

**STUDIES ON DUAL CULTIVATION OF DAINCHA (*Sesbania aculeata* W.)
IN WET SEEDED RICE FOR *IN SITU* GREEN MANURING
CUM SEED PRODUCTION AND N SPLIT STRATEGIES**

Thesis submitted in part fulfilment of the requirements for the award of the degree of
DOCTOR OF PHILOSOPHY (Agriculture) in AGRONOMY
to the Tamil Nadu Agricultural University, Coimbatore.

By

S. ANBUMANI
(I.D. No. 98-806-001)

**DEPARTMENT OF AGRONOMY
CENTRE FOR SOIL AND CROP MANAGEMENT STUDIES
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE-641 003**

2001

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON DUAL CULTIVATION OF DAINCHA (*Sesbania aculeata* W.) IN WET SEEDED RICE FOR *IN SITU* GREEN MANURING CUM SEED PRODUCTION AND N SPLIT STRATEGIES**” submitted in part fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (Agriculture)** in **AGRONOMY** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. S. ANBUMANI** 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, prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Place : Coimbatore

Date : 27.04.01


(Dr. B. CHANDRASEKARAN)
Chairman

Approved by:

Chairman :


(Dr. B. CHANDRASEKARAN) 30.06.01

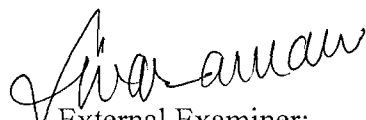
Members :


(Dr. K. VELAYUDHAM)


(Dr. P. MUTHUVEL)


(Dr. U. BANGARUSAMY)

Date :


External Examiner:

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

I wish to express my deep heartfelt sense of gratitude to the Chairman of the Advisory Committee, **Dr. B. Chandrasekaran**, Professor of Agronomy for his benevolent and noble ideas, constructive criticism, valuable guidance, incessant and steadfast inspiration, and keen interest shown throughout the course of investigation which had vivified this script.

I express my profound sense of gratitude and sincere thanks to the members of the Advisory Committee, **Dr. K. Velayudham**, Professor of Agronomy, **Dr. P. Muthuvel**, Professor of Soil Science and Agricultural Chemistry and **Dr. U. Bangarusamy**, Professor of Crop Physiology, for their consistent and constructive suggestions, keen interest and critical planning, execution and perusal of the manuscript.

I will be failing in my duty, if I not place on record my heartfelt gratitude to **Dr. P. Rajendran**, Professor of Agronomy, for his meticulous help, guidance in planning and carrying out this investigation successfully. I sincerely thank **Dr. T.M. Thiagarajan**, Director (SCMS) for his evergreen support and patronage.

I gratefully acknowledge **Dr. N. Sankaran**, Professor and Head, Department of Agronomy, **Dr. T.N. Balasubramanian**, Professor and Head, Department of Agricultural Meteorology **Dr. P. Muthukrishnan**, **Dr. James Martin** and **Dr. K.K. Chandragiri**, Professors of Agronomy, **Dr. P. Subbian**, Deputy Registrar, **Dr. G. Kuppaswamy**, Professor and Head (Agronomy), Annamalai University, **Dr. V. Chellamuthu** Professor and Head (Agronomy), PAJANCOA&RI, Karaikal, **Dr. M. Premsekar** and **Dr. K. Rajendran** Associate professors, **Dr. K. Ramamoorthy**, **Dr. Sathyavelu**, **Dr. A. Christopher Lourduraj**, **Dr. Sathyamoorthy** and **Mr. K. Subramanian**, Assistant Professors of Agronomy for their unflinching help which paved the way to accomplish fruition of this investigation in appropriate time and precision. I wish to place on record, my inestimable gratitude to **Dr. R.S.V. Rai**, Retd. Professor, Tamil Nadu Agricultural University, for editing and fine-tuning the manuscript.

I greatly acknowledge my friends **M/s. Pari, Sridar, Balu, Sababady, Dinahar, Prabu, Sandrou, Ramesh, Ravi, Ravishankar, Karunanidhi, Solai, Siva, Ganesan, Thamiz, Jaya, Iyyanar, Thangaraj, Alagesan** and classmates **Selvi, Kalpana, Sivamurugan, Sakthi, Raja, Samy, Edwin, Sanbagavalli, Jayaramasoundari, Radamani** and junior friends **Ramesh, Srinivas, Rajarathinam, Mari** for their love, inspiration and ever willing help throughout the study period.

I gratefully acknowledge **Mrs. Chandrasekaran** and **Mr. K.C. Balachandar** for treating me as a member of the family.

On a personal note, I wish to place a record of my deep sense of gratitude and indebtedness and loving thanks to my **parents, brothers, sister, uncle, sister-in-laws** and **Ms. B. Rajalakshmi** for their everlasting philip and impetus, encouragement and whole hearted blessings.

I wish to thank **M/s. Sree Ganapathy Computers, Coimbatore** for the neat execution of this thesis.



[S. ANBUMANI]

ABSTRACT

ABSTRACT

STUDIES ON DUAL CULTIVATION OF DAINCHA (*Sesbania aculeata* W.) IN WET SEEDED RICE FOR *IN SITU* GREEN MANURING CUM SEED PRODUCTION AND N SPLIT STRATEGIES

By

S. ANBUMANI

Degree : Ph.D. (Agriculture) in Agronomy

Chairman : Dr. B. CHANDRASEKARAN
Professor of Agronomy
Tamil Nadu Agricultural University
Coimbatore-641 003, India.

2001

Field experiments were conducted in wet seeded rice intercropped with green manure in three seasons viz., *kharif* 1999, *rabi* 1999 and *kharif* 2000 at the wetlands of TNAU campus, Coimbatore. The green manure daincha was raised as intercrop for finding out the feasibility of *in situ* green manuring and seed production at the same time. Various N split doses were tested to correct any temporary setback in the base crop of rice upon incorporation of green manure.

