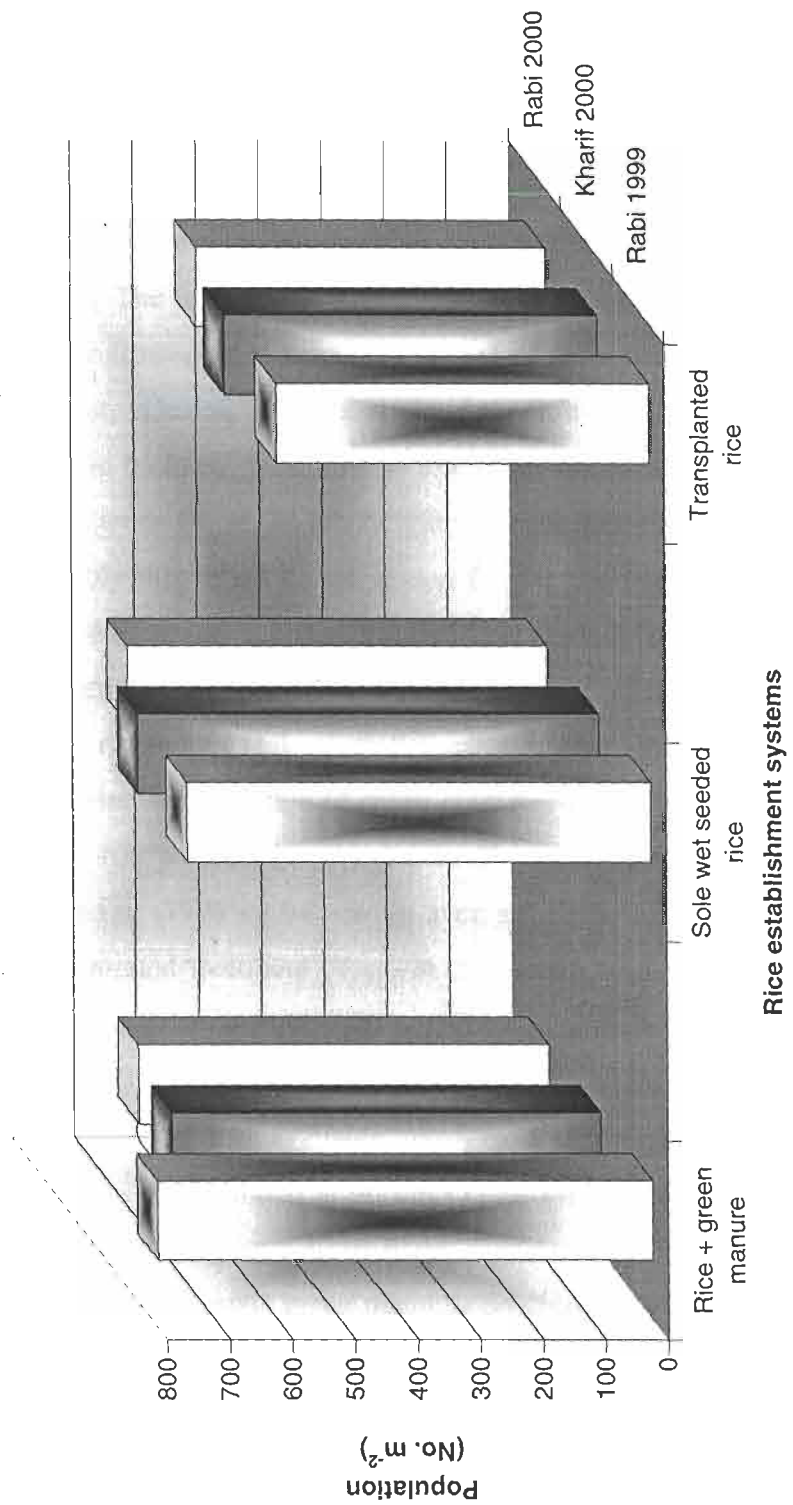


Fig. 11 Rice plant population at flowering

productivity than the earlier accumulation. The discussion thus concentrates on rice DMP at flowering.

Biomass addition from the intercrop dhaincha directly depends on how long it was allowed to grow or in other words it depends on how taller it was grown. Taller dhaincha (60 or 70 cm) as explained has added far higher biomass as compared to early incorporation at 40 or 50 cm height (Tables 20, 21 and 22; Fig.12). At the same time, the extent of green manure biomass addition did not reflect on the associate rice biomass (DMP) production at flowering.

The time gap is rather limited between green manure incorporation stage to rice flowering as compared to that of green manure incorporation stage to rice harvest. During the narrow gap upto flowering, full expression of added green manure biomass, whether it is low (from 40 or 50 cm height of incorporation) or high (from 60 or 70 cm height of incorporation) is more likely to be absent. Possibly that might be the reason for the absence of distinguishing difference in the DMP among the intercropped treatments having wider variation in the green manure biomass addition. Yet, the tender biomass (obtained from 40 cm height) could decay fast and mineralise early making growth of rice (in terms of DMP) fast after incorporation of green manure. That is why in Rice + dhaincha inc. 40 cm + 100 per cent N (T_1), the DMP was fast enough to attain a higher level at flowering (7996 kg ha^{-1} on an average) outdoing even the basally green manure incorporated treatment (T_{13}) (7426 kg ha^{-1}) which had more DMP in the earlier stages (at green manure incorporation and panicle initiation stages).

Green manure tenderness related rice DMP at flowering could be further supported by soil available nitrogen at flowering which was high in Rice + dhaincha incorporated at 40 cm (T_1 to T_3) with decline in its availability as the height increased from 40 to 70 cm (Tables 53, 54 and 55).

Leguminous green manures have two fractions of nitrogen viz., 'fast' and 'slow' N. This 'fast' fraction mineralised from the incorporated green manure could have had short term gain offsetting the effect of even reduced dose of fertiliser N. More possibly this might be the reason for visualizing only a

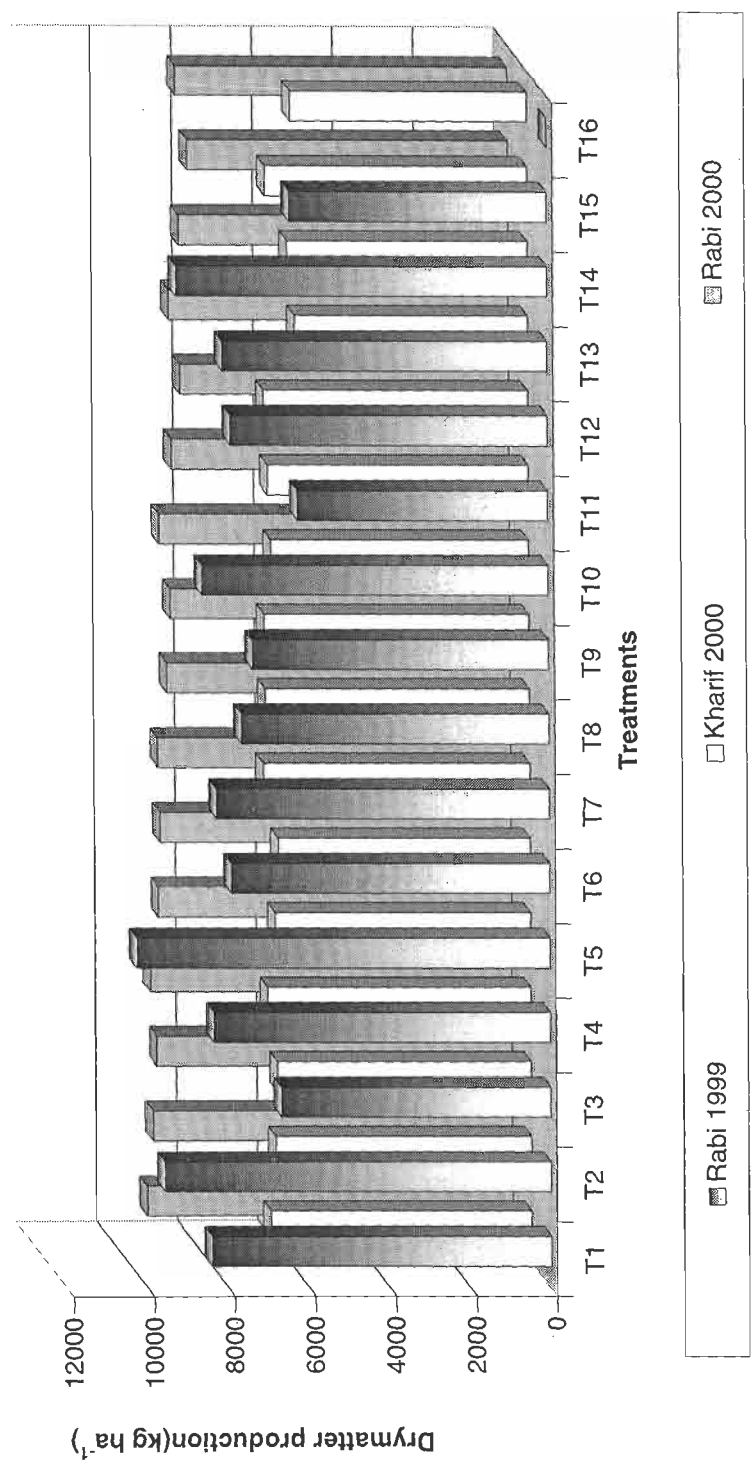


Fig.12 Dry matter production of rice at flowering

marginal increase of DMP at rice flowering for higher dose of N (100 per cent) at any given height of dhaincha incorporation in the intercropped treatments.

In the absence of green manuring and consequently its benefits, the transplanted rice + 100 per cent N (T₁₅) had lower DMP in general at flowering stage. Siddeswaran (1992) and Somasundaram et al. (1996) already reported lack of green manuring affecting the rice growth.

Thus from foregoing discussion, it is seen that intercropped and early incorporated green manure (40 cm height) with recommended dose of N (T₁) would be more ideal for securing higher rice DMP at flowering. Basal incorporation of green manure whether it is in wet seeded (T₁₃) or transplanted rice (T₁₆) had only early increases in the DMP of rice upto PI stage. Intercropping green manure and burying it at tender state was therefore found relatively better than its application basally. Absence of green manuring lowered the DMP of rice.

5.4. Observations on light interception, SPAD 502 and Leaf Colour Chart (LCC)

Light interception is an index of canopy coverage. When two crops are accommodated, canopy coverage would be higher than either of them. This explains the higher interception of light at green manure incorporation stage in Rice + green manure intercropped treatments (T₁ to T₁₂) than the sole wet seeded (T₁₃ and T₁₄) and transplanted (T₁₅ and T₁₆) treatments (Tables 23, 24 and 25; Fig.13).

The minimum fertiliser N in any of the treatments in the present study is 50 per cent of the recommended dose. But the minimum and intermediary dose (75 per cent) as well was integrated with *in situ* green manuring in the standing rice crop. This integration could have had a sound compensatory effect for some period atleast for the reduced fertiliser N. As a result, the canopy development in the crop profile would have been almost similar in all the treatments reflecting on the light interception too. Thus, the compensatory effect might be responsible for similar light harvest as the rice grew and attained flowering.

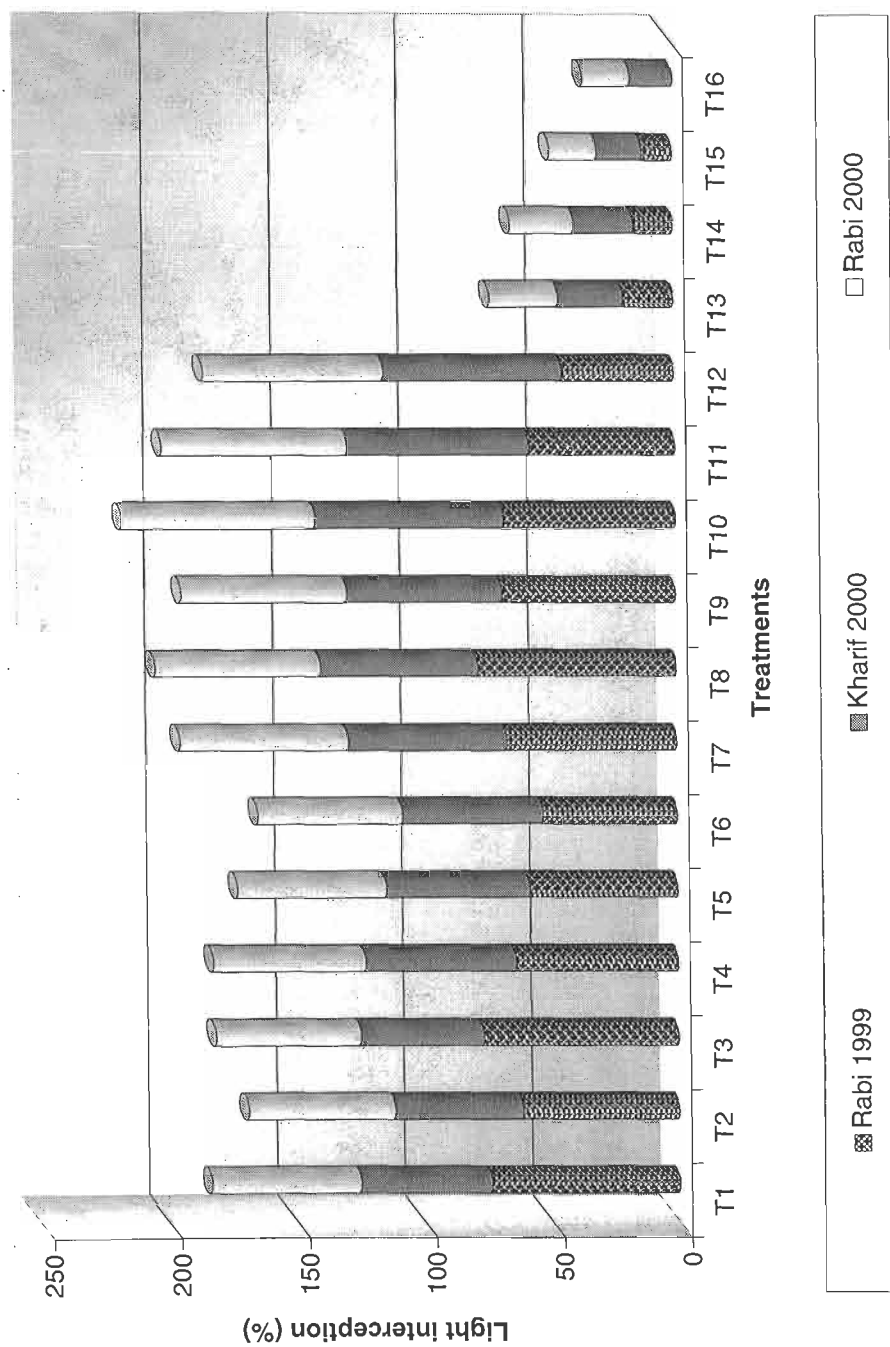


Fig. 13 Light interception by rice + dhaincha

The SPAD 502 meter works on the principle of light interception by the chlorophyll of rice foliage. The LCC values also indicate the chlorophyll status. So light interception, SPAD 502 and LCC values are interrelated and could be positively associated. Thus, SPAD 502 and LCC values did not vary among treatments as in light interception (Tables 26 to 31).

5.5. Uptake of nutrients by rice

5.5.1. Nitrogen uptake

The uptake of nitrogen more decisively reflects on the yield of rice and similar cereals. Much of the photosynthates for the sink are derived from the photosynthesis at and after flowering (Babu, 1995). Therefore the nutrient uptake particularly that of nitrogen during flowering stage (Fig. 14) is more crucial. More the N uptake during this stage, better is the sink accumulation and the yield. Thus the uptake during this period being critical could be clearly seen in the present study in which the average uptake difference between flowering and harvest were 9.3, 31.8 and 43.5 kg ha⁻¹ during *rabi*, 1999; *kharif*, 2000 and *rabi*, 2000 respectively. The corresponding average yields during these seasons were 4291, 5119 and 5755 kg ha⁻¹.

One of the objectives of the present study is to optimise the intercrop growth of dhaincha for higher productivity in rice. When dhaincha was allowed to grow upto 70 cm, the N contribution from it was substantial with a mean value of 110.6 kg ha⁻¹ (over three seasons). It is as low as 43.5 kg ha⁻¹ with 40 cm height of incorporation. Thus, there is a vast difference in the nitrogen addition due to variation in the height of incorporation. The N uptake of rice should have the same trend normally. But it is the other way with 40cm height of incorporation securing slightly higher uptake. The mean N uptake at harvest (average of three seasons) with 40 and 70 cm height of incorporation were 92.4 and 90.9 kg ha⁻¹, respectively (Fig.15). Thus, optimum dhaincha growth from the point of N uptake at harvest lies at 40 cm height *i.e.*, incorporation of dhaincha at tender state. Early decay and fast mineralisation of green manure particularly at the crucial stage of rice flowering to harvest is more important and this was