Intercropping treatments were assigned to mainplots, while that of N split doses in subplots in a split plot design with three replications. Besides exclusive green manuring treatment, every 10, 15 and 20th row were left out for seed production with a check plot of sole rice for comparison. Nitrogen split doses tested were 25:25:25:25, 25:33:21:21 and 25:42:16.5:16.5 per cent during 20, 37, 55 and 70 DAS, respectively. The rice and green manure were sown using rice cum green manure seeder.

Intercropping daincha exclusively for *in situ* green manuring promoted growth and yield attributes which in turn reflected positively on the grain and straw yield of rice than sole rice.

Uptake of all major nutrients was increased markedly upon intercropping and *in situ* incorporation of daincha as compared to sole rice. Soil fertility was also promoted as revealed by the value of soil organic carbon, available N and P in the soil.

Leaving daincha at narrow intervals for seed production i.e., 10th or 15th row affected the rice growth and development reflecting on the yield of rice particularly adjacent rows with poor interception of light. Whereas seed production at farther interval (20th row) caused least reduction in rice grain yield, thereby maximized the rice equivalent yield and returns.

Daincha (seed crop), regardless of row interval, had similar values of yield components *viz.*, number of pods plant⁻¹, seeds pod⁻¹ and test weight.

As regards N split doses, application of 25 per cent on 20 DAS, 33 per cent at the time of green manure incorporation (to correct the temporary setback of rice growth) and the remaining dose at 21 per cent on 55 and 70 DAS was found to be advantageous.

Thus the findings of this innovative approach could be abstracted as under:

- It is feasible to raise daincha in alternate rows as an intercrop in wet seeded rice using newly developed rice cum green manure seeder.
- Besides, *in situ* green manuring, leaving every 20th row for seed production confer not only self manuring by the land but also self production of green manure seed (daincha) by the farmer himself.
- Not altering the total dose of fertilizer N, a split dose per cent of 25:33:21:21 during 20 DAS, at green manure incorporation, 55 and 70 DAS, respectively was found to be ideal way of N application correcting temporary setback, if any upon green manure incorporation .

Thus sustainability of rice culture and of green manure seed production are established from the present study.

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	5
III	MATERIALS AND METHODS	35
IV	RESULTS	55
V	DISCUSSION	147
VI	SUMMARY AND CONCLUSION	178
	REFERENCES	
	PLATES	
	APPENDICES	

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
1	Physico-chemical properties of experimental field	39
2	Characteristics of rice cultivars used in the experiment	40
3	Details of analytical methods employed in soil and plant analysis	52
4	Plant population (No.m ⁻²) and plant height of daincha at the time of incorporation (37 DAS)	56
5	Biomass (t ha ⁻¹) and N accumulation of daincha at the time of incorporation (37 DAS)	57
6	Influence of daincha intercropping/seed production and N split doses on plant height of rice (cm) at active tillering and panicle initiation stages	59
7	Influence of daincha intercropping/seed production and N split doses on plant height of rice (cm) at flowering and maturity stages	60
8	Influence of daincha intercropping/seed production and N split doses on number of tillers of rice (m ⁻²) at active tillering and panicle initiation stages	62
9	Influence of daincha intercropping/seed production and N split doses on number of tillers (m ⁻²) of rice at flowering stage.	63
10	Influence of daincha intercropping/seed production and N split doses on leaf area index of rice.	65
11	Influence of daincha intercropping/seed production and N split doses on leaf area duration (LAD) of rice (d m ⁻² day ⁻¹)	67
12	Influence of daincha intercropping/seed production and N split doses on SPAD values of rice at active tillering and panicle initiation stages	69
13	Influence of daincha intercropping/seed production and N split doses on SPAD values of rice at flowering stage	70
14	Influence of daincha intercropping/seed production and N split doses on dry matter production by rice (kg ha ⁻¹) at active tillering and panicle initiation stages	72
15	Influence of daincha intercropping/seed production and N split doses on dry matter production (kg ha ⁻¹) by rice at flowering stage	73
16	Influence of daincha intercropping/seed production and N split doses on dry matter production by rice (kg ha ⁻¹) at maturity stage	74

...Contd.

TABLE NO.	TITLE	PAGE NO.
17	Influence of daincha intercropping/seed production and N split doses on crop growth rate by rice ($\text{g m}^{-2} \text{day}^{-1}$)	77
18	Influence of daincha intercropping/seed production and N split doses on nitrogen uptake (kg ha^{-1}) by rice at active tillering stage	78
19	Influence of daincha intercropping/seed production and N split doses on nitrogen uptake (kg ha^{-1}) by rice at flowering stage	79
20	Influence of daincha intercropping/seed production and N split doses in on nitrogen uptake (kg ha^{-1}) by rice at maturity stage	80
21	Influence of daincha intercropping/seed production and N split doses on phosphorus uptake (kg ha^{-1}) by rice at active tillering stage	83
22	Influence of daincha intercropping/seed production and N split doses on phosphorus uptake (kg ha^{-1}) by rice at flowering stage	84
23	Influence of daincha intercropping/seed production and N split doses on phosphorus uptake (kg ha^{-1}) by rice at maturity stage	85
24	Influence of daincha intercropping/seed production and N split doses on potassium uptake (kg ha^{-1}) by rice at active tillering stage	88
25	Influence of daincha intercropping/seed production and N split doses on K uptake (kg ha^{-1}) by rice at flowering stage	89
26	Influence of daincha intercropping/seed production and N split doses on K uptake (kg ha^{-1}) by rice at maturity stage	90
27	Influence of daincha intercropping/seed production and N split doses on number of panicles m^{-2} of rice	92
28	Influence of daincha intercropping/seed production and N split doses on number of filled grains panicle ⁻¹ of rice	94
29	Influence of daincha intercropping/seed production and N split doses on percentage of illfilled grains of rice	95
30	Influence of daincha intercropping/seed production and N split doses on panicle length (cm) of rice	97
31	Influence of daincha intercropping/seed production and N split doses on test weight (g) of rice	98
32	Influence of daincha intercropping/seed production and N split doses on grain yield of rice (kg ha^{-1})	100
32a	Influence of daincha intercropping/seed production and N split doses on grain yield (kg ha^{-1}) of rice (pooled mean yield)	101

...Contd.