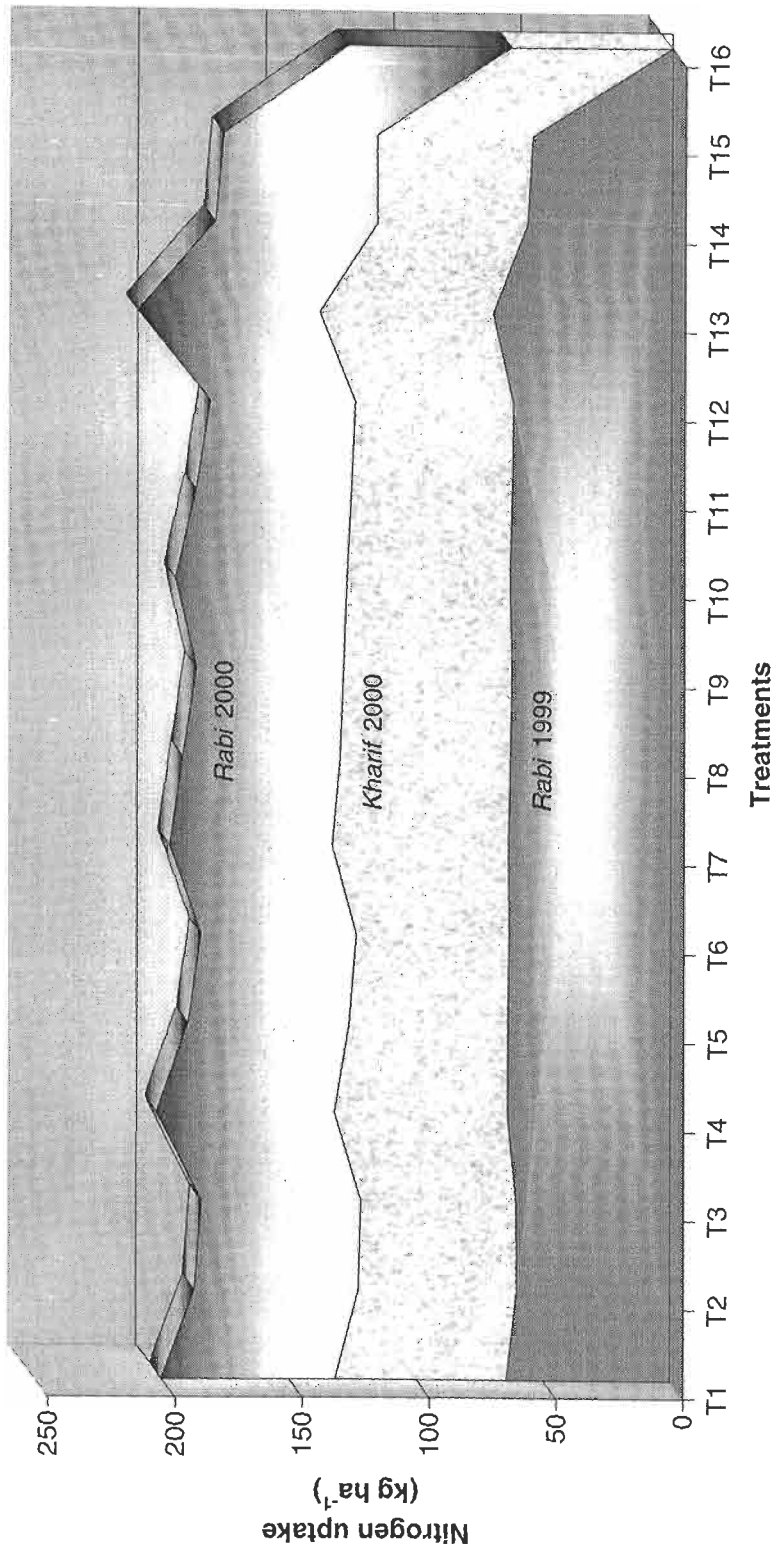


Fig. 14 Nitrogen uptake of rice at flowering

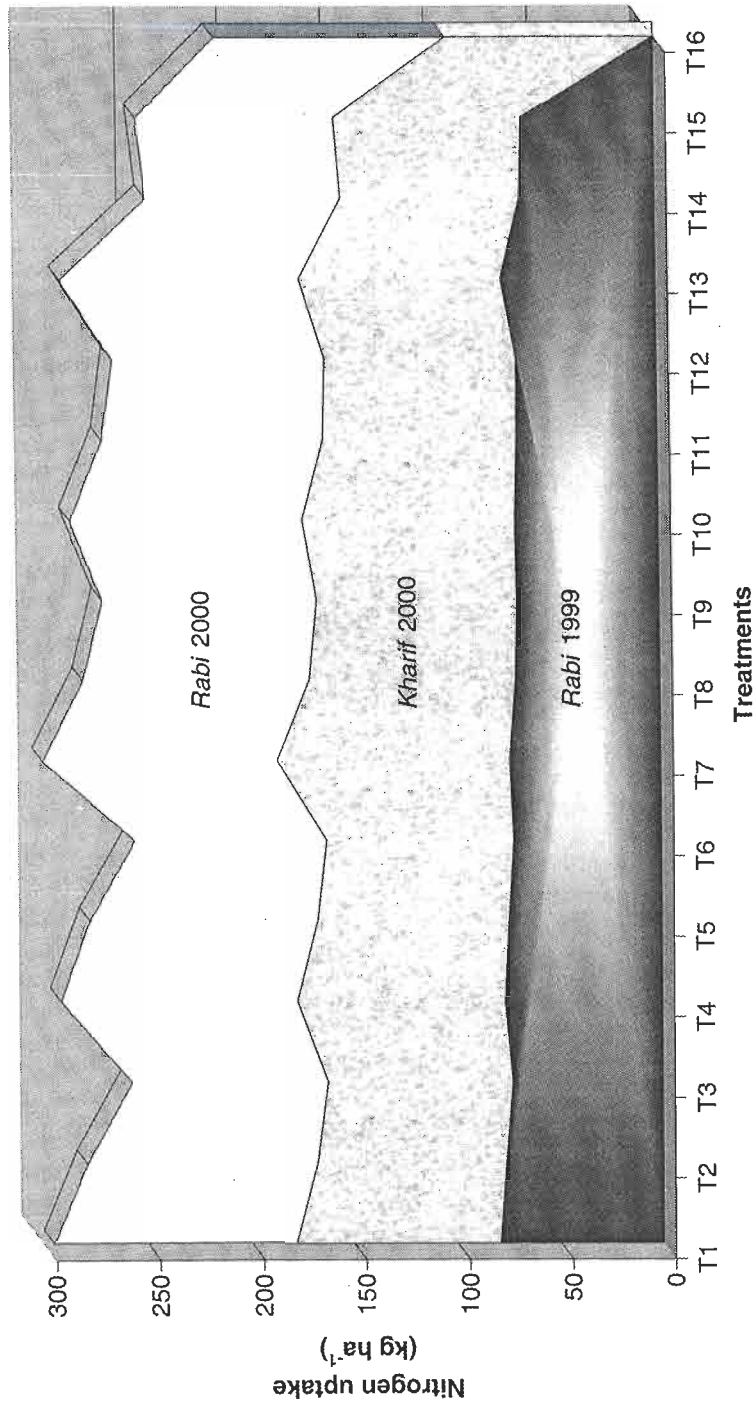


Fig. 15 Nitrogen uptake of rice at harvest

accomplished by early incorporation. The observations in the present study go in tandem with the report of Buresh and De Datta (1991) that the net recovery of N from the green manure is correlated directly to its nitrogen content, inversely to C-N ratio and lignin content. The observation that Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) showing higher N uptake of rice than other intercropping treatments is also supportive of their report.

Despite full dose of nitrogen, the wet seeded as well as transplanted rice (T₁₄ and T₁₅) had less uptake at harvest (82.4 and 83.9 kg ha⁻¹) mainly due to the absence of green manuring. Ramanathan (1995) reported higher uptake in rice due to green manuring and his finding is in agreement with the present observation.

One more notable observation is that what the nitrogen uptake could be attained by basal incorporation of green manure in transplanted rice (T₁₆) could be met with intercropping and burying the green manure at tender state.

Thus, belated incorporation of green manure is not ideal and early incorporation at 40 cm height could be optimum for more uptake of N. Further, the N uptake of rice in the early incorporated green manure (intercrop) is comparable to basally applied green manure. Thus, the N uptake is yet another factor signaling positively the feasibility of intercropping and *in situ* incorporation of green manure in wet seeded rice.

5.5.2. Phosphorus uptake

Fertiliser phosphorus was applied at constant dose uniformly to all the treatments. If the variation in the uptake existed, it could then be due to variation in the fertiliser N dose and green manuring. In the present study, the intercrop dhaincha incorporation at different heights from 40 to 70 cm did not cause any appreciable change in the P uptake of rice (Tables 35, 36 and 37; Fig. 16). The incorporated organic phosphorus is subject to various transformation and fixation processes and its availability therefore may not be rapid as that of organic nitrogen, which has 'fast' and 'slow' fractions. As a result, variation in the P uptake could not be seen much. Tisdale *et al.* (1997) reporting complex

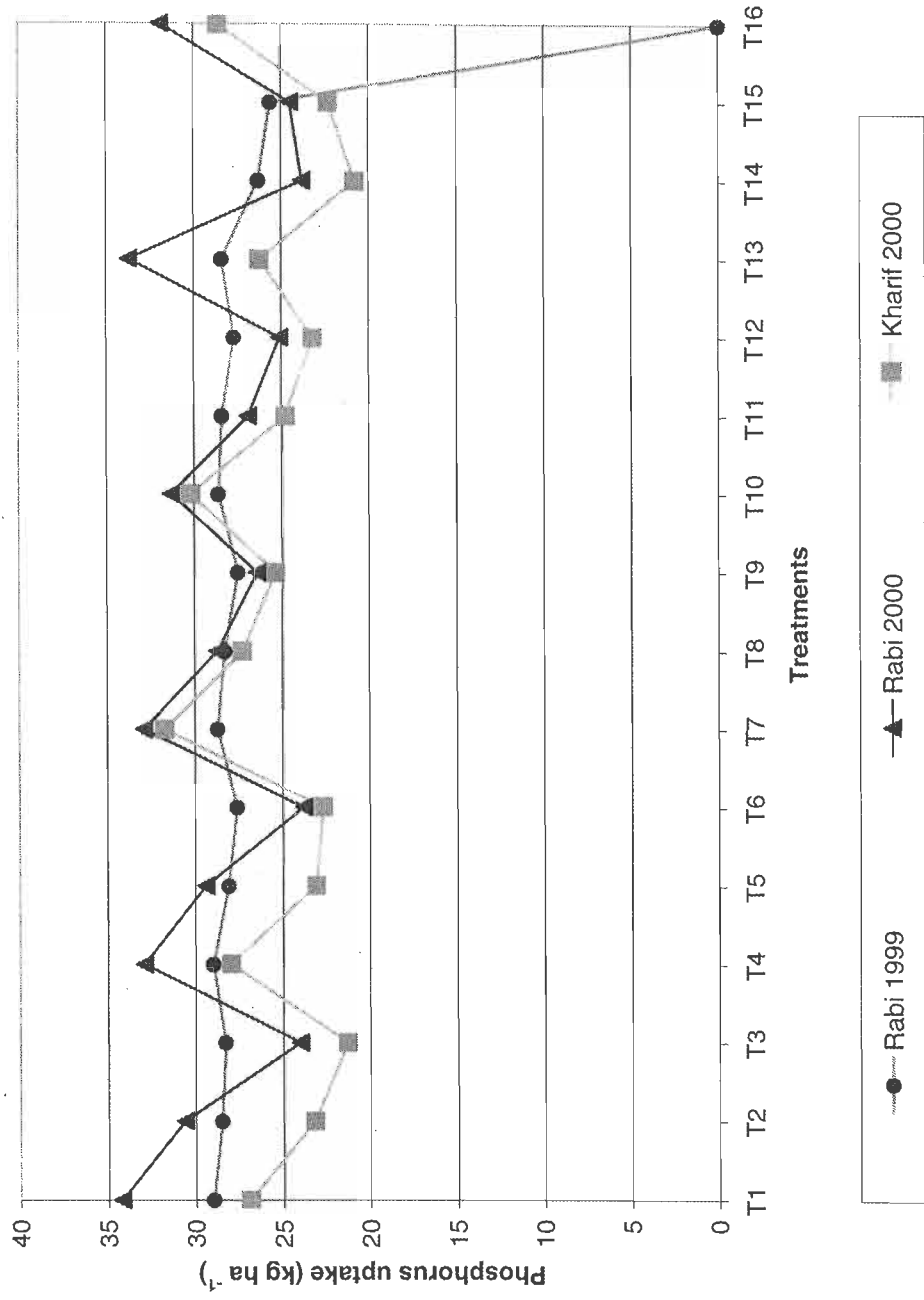


Fig 16. Phosphorus uptake of rice at harvest

transformation and fixation of applied phosphorus, slowing down its availability is in agreement with present observation.

Phosphorus is relatively immobile and the foraging capacity of rice root limits its availability (Palaniappan and Sivaraman, 1996). With the promotion of root growth due to addition of nitrogen, phosphorus availability and in turn its uptake might have got increased in the present study. In view of incorporation of tender green manure (40 cm height) with full dose of N, the treatment, Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) had relatively more uptake in two out of three seasons.

Reduction in the uptake of phosphorus is marked be it wet seeded or transplanted rice (T₁₄ and T₁₅) in the absence of green manuring and consequent reduction in phosphorus availability. Reduction in P uptake due to the absence of green manuring as reported by Sreeramachandrasekaran *et al.* (1996) is in agreement with the present finding.

5.5.3. Potassium uptake

Unlike phosphorus, fixation of potassium is not a major limitation and its uptake was similar to that of nitrogen. In view of tender nature of green manure at 40 cm height with full dose of nitrogen i.e., Rice + dhaincha inc. 40 cm + 100 per cent N treatment (T₁) showed higher uptake with a considerable decrease as the height of incorporation increased (40 to 70 cm) in two out of three seasons (Tables 38, 39 and 40).

Potassium absorption is in association with N uptake and in view of this, the uptake of potassium got decreased at reduced dose of fertiliser N (100 to 50 per cent).

Green manures contribute potassium and other elements also (Bhuiyan *et al.*, 1988) and in the absence of green manuring in T₁₄ and T₁₅, its uptake could be low only.

5.6. Soil fertility status

5.6.1. Soil organic carbon

The organic carbon status in the soil is a function of quantity of green

manure biomass incorporated into the soil. Thus, with increased height of incorporation of dhaincha and consequent higher biomass addition, the organic carbon content in the soil got increased at various rice stages (Tables 50, 51 and 52; Fig. 17, 18 and 19) Deka Medhi and De Datta (1996) and Gurung and Sherchen (1996) observed higher organic carbon content with increased application of green manures and their observation is supportive of the present results.

Reduction in fertiliser N to rice led to less contribution of root biomass reducing the carbon status in the soil. Built up of organic carbon with increased dose of nitrogen was earlier reported by Siddeswaran (1992) and Premsekar (1993) and the present results are with the same trend only.

Non-application of green manures did not increase the soil organic carbon content in the treatments T₁₄ and T₁₅. It only shows the inevitability of organic (green) manuring for rice.