TABLE NO.	TITLE	PAGE NO.
33	Influence of daincha intercropping/seed production and N split doses on straw yield of rice (kg ha^{-1})	103
34	Influence of daincha intercropping/seed production and N split doses on harvest index of rice	104
35	Influence of daincha intercropping/seed production and N split doses on rice grain yield, daincha seed yield and rice yield equivalent	105
36	Combined influence of daincha intercropping with N split doses on rice grain yield, daincha seed yield and rice yield equivalent (kg ha^{-1})	106
37	Influence of daincha intercropping/seed production and N split doses on agronomic efficiency (kg grain/kg N)	108
38	Influence of daincha intercropping/seed production and N split doses on apparent recovery (%)	110
39	Influence of daincha intercropping/seed production and N split doses on partial factor productivity (kg grain/kg N)	111
40	Influence of daincha intercropping/seed production and N split doses on soil organic carbon content (%) at active tillering at panicle initiation stages	113
41	Influence of daincha intercropping/seed production and N split doses on soil organic carbon content (%) at flowering and maturity stages	114
42	Influence of daincha intercropping/seed production and N split doses on available soil N (kg ha^{-1}) at active tillering and panicle initiation stages	116
43	Influence of daincha intercropping/seed production and split doses on available soil N (kg ha^{-1}) at flowering stage	117
44	Influence of daincha intercropping/seed production and N split doses on available soil N (kg ha^{-1}) at maturity stage	118
45	Influence of daincha intercropping/seed production and N split doses on available soil P (kg ha^{-1}) at active tillering at panicle initiation stages	120
46	Influence of daincha intercropping/seed production and N split doses on available soil P (kg ha^{-1}) at flowering stage	121

...Contd.

TABLE NO.	TITLE	PAGE NO.
47	Influence of daincha intercropping/seed production and N split doses on available soil P (kg ha^{-1}) at maturity stage	122
48	Influence of daincha intercropping/seed production and N split doses on post harvest K in soil (kg ha^{-1})	124
49	Influence of daincha intercropping/seed production and N split doses on light interception (%) before GM incorporation	125
50	Influence of daincha intercropping/seed production and N split doses on light interception of rice (%) at active tillering at panicle initiation stages	126
51	Influence of daincha intercropping/seed production and N split doses on light interception of rice (%) at flowering and milky stages	127
52	Influence of daincha intercropping/seed production and N split doses on net income (Rs. ha^{-1}) and benefit cost ratio (BCR) of rice	129
53	Combined influence of intercropping with N split doses on net income (Rs. ha^{-1}) and benefit cost ratio (BCR) of rice	130
54	Influence of daincha intercropping/seed production and N split doses for rice on plant height, branches plant^{-1} and canopy coverage of daincha seed crop	133
55	Influence of daincha intercropping/seed production and N split doses for rice on yield attributes of daincha seed crop	135
56	Influence of daincha intercropping/seed production and N split doses for rice on seed and haulm yield and test weight of daincha seed crop	137
57	Influence of daincha intercropping/seed production and N split doses for rice on NPK uptake (Kg ha^{-1}) of daincha seed crop at maturity stage	139
58	Influence of daincha intercropping for seed production on yield, yield attributes and light interception (%) of rice during <i>kharif</i> 1999	141
59	Influence of daincha intercropping for seed production on yield, yield attributes and light interception (%) of rice during <i>rabi</i> 1999	142
60	Influence of daincha intercropping for seed production on yield, yield attributes and light interception (%) of rice during <i>kharif</i> 2000	143
61	Monetary profit /loss of rice + daincha (seed crop) intercropping in wet seeded rice	145

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1a	Weather for the cropping period - <i>kharif</i> 1999	36
1b	Weather for the cropping period - <i>rabi</i> 1999	37
1c	Weather for the cropping period - <i>kharif</i> 2000	38
2	Layout of the experimental field	42
3a	Drum seeder (rice + green manure)	43
3b	Rice + Daincha intercropping	43
4a	Every 10 th row for daincha seed production	45
4b	Every 15 th row for daincha seed production	45
4c	Every 20 th row for daincha seed production	45
5	Influence of daincha intercropping/seed production and N split doses on dry matter production of rice at maturity stage	151
6	Influence of daincha intercropping/seed production and N split doses on nitrogen uptake by rice at maturity stage	154
7	Influence of daincha intercropping/seed production and N split doses on number of panicles m ⁻² of rice	156
8	Influence of daincha intercropping/seed production and N split doses on percentage of illfilled grains	157
9	Influence of daincha intercropping/seed production and N split doses on grain yield of rice	159
10	Influence of daincha intercropping/seed production and N split doses on agronomic efficiency	162
11	Influence of daincha intercropping/seed production and N split doses on apparent recovery	163
12	Influence of daincha intercropping/seed production and N split doses on partial factor productivity	164
13	Influence of daincha intercropping/seed production and N split doses on post harvest available soil N	168
14	Influence of daincha intercropping/seed production and N split doses on post harvest available soil P	169
15	Influence of daincha intercropping/seed production and N split doses on light interception (%) at milky stage of rice	172
16	Influence of daincha intercropping/seed production and N split doses on net income of rice	173
17	Influence of intercropping treatments on seed yield of daincha	175

LIST OF PLATES

PLATE NO.	TITLE
1	Field view - Sowing by drum seeder (rice + daincha)
2	Field view of rice + daincha on 37 DAS
3	Trampling with IRRI Cono weeder on 37 DAS
4	Field view - Seed production row (early stage)
5	Field view - Seed production row (later stage)
6	Initial setback of rice crop after daincha incorporation
7	Daincha - Every 10 th row for seed production
8	Daincha - Every 15 th row for seed production
9	Daincha - Every 20 th row for seed production
10	Recording - Light availability (canopy top)
11	Recording - Light availability (canopy bottom)
12	Recording - Chlorophyll (SPAD 502)

LIST OF APPENDICES

APPENDIX NO.	TITLE
I	Effect of shading at different growth stages on yield components and yield of paddy variety IR7474-82-6
II	Weather data during the cropping periods (<i>kharif</i> and <i>rabi</i>)
III	Details of cost of rice production
IV	Economics of daincha intercropping/seed production and N split dose in wet seeded rice during <i>kharif</i> 1999
V	Economics of daincha intercropping/seed production and N split dose in wet seeded rice during <i>rabi</i> 1999
VI	Economics of daincha intercropping/seed production and N split dose in wet seeded rice during <i>kharif</i> 2000

INTRODUCTION

CHAPTER I

INTRODUCTION

Rice is a staple food crop of Asia in general and India in particular. It is being grown over an area of 44.60 million hectares with a production of 85.99 million tonnes (Anon, 2000) and it continues to hold the key to sustain food production by contributing 20-25 per cent of agriculture GDP and assures food security in India for more than half of the total population. However, from the standpoint of net returns to the farmers, it is a lacklustre crop.

Uncertainty in release of canal water, non availability of labour in time and wage hike have rendered transplanting less remunerative and less attractive (DRR, 1999). In recent years, price ratio of output to input has become abysmally less favourable to farmers owing to manifold escalation of input cost and labour prices but, the price of rice has not increased proportionately due to Government policy interventions (Bhuiyan *et al.*, 1995). Therefore, pursuit of alternative rice culturing which comprises less inputs and maintains high yields is an important long felt need.

Wet seeding does away with the need for seedling, nursery preparation, uprooting of seedling and replanting (Pandey, 1995). Typically it takes 30 persons day per hectare compared to 1-2 persons day in wet seeding (Anon, 1999). It holds special significance in present day production system with regard to saving labour, time, energy and increasing profitability and cropping intensity by decreasing turn around period and precluding arduous operations like nursery preparation and manual transplanting (Pandey and Velasco, 1999). It also reduces drudgery, ensures more efficient water use, higher tolerance to water deficit and increased benefit cost ratio (Subbaiah and Balasubramanian, 2000).

Decelerating and declining trends in rice productivity under irrigated ecosystems is a matter of paramount concern (FAO, 1997). Intensive cultivation has been shown to potentially degrade the resource base (Pingali *et al.*, 1990). Hence, soil research emphasizes prevention of soil health deterioration and yield decline. The declining trend

is mainly attributed to reduced use of organic manures and micronutrient deficiencies (Ramalingam *et al.*, 2000). Sustainability of rice production depends on maintenance of key resources particularly soil. Maintenance of organic matter in tropical situation like South India is an inherent predicament, unlike in temperate countries.

The importance ascribed to sustainability at present is an appropriate attempt to promote organic manures, which can sustain soil health. The bulkiness as well as non-availability of organic manures restrain their use and necessitate evolving viable alternatives. Green manures are agro-biologically viable and ecologically sound alternatives which shall serve the dual purpose of increasing crop productivity as well as improving long term soil fertility in sustainable crop production (Singh *et al.*, 1991).

Though green manures constitute a feasible and appropriate substitute to build up of soil fertility without endangering the resource base, in the intensive and profit oriented cropping system, the situation may not permit the farmers to earmark their already small land area for 6 to 7 weeks exclusively for green manure cultivation without any revenue (Zaman *et al.*, 1991; Kannaiyan, 2000). This apart separate cultivation of green manure prior or after rice warrants tillage and seeding operation which involve labour and cash outlay that may be oppressive on the farmers (Garrity and Flinn, 1988).

Therefore, evolving a suitable system for fitting green manures without sacrificing any of the economic crops in the system mooted the strategy of growing green manures along with rice as a dual culture. But this is bristled with its own limitations since it is believed that these intercrops may compete for resource pools and usher in reduction in rice yield (Abraham Varughese and Sushama Kumari, 1993).

There is a greater possibility of intercropping green manures during early stage of rice crop with less interference on rice growth (Gracy Mathew *et al.*, 1991). This situation can effectively be capitalised by raising daincha as a green manure crop concurrently with wet seeded rice using TNAU drum seeder developed by Rajendran *et al.*(1999). *Sesbania aculeata* is a widely cultivated green manure in India. It has wide adaptability (water logged, salinity, severe drought) and accumulates large biomass in a

shorter period of time (Pandey, 1996). This besides, it is already familiar to the farmers (Bhuiyan and Zaman, 1996).

Availability of seed is a major constraint for the large scale adoption of green manures in integrated nutrient management, even though use of green manures is an age old practice (Ali and Narsico, 1993). Non-availability of adequate green manure seeds, costly establishment, high price of land, labour and affordable price of the mineral fertilizers are the major constraints to green manure use in low external input sustainable agriculture (Ladha *et al.*, 1992). Scarcity of seed is the main impediment to quick expansion of *Sesbania* green manuring. There is also little scope for growing *Sesbania* as sole crop for seed production as most of the land is harnessed for rice cultivation in the lowland ecosystem (Sirajul Islam *et al.*, 1999).