5.6.2. Soil available N, P and K

Soil available nitrogen dynamics indicated the usefulness of intercropping green manure in wet seeded rice. While at rice flowering, the available nitrogen in the soil was more with reduced height of incorporation (40 cm height) owing to tender state of green manure (Tables 53 to 55 and 57 to 62). Increase in the height of incorporation, 60 or 70 cm on the other hand had low available nitrogen. 'Fast' fraction of nitrogen in the green manure categorised by Bouldin (1988), might have contributed for the built up of available N in the soil at rice flowering stage (Fig. 20) with tender green manure. But, further increase subsequently might have depended upon the availability of 'slow' fraction which would be more with increased heights of incorporation resulting in higher values of available N in the soil at 60 cm and more pronouncingly at 70 cm height at rice harvest stage (Fig. 21). These sorts of fluctuations in the soil available N during various rice growth stages were absent in the basal green manure incorporated treatments (T₁₃ and T₁₆). This is more possibly due to application of grown up green manures basally having sizeable fraction of hemi-cellulose or lignin, which could decompose

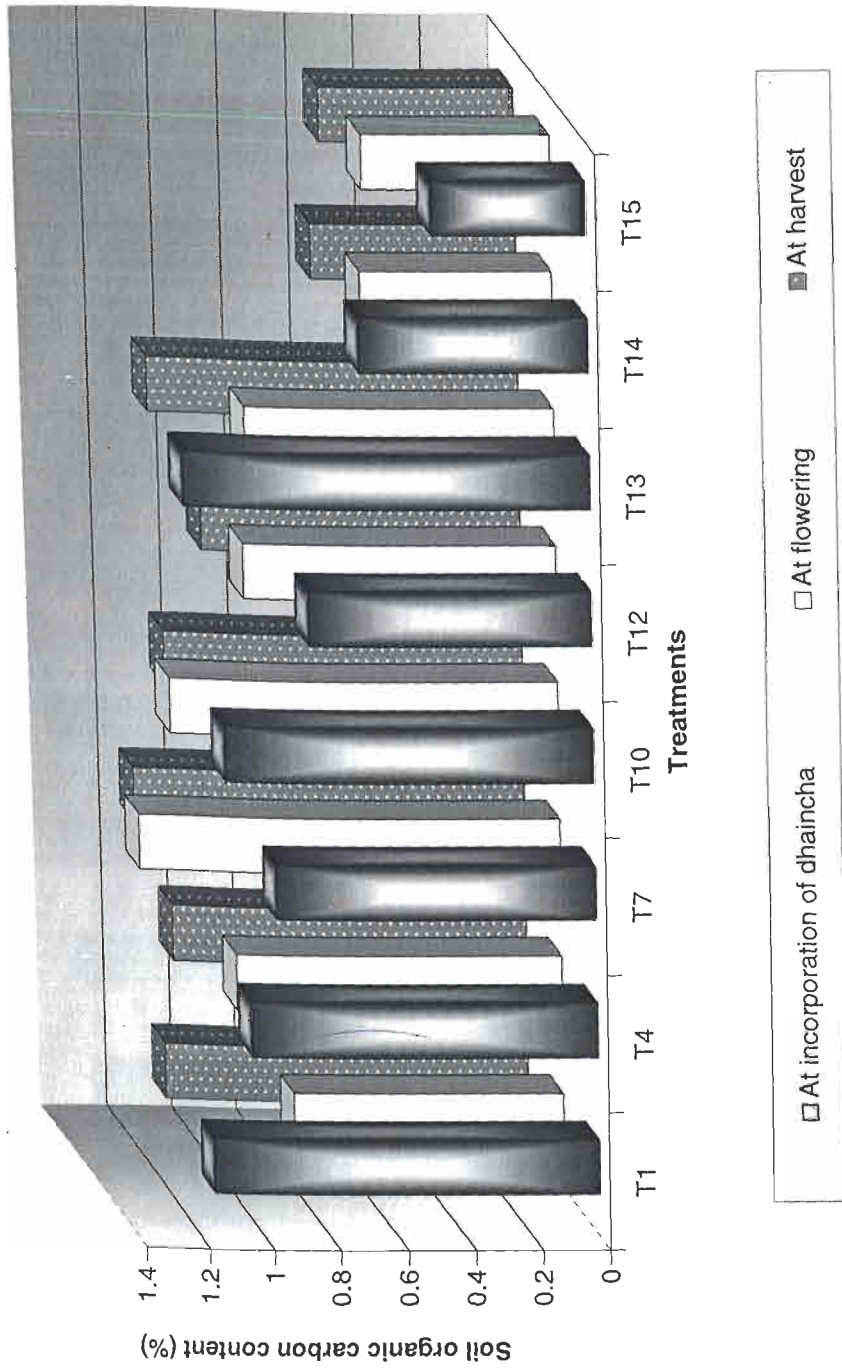


Fig. 17 Soil organic carbon content during rabi 1999

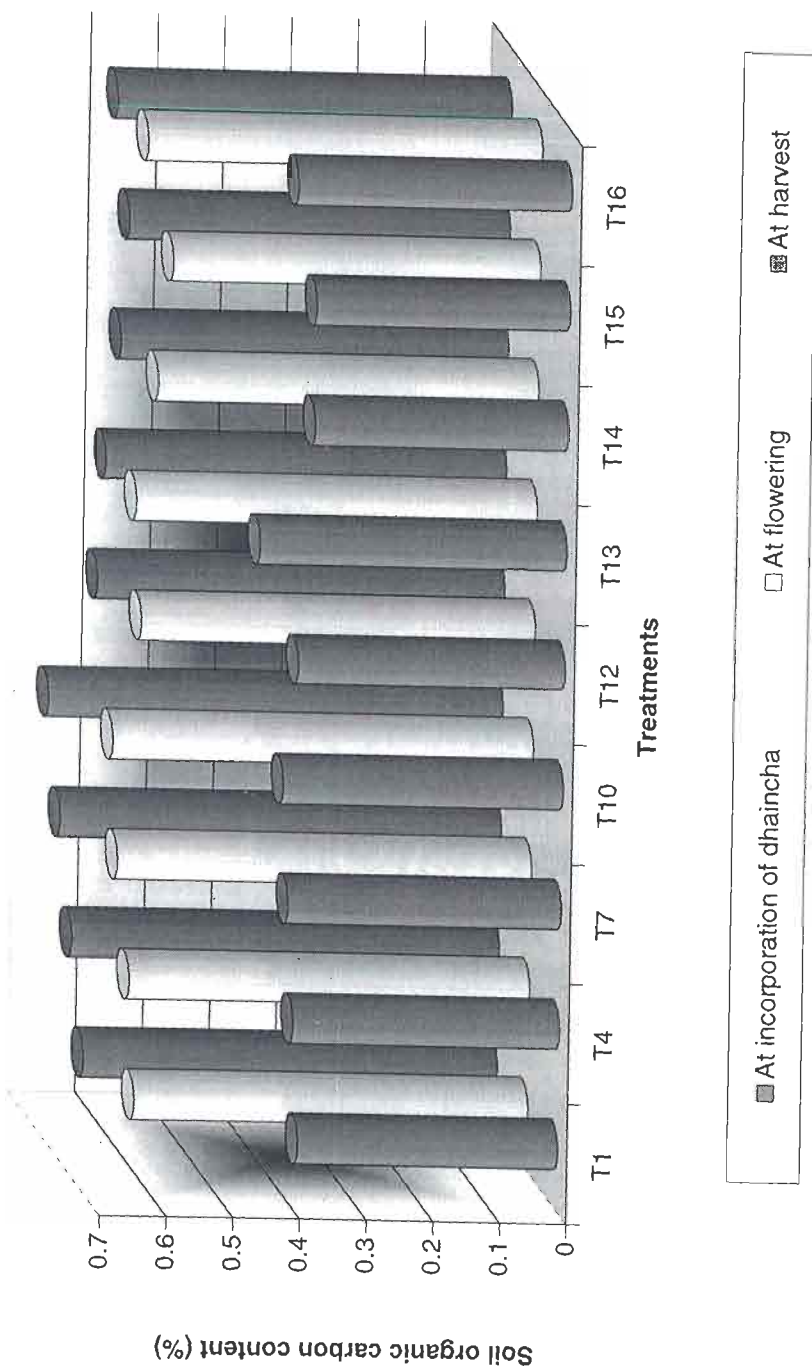


Fig. 18 Soil organic carbon content during *kharif* 2000

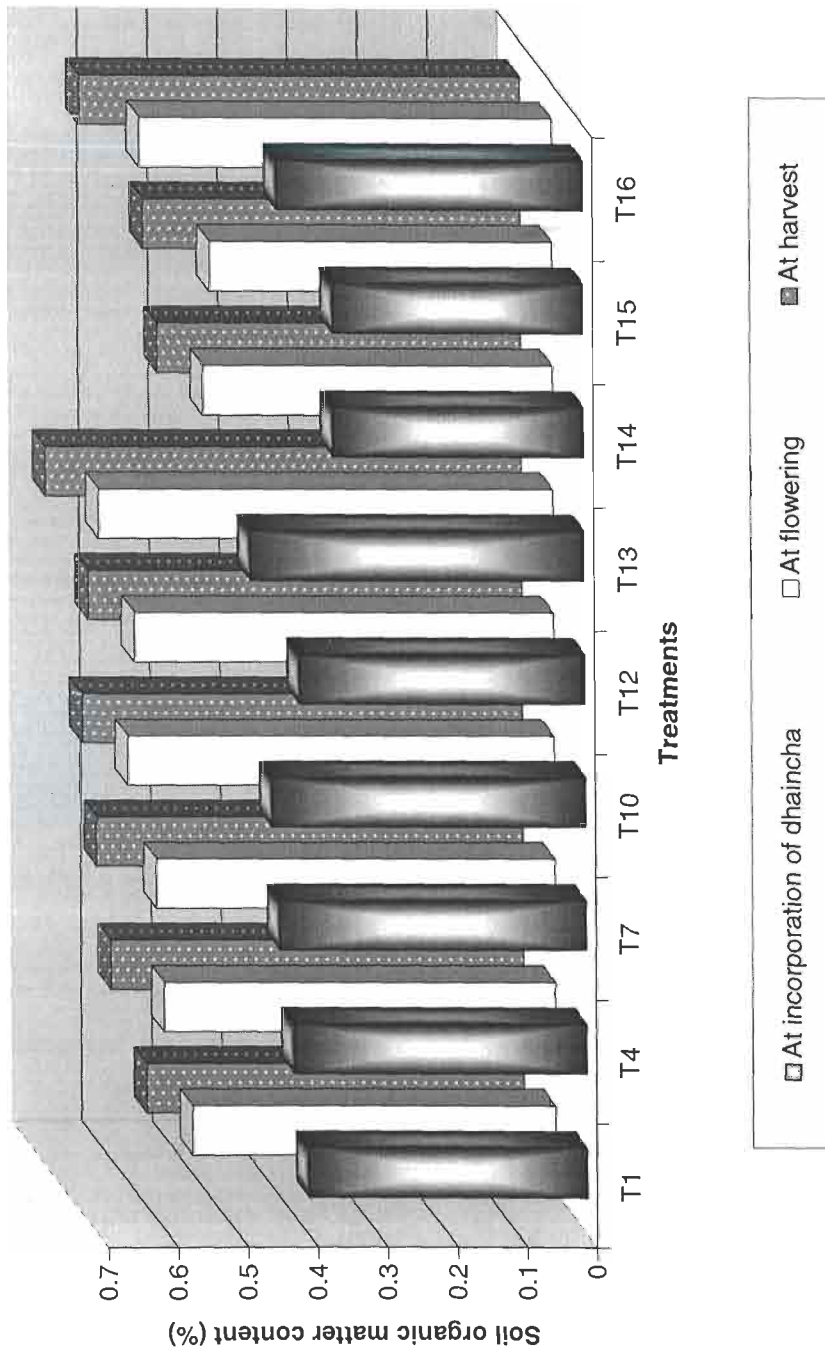


FIG. 19 Soil organic carbon content during *rabi* 2000

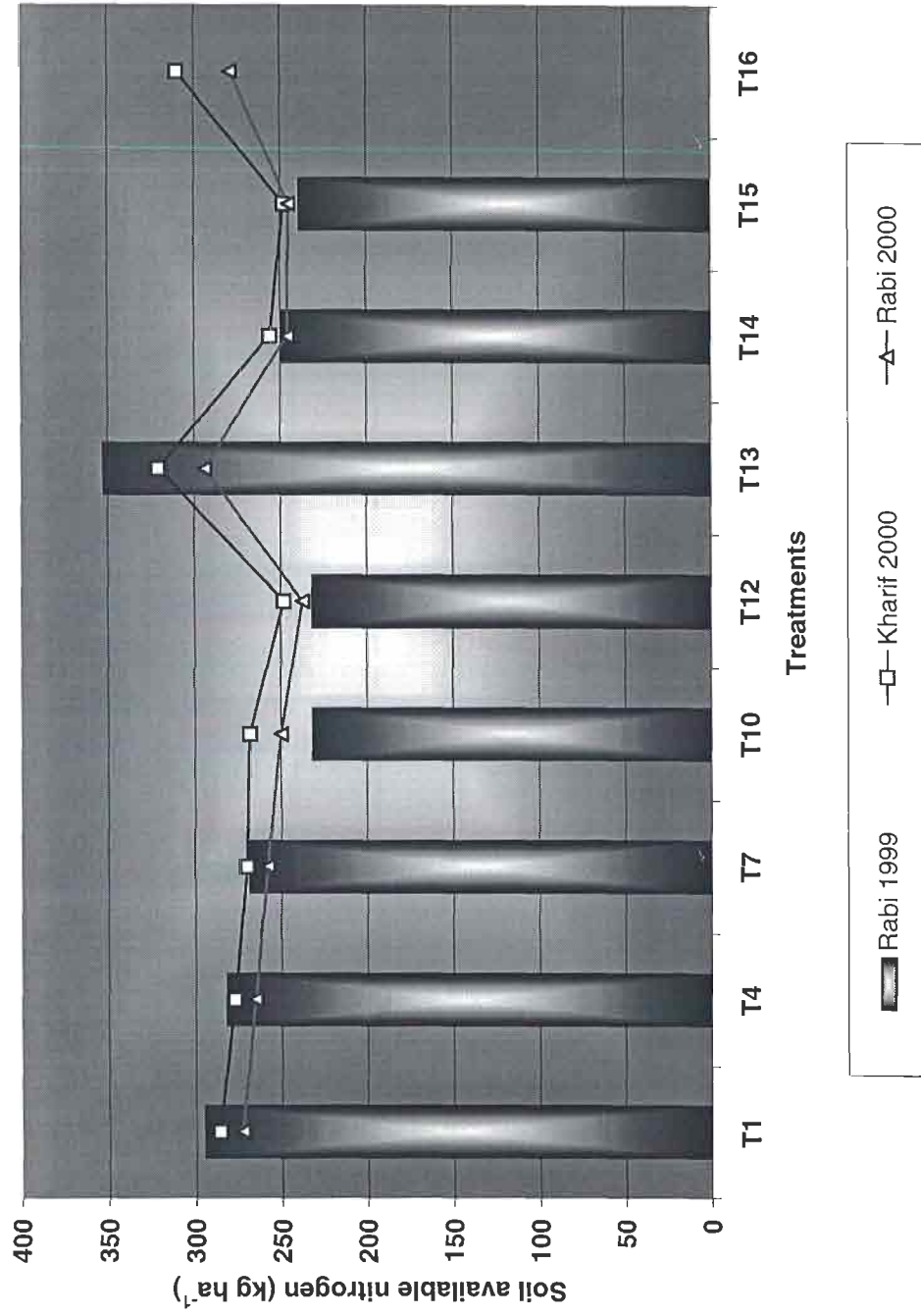


Fig. 20 Soil available nitrogen at flowering

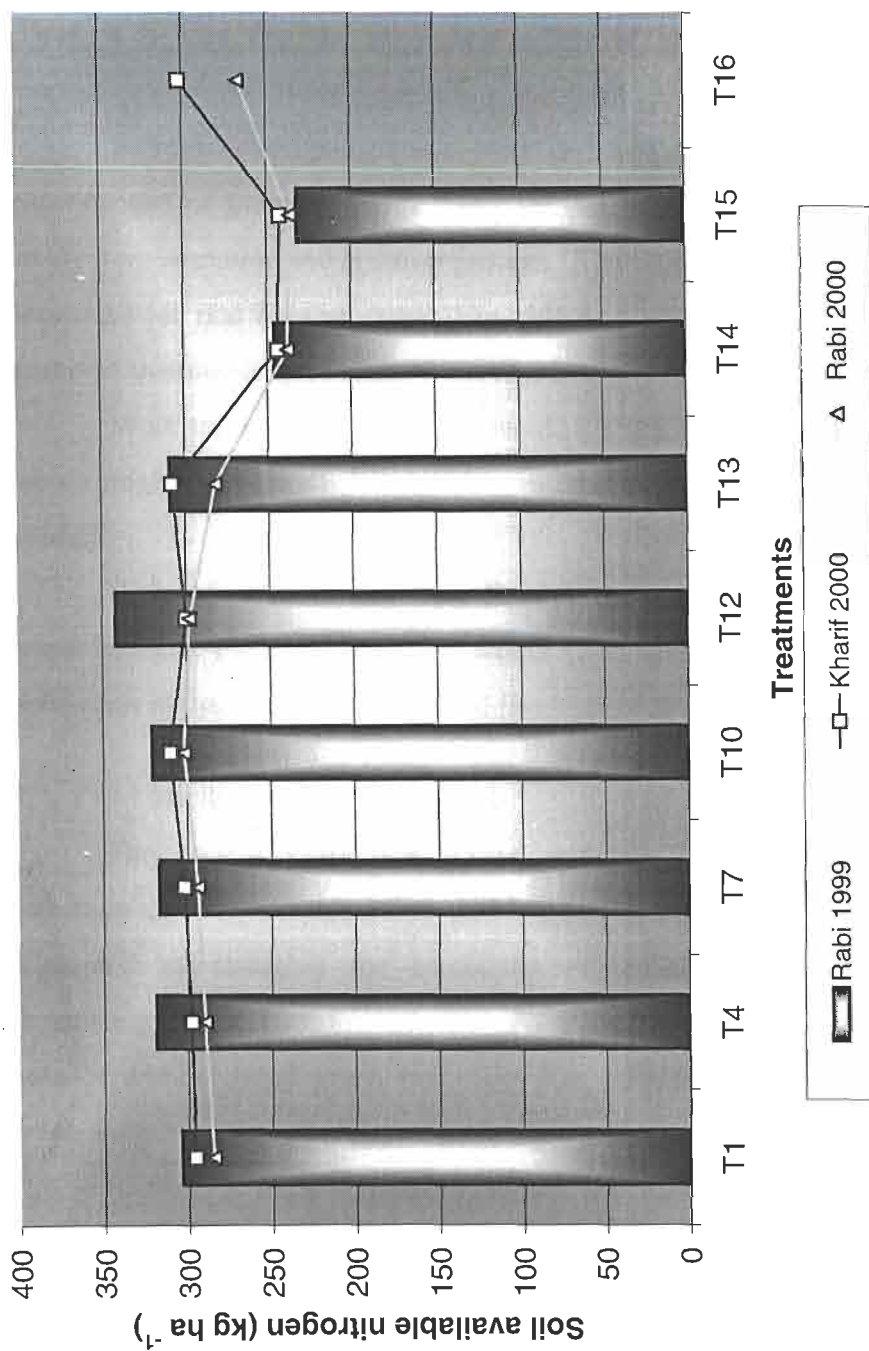


Fig. 21 Soil available nitrogen at harvest

steadily keeping almost uniform level of available N in the soil. Further, the poor status of soil available N despite 100 per cent fertiliser N application in the treatments T₁₄ (wet seeded rice) and T₁₅ (Transplanted rice) is attributed to the skipping of green manure application either basally or through intercropping. Thus, it is seen that the favourable effect of green manuring outcores well impressively the fertiliser N regarding soil fertility.

As regards soil phosphorus, 'fast' or 'slow' fractions do not exist here as in the nitrogen of green manures. Further, the released phosphorus is subject to many transformation and fixation process. That is why its greater availability was seen only at rice harvest stage (Fig. 22) and that too with increased biomass received treatments as a result of increased height of incorporation (60 or 70 cm).

More the fertiliser N, more would be the rice root growth and activity, which might have resulted in higher available phosphorus as seen in the present study.

Reduced dose of nitrogen limited the rice growth and absorption of potassium and more possibly this would have resulted in higher availability of potassium in the soil at 50 per cent of fertiliser N as observed in the present study.

5.7. Yield attributes and yield of rice

The present study was started with the twin core objectives of cost reduction and crop sustainability through soil sustainability. Cost reduction was attempted by changing the establishment technique from the conventional transplanting to wet seeding of rice. For effective comparison, transplanted rice with or without basal green manuring was included. Because of inclusion of green manure as an intercrop, reduction in the fertiliser N usage was also aimed at.