A minimum period of 2-3 weeks is required for decomposition of incorporated green manure to release N (Dey and Jain, 1997). Green manure addition one week prior to transplanting coincided with the time of N demand of crop (after it regained foraging ability from transplant shock) as outlined by Sur *et al.*, 1993.

Further, when green manure is trampled in the standing rice crop at about 37 DAS, there would be a temporary setback in the growth of rice due to decomposition of the green manure. This needs correction by external application of inorganic N. As a panacea to this problem, increasing the starter dose of N application at the time of daincha incorporation by adjusting the split levels without increasing the total N may be resorted to.

Rice land itself should produce rice, green manure and seed for sowing green manure in the succeeding season to overcome the constraints. Keeping in view of the above factors a study on “dual cultivation of daincha in wet seeded rice for *in situ* green manuring cum seed production with suitable N split doses strategies” was formulated with the following objectives:

- To find out the feasibility of intercropping daincha (*Sesbania aculeata*) in wet seeded rice for green manuring cum seed production.
- To find out an optimum row ratio of rice and green manure seed crop with no/least detrimental effect to rice.
- To study the added advantages of the dual cropping of green manure and their effect on growth and development of wet seeded rice.
- To find out a suitable nitrogen split dose strategy in order to correct setback in mid-season crop (rice) due to incorporation of green manure.
- To find out the influence of green manure *in situ* incorporation on soil health.
- To evaluate economics of dual cropped daincha in wet seeded rice.

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

Rice is a predominant food crop mainly produced by two principal methods, viz., transplanting and direct seeding. Though transplanting is popular, wet seeding is gaining acceptance worldwide, especially in Asia due to manifold reasons (Pandey, 1995). Uncertainty in release of canal water, non-availability of labour in time and escalation in wages have made transplanting more cumbersome and expensive now than ever before. Transplanting by contract labour led to less number of hills per unit area than the recommended population (DRR, 1998). This precarious situation invites, viable, cost-effective, labour saving substitution such as direct seeding. Accordingly, in South East Asia, over the past 10-15 years there has been a shift in rice production system from transplanting to direct seeding (Moody, 1993), as it involves minimal use of labour force relative to transplanting system (Jayadeva *et al.*, 1998). The man days required for manual transplanting was 317 compared to 214 ha⁻¹ for transplanter.

Growing of green manures exclusively for green manuring purpose, is still an cumbersome approach consuming additional time, water and labour besides affecting the cropping intensity (Zaman *et al.*, 1991). Inclusion of flood tolerant leguminous green manure as an intercrop in rice would be a potential solution to the said predicaments. Though the importance of raising green manures is increasingly realized, the availability of quality seeds is a major impediment in recent years (Becker *et al.*, 1995; Palaniappan and Siddeswaran, 1999).

Nitrogen is widely recognized as the most limiting nutrient in rice production. In India, two third of rice soils are reported to lack adequate N (Mahapatra *et al.*, 1985). Therefore, inclusion of green manures in nitrogen management will pave way for higher efficiency. *In situ* growing and incorporation of green manure crop in standing rice crop with nitrogen management strategies to tackle the temporary lock up of N is desirable.

The available literature on intercropping daincha in wet seeded rice for *in situ* green manuring cum seed production with nitrogen split-dose strategies is reviewed in this chapter.

2.1. Wet seeded rice

2.1.1. Prospect and retrospect

Transplanting is the most common method in Asia's irrigated rice growing areas (De Datta, 1986); this practice is increasingly being replaced by direct seeding as labour becomes scarce and cost prohibitive (Erguiza *et al.*, 1990; Madhu and Nanjappa, 1995; Govindarasu *et al.*, 1998; Ito, 1998; Jayadeva *et al.*, 1998). Consistent decline in rice yield and profit is rampant in irrigated lowlands of Asia because more than 21 per cent of total cost of production is accounted for transplanting alone. Therefore, the pursuit 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, profuse tillering cultivars, selective herbicides and improved fertilizer management coupled with reduced cost of production had encouraged many farmers to switch from transplanting to wet seeding (De Datta, 1986; De Datta and Flinn, 1986).

Transplanting seedlings typically takes 20 persons day⁻¹ ha⁻¹. The cost of labour required for transplanted rice cultivation is almost two times more than that for wet seeded rice (Coxhead, 1984; Sivaperumal, 1995). Direct seeding is a labour saving feature and it does away with the need for seedling, nursery preparation, uprooting of seedlings and replanting. Wet seeding, on the other hand, requires only 1-2 persons day⁻¹ ha⁻¹ (Pandey, 1995; Santhi *et al.*, 1998). It is also less affected by labour bottlenecks during labour peaks and helps for timely sowing (Singh *et al.*, 1994).

Wang and Sun (1990) noticed that duration was shortened by 7-15 days in direct seeded rice compared to transplanted rice. Therefore, late seeding has proved to be comparatively better than late transplanting (Pajankar *et al.*, 1997). Further, wet seeded

rice yields were high in both water sufficient and water stress situations (Sattar, 1992). Wet seeded rice was more drought tolerant than transplanted rice (Khan, 1990).

Wet seeding offers a significant potential for improving the water use efficiency by reducing the water requirement (Bhuiyan, 1993). Kandasamy (1987) obtained a saving of 298.8 mm of water under direct sown crop which was 22.1 per cent less than the amount used by transplanted crop.

That wet seeded rice produces similar (or) higher yield than transplanted rice is well documented (Moody, 1993; Ramasamy *et al.*, 1994; Rachel and Martin, 1995; Majid *et al.*, 1996).

/

Vigorous growth of seedlings in direct seeded puddled rice facilitated rapid uptake of N (Peng *et al.*, 1996), reduced ammonium volatilization by 28 per cent and total N loss by 10 per cent (De Datta *et al.*, 1989). Ultimately, the recovery of inorganic N was greater in wet seeded rice (47%) than in transplanted rice (37%) (Diekmann, 1990). Under similar N management practices, Obcemea *et al.* (1990) observed a net saving of 9 to 10 per cent of applied inorganic N in wet seeded rice.