In such a study explained above, the yield is the ultimate pointer of usefulness or otherwise of any of the treatment tested. The first question that may arise is whether green manuring is necessary at all. Skipping green manure in both wet seeded (T₁₄) and transplanted (T₁₅) rice reduced the yield attributes *viz.*, number of panicles m⁻² and filled grains panicle⁻¹ when the three season's results are collectively looked into (Tables 41, 42 and 43). It is despite recommended

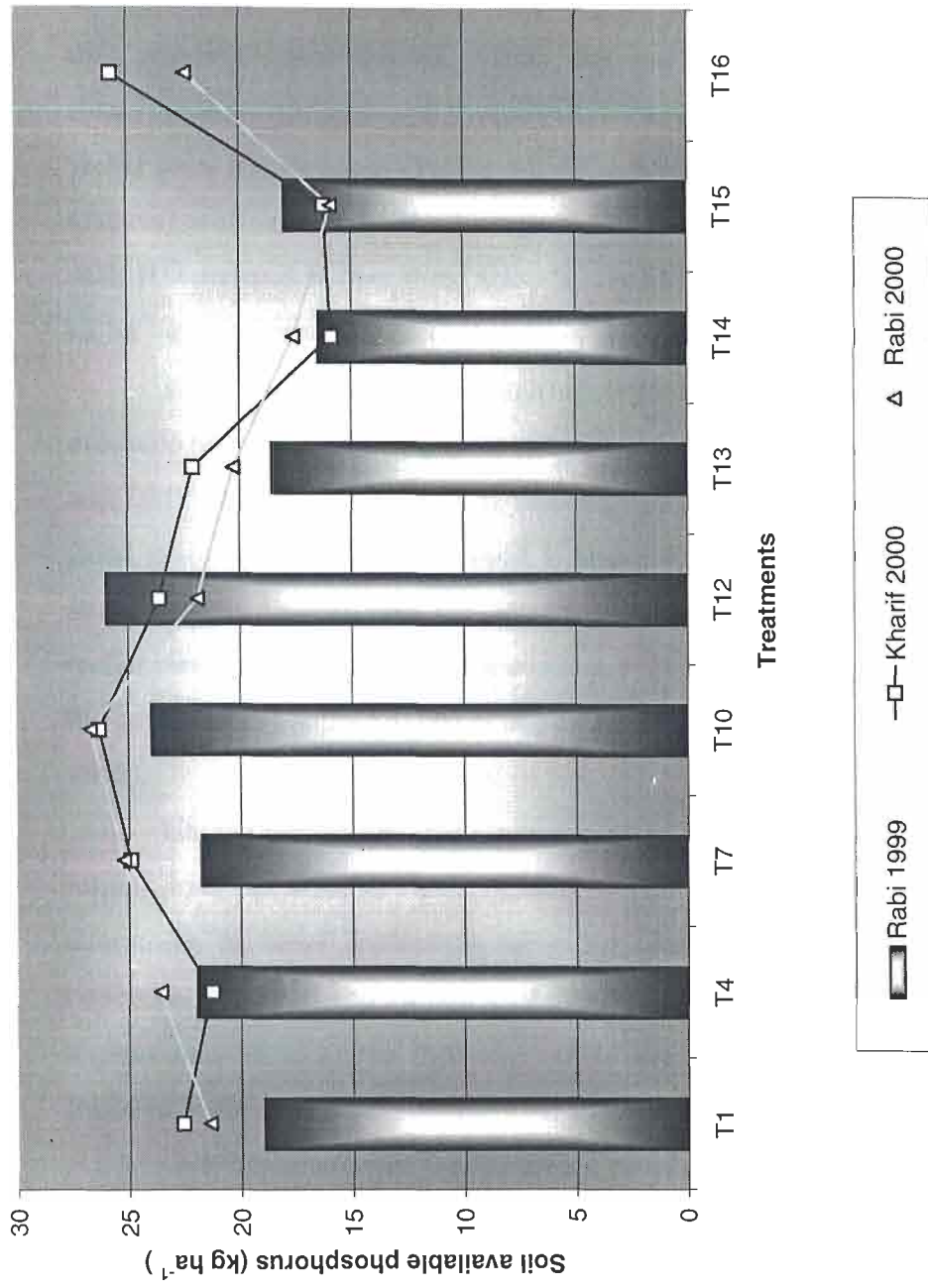


Fig. 22 Soil available phosphorus at harvest

dose of nitrogen (100 per cent) received by these treatments. The average number of panicles m^{-2} and filled grains panicle⁻¹ (Fig. 23) in the above two treatments were 476, 451; 127, 135 respectively. While, it was 575 panicles m^{-2} and 147 filled grains panicle⁻¹ in the green manured treatments receiving the same 100 per cent N (T₁, T₄, T₇, T₁₀, T₁₃ and T₁₆). This observation clearly establishes the fact that skipping green manure affects the soil sustainability and in turn crop sustainability. Because yield attributes were affected, the rice grain and straw yields were also reduced (Tables 44, 45 and 46; Fig. 24, 25 and 26) when green maturing was excluded. The average grain yield in the green manured treatments with 100 per cent N over three seasons was 5570 kg ha^{-1} , while it was only 4514 kg ha^{-1} in non-green manured treatments on equal fertiliser N basis.

In the absence of green manuring, organic carbon status in the soil and soil available nitrogen and phosphorus got reduced. It reflected on the rice population and DMP culminating in reduced values of yield attributes *viz.*, panicles m^{-2} and filled grains panicle⁻¹. As a result it ended up in relatively low rice grain and straw yields. In line with the present results, skipping the green manure was earlier reported to have affected the rice growth and yield attributes and ultimately the grain yield (Sanjay Sharma *et al.*, 2000; Salu Reddy *et al.*, 1995; Tiwari *et al.*, 1995).

Having established that green manuring is essential, the next question that might arise is whether intercropping green manure could be an effective alternative to basal application of green manure in as much as availability, collection, transport and trampling of green manure are major constraints. Raising a green manure in a brief time slot and *in situ* incorporation of the same is also found to be an unattractive proposition as fertilisers come handy to the farmers.

Over three seasons, green manure (dhaincha) intercropping was found not only an alternative to basal incorporation of green manures but also improved the soil sustainability in terms of organic carbon status and available N, P and K. This soil available N, in fact, was higher due to intercropping and incorporating dhaincha at tender state (40 cm height). The soil available N at flowering which had consistent higher positive association with the yield (correlation matrix in