Farmers with small families in relation to the size of the farm prefer direct seeding to deal with paucity of labour (Erguiza *et al.*, 1990; Pandey *et al.*, 1995).

Poor, uneven crop stand coupled with inadequate weed control are the major reasons for poor performance of direct seeding under certain extraordinary situations (Moody, 1982; Govindarasu *et al.*, 1998).

2.1.2. Wet seeding methods

Wet seeding technique includes broadcasting or drilling pre-germinated seeds on puddled soil and is adopted in many south east Asian countries (Wan and Daud, 1990; Moody, 1993). Research conducted by Khuntia *et al.* (1989) revealed that direct seeding either by broadcasting or drilling gave similar yields as transplanted crop. Seed drilling resulted in 10 per cent more seedlings and better crop establishment than manual broadcasting under submerged field (Okazaki *et al.*, 1990).

Pradhan (1969) had demonstrated the successful adoption of direct seeding in lines in puddled rice fields using a seed drill (seeder). This practice could replace transplanting without any attendant reduction in yield but with reduced cost. Row sown rice showed rapid establishment and greater vegetative growth due to absence of transplantation shock. Tiller number per unit area and leaf area index were also more in row sown rice than in broadcast and transplanted rice (Dingkuhn *et al.*, 1990 b; Bharathi, 1996). Singh and Singh (1993) reported that rice sown in line was superior to broadcast and transplanted crop. Direct seeding by employing drum seeder proved superior to broadcasting of seeds (Bhuvanewari, 1998). Direct sowing using drum seeder enhanced early crop establishment and reduced the crop duration by two weeks besides giving higher yield than transplanting (Javellana *et al.*, 1988). Ramamoorthy and Subbaiah (1999) observed that wet seeded rice culture by drum seeder could be a viable alternative to transplanted rice in irrigated areas of India.

2.1.3. Growth attributes of wet seeded rice

Dingkuhn *et al.* (1990a) noticed that the growth dynamics of direct seeded flooded rice was profoundly different from that of transplanted rice. Early establishment of direct seeded crop in the absence of transplantation shock with better coincidence of nutrient requirement of the crop resulted in higher vegetative growth (Sharma *et al.*, 1989). Wet seeded rice starts tillering earlier than transplanted rice because its growth proceeds without the set back caused by uprooting injury to the root of seedlings (Yoshida, 1981).

Drilling sprouted seeds in puddled soil by paddy row seeder gave more number of hills m^{-2} than broadcasting sprouted seeds (Singh and Garg, 1983). Direct seeded rice produced significantly higher number of tillers than transplanted one (Shekar and Singh, 1991; Sharma and Sharma, 1994; Prabhakar and Narsa Reddy, 1997). Rachel Sophia Alexander (1994) reported higher dry matter production with wet seeded rice than with transplanted rice.

Crop growth rate from sowing to mid-tillering of broadcast seeded rice was four folds higher than that of transplanted rice in dry season and two folds higher in wet

season from panicle initiation to physiological maturity, the trend was reversed (Peng *et al.*, 1996). Direct seeded rice accumulated more dry matter than transplanted rice upto 45 DAS but beyond this the reverse was true (Pal *et al.*, 1999). Nabheerong (1995) found higher root length and total dry weight in wet seeded rice than in transplanted rice.

2.1.4. Yield components and yield of wet seeded rice

Shad and De Datta (1986) reported increased number of panicles m^{-2} and spikelets panicle⁻¹ in direct sown and transplanted conditions respectively. Direct seeding of sprouted seeds under puddled condition resulted in significant improvement in yield attributes like number of effective tillers, proportion of spikelets fertility, test weight and grain yield (Shekar and Singh, 1991). According to Thakur (1993), panicles m^{-2} were more or less the same in both direct seeded and transplanted crops.

Bhuiyan *et al.* (1995) noticed that wet seeded rice had consistently higher number of panicles per unit area, lower number of spikelets per panicle, higher percentage of filled grains and 24 per cent higher grain yield than transplanted crop.

Rice established through drum seeder recorded significantly more number of panicles m^{-2} than transplanted rice (Narasimman *et al.*, 2000; Subbaiah *et al.*, 2000).

Wet seeding produced almost similar grain yield as transplanted rice (Singh and Garg, 1983; Singh and Bhattacharyya, 1989; Sharma and Sharma, 1994).

Drill/direct seeding of sprouted seeds in line gave significantly higher grain yield than broadcast and transplanted crop (Singh and Singh, 1993; Bhuvaneshwari, 1998; Angadi *et al.*, 2000).

2.1.5. Physiological attributes of wet seeded rice

During vegetative phase, tillering, leaf area expansion, N uptake and dry matter accumulation were more rapid in broadcast seeded rice than in transplanted rice. Whereas during reproductive phase from panicle initiation to flowering and grain filling, canopy CO_2 assimilation and crop growth rate of broadcast seeded rice were depressed

due to lower leaf N content and greater mutual shading (Dingkuhn *et al.*, 1990a,b, 1991, 1992 a,b; Schnier *et al.*, 1990b).

Akita (1989) reported that higher leaf area index resulted in exposure of lower stratum of rice canopy to darkness which led to an unfavourable photosynthesis/respiration balance.

Wet seeded rice matured about two weeks earlier than transplanted rice (Wang and Sun, 1990; Bhuiyan *et al.*, 1995).