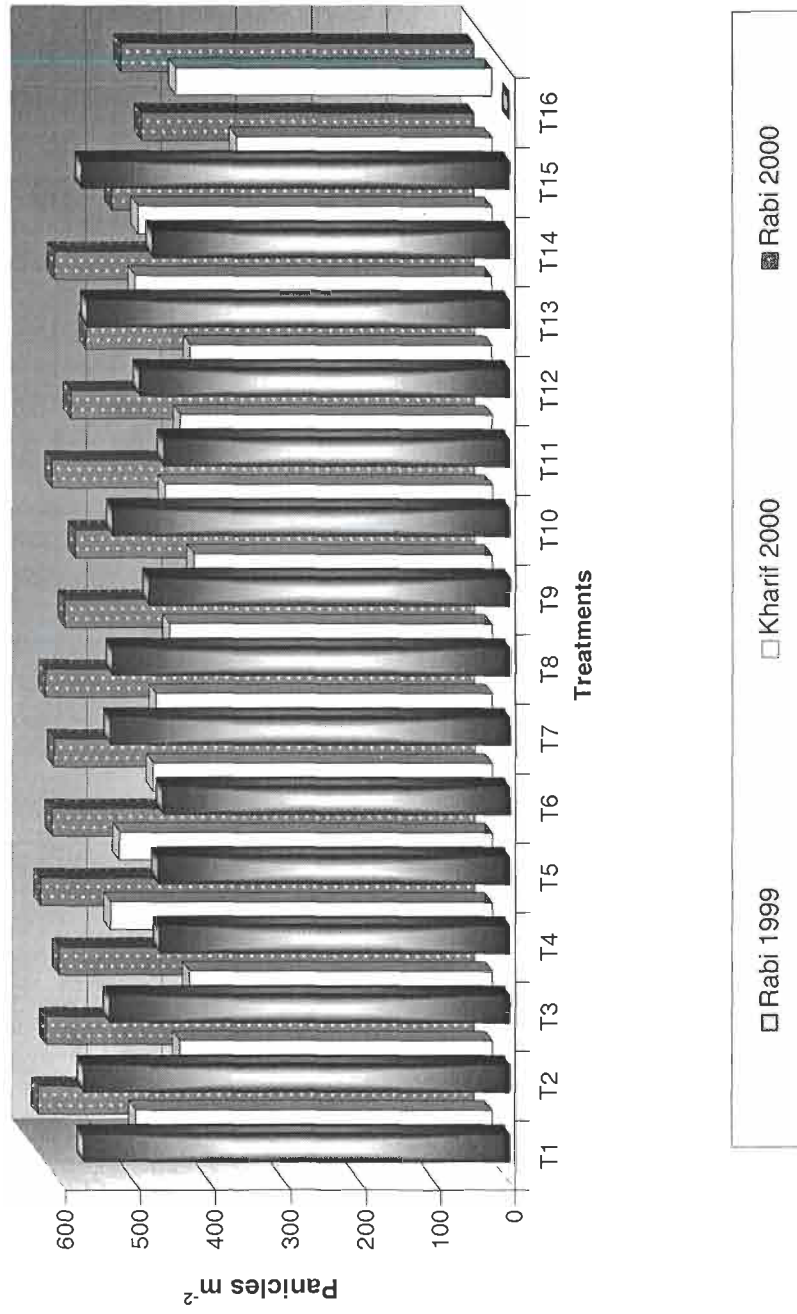


Fig. 23. Panicles m⁻²

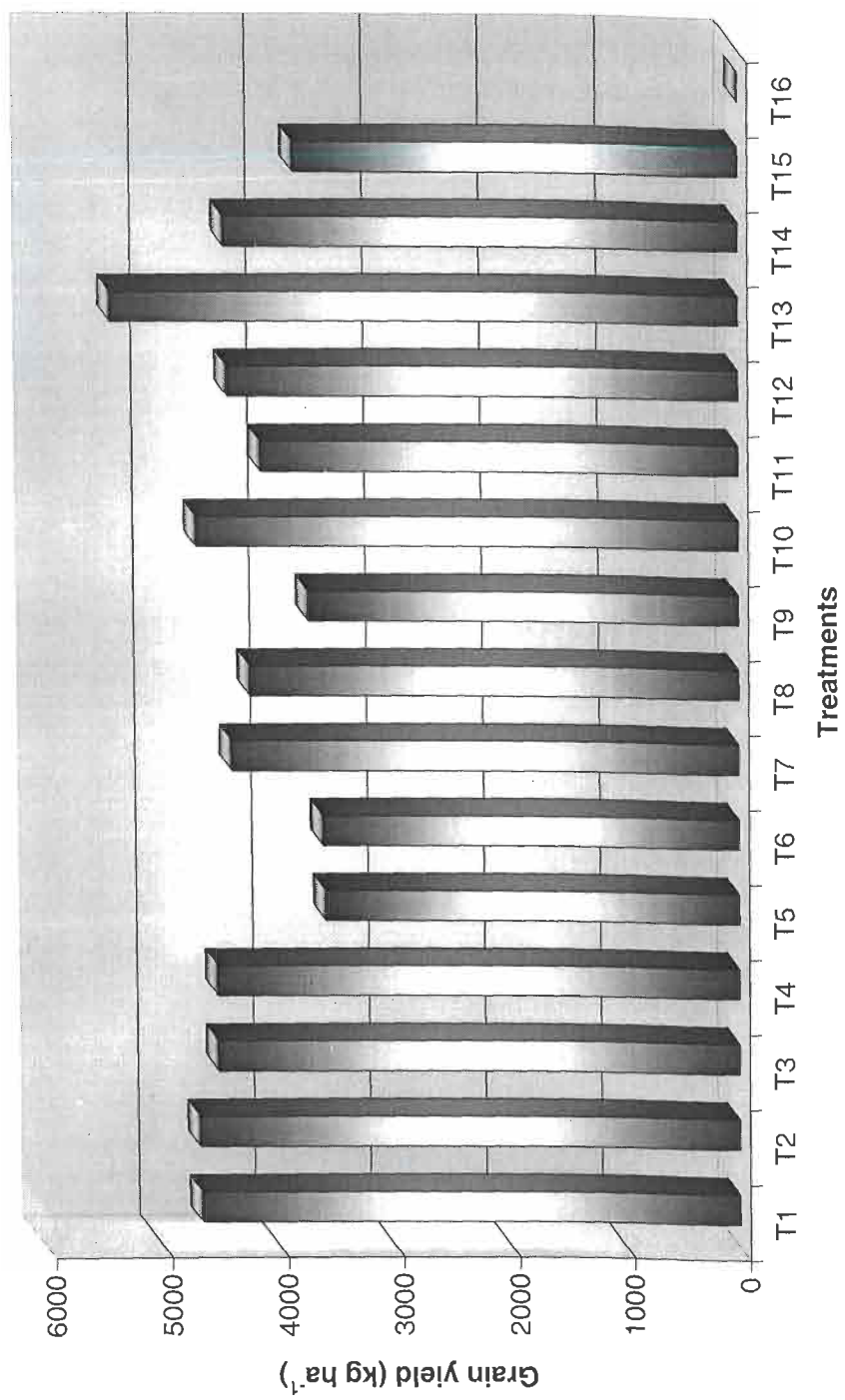


Fig. 24 Grain yield during *rabi* 1999

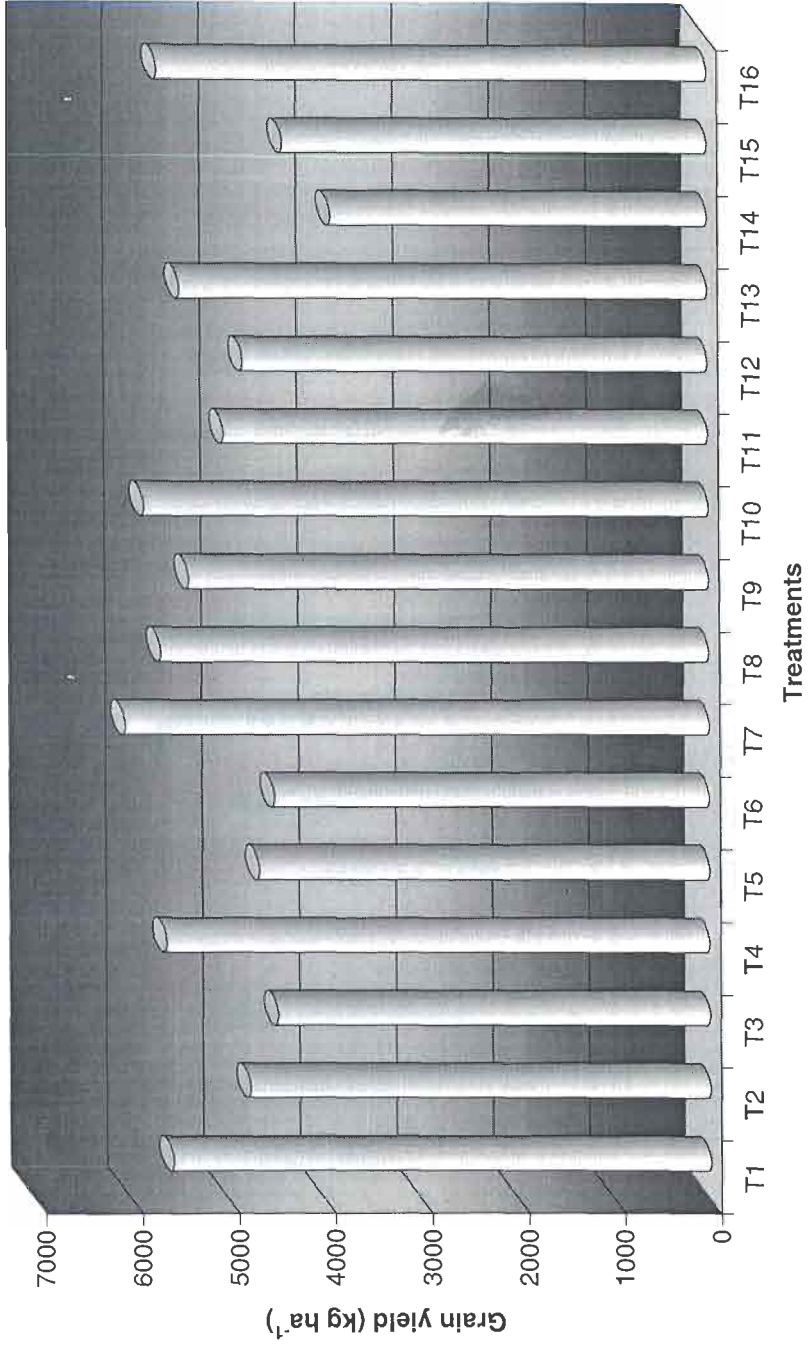


Fig. 25 Grain yield during *kharif* 2000

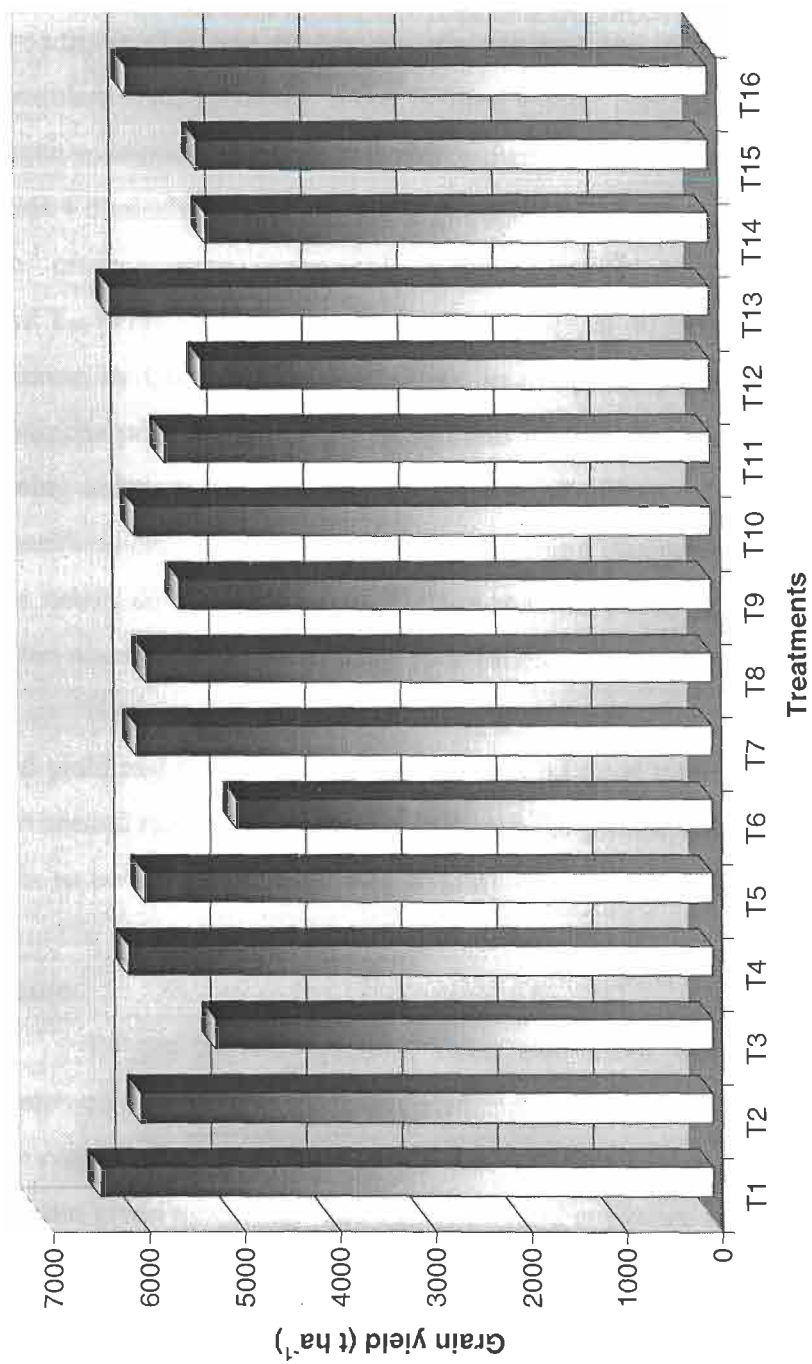


Fig. 26 Grain yield during rabi 2000

table 47) in all the three seasons was, in fact, more with Rice + dhaincha inc. 40 cm + 100 per cent N (T₁). As a result rice DMP got increased at flowering and harvest stages. This treatment had shown higher soil available phosphorus also reflecting on rice population and DMP. In view of improved soil fertility and rice growth, it (T₁) had higher panicle number and filled grains panicle⁻¹. This treatment had, however, more illfilled grains panicle⁻¹ as compared to basally green manured treatments. Better growth and yield attributes in this treatment, Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) resulted in higher yield (5540 kg ha⁻¹ on an average) comparable to that of basally green manured treatments, T₁₃ and T₁₆ (5776 kg ha⁻¹ on an average). Further, at 40 cm height, trampling of green manure by Conoweeder as practised in the present study is less drudgery. The dhaincha population, its nodulation and biomass addition as an intercrop in rice facing submergence are also satisfactory as discussed earlier. Thus, on many considerations, the feasibility of intercropping dhaincha in wet seeded rice using the newly developed Rice *cum* green manure seeder is established provided the green manure is buried at tender state (40cm).

Having seen the inevitability of green manuring for maintaining soil health and yield and having established the feasibility of intercropping green manure in wet seeded rice as an alternative approach for promotion of green manuring, lastly it is to be known whether wet seeding of rice is an alternative to transplanting from the point of rice yield and economics. This is also discussed in the costs and returns.

To get the true picture, these two kinds of establishment are to be compared with or without green manuring. On this basis, wet seeded rice + 100 per cent N (T₁₄) and transplanted rice + 100 per cent N (T₁₅) were maintained without green manuring. The values of yield attributes *viz.*, panicles m⁻² and filled grains panicle⁻¹ were relatively higher in wet seeded rice (T₁₄) in two out of three seasons than that of transplanted rice (T₁₅). The average yields in both kinds of establishments were identical (4515 kg ha⁻¹ in wet seeded rice and 4513 kg ha⁻¹ in transplanted rice). With the inclusion of green manure also, the comparison is made as below.

The identified better treatment, Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) secured comparable values of yield attributes and yield (5986 kg ha⁻¹ on an average of *kharif* and *rabi*, 2000) as that of transplanted rice + basal inc. 6.25 t ha⁻¹ of green manure + 100 per cent (T₁₆) (5889kg ha⁻¹ on an average of *kharif* and *rabi*, 2000). Further, the wet seeded rice was raised with sizeable cost reduction avoiding nursery and transplanting and the green manure was also not raised in a separate season. Besides, collection, transport and trampling of green manures, all are avoided by intercropping. Thus, both with and without green manuring situations, the wet seeded rice outscores transplanting.

Thus it is seen that growing dhaincha upto 40 cm height as an intercrop in rice is found optimum. Higher values of yield attributes and yield could be secured from such tender green manure incorporation with recommended dose of fertiliser N. Comparable yields as that of basally green manured treatments could be secured. Feasibility of intercropping dhaincha is thus established.

As regards substitution of fertiliser N, a meaningful comparison can be had by having majority of the farmers' practice *viz.*, transplanted rice + 100 per cent N (T₁₅) as standard. It is already seen that incorporation of green manure at tender state (40 cm height) is ideal. Therefore, the standard treatment (T₁₅) has to be related with Rice + dhaincha inc. 40 cm (75) or Rice + dhaincha inc. 40 cm (50) per cent N. The transplanted rice + 100 per cent N (standard) got on an average grain yield of 4513 kg ha⁻¹, while Rice + dhaincha inc. 40 cm + 75 per cent N produced 5138 kg ha⁻¹ and 50 per cent N 4727kg ha⁻¹. Thus, it is seen that 50 per cent fertiliser N could be substituted by following Rice + dhaincha inc. 40 cm + 50 per cent N (T₃). But if higher yields are the target, 100 per cent fertiliser N is required and substitution may not be relevant then. In as much as the cost and returns could give more confirmative and comparable information, they are now discussed below.

5.7. Costs and returns

The gross and net returns were higher with wet seeded rice and so also B-C ratio (Tables 44, 45 and 46). The corresponding net returns (Rs. ha⁻¹) during

kharif and *rabi*, 2000 in the identified better treatment, Rice + dhaincha inc. 40 cm + 100 per cent N (T₁) and transplanted rice with basal incorporation of 6.25 t ha⁻¹ of green manure + 100 per cent N (T₁₆) were 22720, 20536 and 27160, 22255. Thus, without collection, transport and trampling basally, by intercropping green manure at 40 cm height in wet seeded rice by sowing them in alternate rows with the newly developed seeder and applying 100 per cent fertiliser N to rice, yield and profit maximisation are possible. The soil sustainability is also kept up at the same time.

Future line of work

A useful line of work in this direction could be having long term studies of rice + dhaincha intercropping and consequent effect on soil health and rice productivity.

1. In long duration rice varieties, optimisation of dhaincha growth needs separate studies.
2. Earlier workers reported that direct seeded rice had early maturity by a week (Peng *et al.*, 1996; Santhi *et al.*, 1998). But in the present study, it was seen clearly that the duration of wet seeded rice got extended by 5 to even 17 days (Table 48) as compared to transplanted rice (*Vide* Plate 8). Built up of soil nitrogen at harvest due to intercropping green manure might have prolonged the duration as correlated (*vide* Table 49). It needs further examination as the observation in the present study seems to be a deviation.
3. Since both soil and crop sustainability are secured simultaneously in the present study using the seeder which is first of its kind in rice research, large scale demonstration of findings would be worth.

Summary and conclusion

CHAPTER VI

SUMMARY AND CONCLUSION

A field experiment was carried out to find out the feasibility of intercropping green manure (dhaincha) in wet seeded rice. Sowing of component crops was done by using TNAU Rice cum green manure seeder. The present study using the seeder is first of its kind in rice research. The study was undertaken for three seasons *viz.*, *rabi*, 1999 at TNAU, campus, Coimbatore and *kharif* and *rabi*, 2000 at Agricultural Research Station, Bhavanisagar.

The treatment structure comprises of intercropping dhaincha and incorporating it at various heights *viz.*, 40 to 70 cm at 10 cm increments for each height maintaining 50, 75 and 100 per cent of recommended nitrogen to rice. Sole wet seeded rice + 100 per cent N with basal incorporation of green manure and without green manure and similar two treatments in transplanted rice were included to find out comparative use of wet seeding as an alternative establishment practice to rice transplanting (as an objective) and also to observe the feasibility of intercropping green manure in the former. Altogether there were sixteen treatments replicated thrice in randomised block design.

Height optimisation of intercropped dhaincha, extent of substitution of fertiliser N and soil fertility dynamics are the other objectives of the study.

The findings and interpretations are summarised and concluded below.

The growth of intercropped dhaincha was quite asymmetrical having slow growth initially upto 35 - 40 cm and attaining a fast growth afterwards mediated by prevailing temperature.

The population of intercropped dhaincha had natural thin out as it grew from 40 to 70 cm. It indicates the intraspecies competition evidently supportive of weed suppression in between rice rows.

Nodules of intercrop dhaincha ranged from 17.2 to 54.9 plant⁻¹ and the biomass production from 7.3 to 28.4 t ha⁻¹ depending upon the height of incorporation. The nitrogen contribution ranged from 36.9 to as high as 139.5 kg ha⁻¹.

Thus, the growth and N contribution of dhaincha as an intercrop are found satisfactory tolerating the water stagnation induced for the associate rice.

The availability of enough green manure is a constraint and allocating an exclusive time slot for raising green manure is a limitation voiced so far. These are addressed in the present study. The focus from the results now shifts from "constraint" to "concern" of excess biomass production of dhaincha as the minimum production itself is 7.3 t ha^{-1} .

The population of wet seeded rice in rice + green manure treatments was higher as compared to transplanted rice. Thus, wider inter row spacing of wet seeded rice (25 cm) maintained to accommodate dhaincha is not a limitation in securing the rice population.

Biomass addition from the taller dhaincha (60 or 70 cm) was far higher as compared to 40 cm height. Upon incorporation, higher green manure biomass did not reflect on the same way on rice biomass (DMP) production. In fact, incorporation at tender state (40 cm) with 100 per cent N to rice (Rice + dhaincha inc. 40 cm + 100 per cent N) had more rice DMP owing to fast decay and mineralisation and resultant higher soil available nitrogen at rice flowering.

The 'fast' fraction of N of the intercropped green manure had more compensatory effect on rice DMP offsetting the effect of reduced dose of fertiliser N. Basal incorporation of green manure had only early increases of DMP.

Light interception, SPAD 502 and LCC values did not vary much due to integration of green manure (as an intercrop) along with N fertiliser. The 'fast' N of intercropped green manure might have contributed for similar crop profile in all the intercropped treatments causing not much variation in these parameters.

The uptake of nitrogen between flowering and harvest reflected positively on the rice yield as observed from the three seasons study.

The N uptake of rice did not depend on how taller the intercrop dhaincha was grown and what was the N contribution by it. The uptake on the other hand was slightly higher with 40 cm height. Thus, Rice + dhaincha inc. 40 cm + 100 per cent N to rice secured higher uptake of N, P and K by rice.

Absence of green manuring resulted in lesser uptake of nutrients showing the inevitability of the practice.

Soil organic carbon content got increased with addition of green manure biomass. Reduction in fertiliser N to rice reduced the soil carbon content possibly due to less contribution of rice root biomass. Absence of green manuring either basally or by intercropping resulted in lower organic carbon status in the soil.

Fluctuations in the soil available N, P and K existed depending upon the state of green manure incorporation. Burial of tender (40 cm) intercropped green manure resulted in higher soil available N at flowering. Later on, at harvest, it was the taller dhaincha which contributed more for the soil available nutrients. This might be due to contribution from 'slow' N.

Higher availability of soil N at flowering resulted in higher uptake and DMP of rice in Rice + dhaincha inc. 40 + 100 per cent N.

Despite 100 per cent of recommended N to rice, skipping green manure resulted in poor uptake of nutrients warranting its need for better rice growth and yield.

Skipping green manure thus affected the soil sustainability which in turn affected the crop sustainability in terms of yield attributes viz., number of panicles m^{-2} and filled grains panicle⁻¹ and grain and straw yields ultimately.

Intercropping green manure in wet seeded rice was found to be an effective alternative to basal incorporation in maintaining higher status of organic carbon and available N and P in the soil at the crucial stage of rice flowering provided it is buried at tender state (40 cm height).

With 100 per cent N to rice, such tender state of intercrop green manure incorporation resulted in higher soil available N and P at flowering ultimately increasing the yield attributes, grain and straw yields of rice as that of basal incorporation of green manure with the same 100 per cent fertiliser N. Thus, the feasibility of intercropping and *in situ* incorporation of dhaincha is established.

Wet seeded rice was found to outscore rice transplanting in term of economics under identical situations.

As compared to farmers' practice of transplanting rice + 100 per cent N, intercropping green manure in wet seeded rice and incorporating it at 40 cm height all with tools could substitute even 50 per cent of fertiliser N in terms of rice yield. But if higher yields are the target, Rice + dhaincha inc. 40 cm + 100 per cent fertiliser N is required. This treatment is identified for the farmers to follow as a better practice for securing higher returns and B-C ratio as compared to transplanted rice. Cost reduction in rice cultivation is also accomplished.

Long term study on Rice + green manure intercropping is required to find out soil and crop sustainability in the long run. Meanwhile, large scale demonstration of Rice + dhaincha inc. 40 cm height + 100 per cent N to rice is worth to pursue in farmers' holdings in comparison with transplanted rice.

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PLATES



Plate 1. TNAU Rice *cum* green manure seeder



Plate 2. Sowing in progress using the seeder



Plate 3. Conoweeder



Plate 4. Experimental crop of rice + green manure



Plate 5. Trampling dhaincha using IRRI Conoweeder



Plate 6. Dhaincha incorporated and to be incorporated rows



Plate 7. General view of the experimental crop



Plate 8. Early maturity of transplanted rice

Appendices

APPENDIX I

Treatmentwise cost of cultivation

Treatments	Season		
	<i>rabi</i> 1999	<i>kharif</i> 2000	<i>rabi</i> 2000
T ₁	12873	12872	22720
T ₂	12498	12573	17907
T ₃	12124	12274	16354
T ₄	12873	12872	23105
T ₅	12498	12573	17268
T ₆	12124	12274	16547
T ₇	13071	13142	25518
T ₈	12696	12843	23449
T ₉	12322	12544	21897
T ₁₀	13269	13412	23970
T ₁₁	12894	13113	18964
T ₁₂	12520	12814	17985
T ₁₃	14695	14693	20260
T ₁₄	12695	12693	12228
T ₁₅	13069	13887	14459
T ₁₆	-	15887	20536