2.1.6. Economic advantages of wet seeding

Erguiza *et al.* (1990) suggested that a decline in the real price of rice, when other prices were held constant, would encourage farmers to adopt cost saving innovations to sustain farm profit. In Phillipines, experiments showed that considerably less labour was needed in producing broadcast seeded flooded rice than transplanted rice mainly due to labour saving in transplanting (Coxhead, 1984; Luman, 1988). On the other hand, land preparation and water control costs were higher for broadcast seeded flooded rice than for transplanted rice (De Datta and Ampong-Nyarko, 1988). However, the net effect favours direct seeded rice.

Purohit *et al.* (1990) found that drill sowing maximized net return ha^{-1} than broadcasting. However, highest cost benefit ratio was almost alike under direct seeding and transplanting (Thakur, 1993).

By employing drum seeding, higher net savings averaged Rs.1,911/- and Rs.2,233/- in *kuruvai* and *thaladi* seasons respectively compared to transplanted rice (Santhi *et al.*, 1998). Yashwant Singh (1999) reported that direct sowing by using drum seeder was the cheapest method of rice establishment and that the net return was as good as in transplanted crop. Among different rice establishment methods, direct seeding 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).

2.2. Green Manuring

2.2.1. Importance of green manuring

Green manuring is an age old practice and refers to addition of green plant tissue to soil for increasing fertility. It is an inexpensive, eco-friendly alternative to mounting prices of fertilizer nitrogen and has become an effective technology in economizing the agricultural production system, ensuring productive capacity of soil without causing any environmental problem (Bana and Pant, 2000). However, green manure use in lowland rice has dramatically declined over the last 30 years. The relatively affordable price of N through urea is probably the main determinant for this long term reduction. Unreliability of green manure performance, non-availability of seeds and labour intensive operations are major agronomic constraints (Mathias Becker, 1996).

Green manures, particularly the legumes are comparatively high in N, low in C/N ratio and behave almost like chemical nitrogenous fertilizers. 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).

Cultivation of nitrogen fixing leguminous green manure crops would be an efficient way of improving soil fertility status and sustainability (Kannaiyan, 1993a). It also improves soil microbial population and soil enzymes (Janzan and Radder, 1989; Kannaiyan and Kalidurai, 1989; Kalidurai and Kannaiyan, 1991; Kannaiyan, 1993b). The average N loss in flooded soils from applied green manures was considerably lower (14%) than in those from split applied urea (35%), thus resulting in less pollution to the environment (Becker *et al.*, 1994).

Green manure addition alone increased the physiological efficiency in rice and it was better than chemical fertilizers and integrated N sources (Budhar and Palaniappan, 1996). It also influenced photosynthetic activity by rapid evolution of CO₂ immediately after incorporation (Bharadwaj and Dev, 1985). Jin (1984) recorded more/effective

utilization of solar energy and temperature when green manure was included in a rice-based cropping system.

2.2.2. Daincha (*Sesbania aculeata*) an ideal green manure

For lowland rice ecosystem, green manure crop should possess certain important traits like early establishment, high seedling vigour, tolerance to flooding and drying, short duration with fast growth, early onset of biological nitrogen fixation (BNF), photoinsensitivity, ease of incorporation, wide adaptability, pest resistance, high production and viability of seeds (FAO, 1977; IRRI, 1988; Ladha *et al.*, 1988; Cosico, 1990).

Sesbania aculeata had wider acceptance among farmers and it occupied prime place in India from early times (Dommergues, 1982).

Pandey (1996) found that daincha could withstand severe drought and could grow in poorly drained land and in soils which are slightly saline. Daincha accelerates the rate of reclamation besides concurrently increasing the productivity status of soil. *Sesbania* can be grown in saline soil without reduction in total N contribution from *Sesbania* to the soil (Saradha Ramani *et al.*, 1989). Bindra and Thakur (1995) reported that *S. aculeata* was a better green manure than others. Further it improved sodic soil faster than other organic sources (Kumar and Yadav, 1995).

Sesbania aculeata and *S. rostrata* are the most promising species (Mappaona *et al.*, 1995). Daincha is fast growing and produces a dry matter of 2.0 t ha⁻¹ within 45 days. In addition, it is already familiar to farmers (Bhuiyan and Zaman, 1996). Among *Sesbania* species, *S. aculeata* recorded higher biomass on 40 DAS and *S. rostrata* on 60 DAS (Kalidurai, 1998).

Meelu *et al.* (1985) obtained 33.4 t ha⁻¹ of biomass production in 45 day old *S. aculeata*. Rajbhandari (1984) obtained fresh biomass yields of 2.2, 11.5 and 26.3 t ha⁻¹ from *S. aculeata* on 24, 36 and 48 DAS, which were superior to cowpea as green manure.

Among the green manure crops, daincha (*S. aculeata*) accumulated the largest amount of biomass (26.3 t ha⁻¹) followed by *S. rostrata* (24.9 t ha⁻¹), but in terms of N contribution both were comparable yielding 145 and 146 kg ha⁻¹ respectively (Palaniappan *et al.*, 1990). Both these green manure crops have similar performances under conducive conditions (Sharma and Moorthy, 1988).

Sensitivity of green manure legumes to photoperiod is another important constraint to green manure use. During short day season, vegetative growth is curtailed by early flowering (Sprent *et al.*, 1988). As a result, biomass and N yield of photosensitive species are low (Morris *et al.*, 1985). *S. rostrata* is relatively more sensitive to photoperiod.

Photoperiod sensitivity of *S. rostrata* limited its use to long day period (Becker *et al.*, 1988). Further, the dormancy imposed by the extremely hard seed coat of *S. rostrata* often retarded germination, leading to poor stands. *S. aculeata* produced deeper roots (24 cm) than *S. rostrata*. *S. rostrata* also proved sensitive to high pH (Tamizhvendan and Rajeswari, 1999).

2.2.3. Influence of green manuring on rice

2.2.3.1. Influence of green manuring on rice growth

Application of green manures promotes growth of rice by increasing plant height (Pillai and De, 1980; De Datta, 1981; Nachimuthu, 1985; Balasubramanian, 1989; Joseph, 1998) and tiller production, LAI and DMP (Shanmugam, 1983; Sankaranarayana, 1985; Venkitasamy, 1986; Balasubramanian and Palaniappan, 1993; Somasundaram *et al.*, 1996; Bayan, 2000).

Intercropping of *S. aculeata* in rice and subsequent *in situ* incorporation produced higher growth components (Joseph, 1998). Likewise, intercropping of *S. rostrata* in rice and subsequent incorporation showed higher biomass, while pure stand of rice without green manure recorded low DMP (Ramanathan, 1995).

Hiremath and Patel (1998) reported that growth attributes of summer rice such as LAI, LAD, CGR and NAR were comparable between green manuring using *S. aculeata*

(or) *Crotalaria juncea* with 100 kg N ha⁻¹. *In situ* incorporation of intercropped *S. rostrata* in rice increased plant height, LAI and tillers of semi-dry rice (Jayachandran and Veerabadran, 1996a).

2.2.3.2. Influence of green manuring on rice yield and yield determinants

Intercropping *Sesbania aculeata* in rice and incorporating it on 35 DAS along with application of 100 per cent recommended N uniformly increased the yield components *viz.*, productive tillers m⁻², filled grains and 1000 grain weight (Joseph, 1998). Likewise, intercropping of *S. rostrata* also positively increased yield parameters (Jayapaul *et al.*, 1995). Addition of green manure at 1.5 t ha⁻¹ contributed considerable amount of nutrient which improved yield components of rice (Kumar *et al.*, 1998; Vinod Kumar *et al.*, 1999).

Daincha incorporation increased rice grain yield (Hati, 1987; Regmi, 1998; Basnet, 1999). Incorporation of green manure significantly increased rice grain yield when compared to non-incorporation (Sharma and Das, 1994; Diekmann *et al.*, 1996; Muneshwar Singh *et al.*, 1997; Power, 1997; Paturde and Patnakar, 1998).

2.2.3.3. Influence of green manuring on nutrient uptake

Several workers have reported increased N uptake following green manure application in rice (Rao and Ghai, 1987; Ventura *et al.*, 1987; Singh *et al.*, 1988; Ladha *et al.*, 1989; Deepa Thomas, 1996; Joseph, 1998; Kumar *et al.*, 1999). Balasubramanian *et al.* (1991) and Padmavathy (1992) documented that green manure (daincha) addition increased NPK uptake of rice and grain yield. Addition of *S. aculeata* increased N uptake and N use efficiency (Panda *et al.*, 1994). Medhi *et al.* (1997) and Sarmah (1997) recorded improvement in P uptake with green manuring.

2.2.4. Age and time of green manure incorporation

Nitrogen contribution from green manure crop depends on the decomposition period after incorporation, which in turn, is determined by the nature of the plant material added, C/N ratio, environmental condition and time of incorporation. Age of

green manure has a definite impact on its N content with optimal level at 45 days that declines as the age advances (Yadvinder Singh *et al.*, 1991).

Incorporation of 45 day old green manure crop seems to be more useful in practice even with lower yield of green matter (Bharadwaj, 1982). Khind *et al.* (1983) and Bouldin (1988a) found that 60 day old daincha incorporation added more biomass and nitrogen to soil. In contrast to earlier finding, Ghai *et al.* (1985) reported that the rate of N accumulation by *S. aculeata* started decreasing after 50 days. Ndoye and Dreyfus (1988) opined that *S. rostrata* can produce 25.3 t ha⁻¹ fresh biomass within 45 days. *S. aculeata* recorded maximum biomass between 40 and 50 DAS. Suggesting it to be the ideal time for incorporation into the soil (Kalidurai, 1998).

Palaniappan and Budhar (1989) reported that green manuring at 12.5 t ha⁻¹ applied 15 days prior to rice transplanting along with 100 kg N ha⁻¹ was superior to other methods of N application. Whereas, Rajeswari (1990) stated that incorporation of green manure at 45 day growth and a week period for decomposition before transplanting was sufficient to maintain soil productivity.

Ghai *et al.* (1988) observed extended period of green manure decomposition to result in lesser N contribution to the subsequent rice crop, mainly due to rapid decomposition of the succulent, low C/N ratio, green matter under semi anaerobic conditions in tropical climate (Bhardwaj and Dev, 1985) followed by extensive loss of ammonia through volatilization (Rao and Batra, 1983). Sur *et al.* (1993) reported that a minimum time should be allowed between burying green manure and transplanting of rice for decomposition and nutrient release.

2.2.5. Mineralization and decomposition of green manure

Green manures and crop residues must undergo decomposition and mineralization before their N becomes available to crops. An understanding of the time trends of nitrogen release from green manure is imperative for regulating the time and amount of supplemental N application which ultimately maximizes the efficiency of nitrogen from both the sources (Brar and Sidhu, 1995). Application of urea along with *Sesbania*

significantly changed the release pattern of NH_4^+ - N from *Sesbania* over a period than incorporation of *Sesbania* alone (Biswas and Goswami, 1995).

Mineralization helps in the replenishment of available forms of an element which was temporarily locked up (Alonge, 1988). In wetland rice fields, 40 per cent of the C and 80 per cent of the N of *S. aculeata* green manure was mineralised in the first 10 days after incorporation (Beri *et al.*, 1989). Therefore, synchronization of organic N mineralization from green manures with crop demand is a critical component of low external input sustainable crop production (Dey and Jain, 1997).

Decomposition period of 7-10 days is required after incorporation of green manures under tropical and subtropical conditions (Ghai *et al.*, 1988). Singh *et al.* (1991) found that accumulation of NH_4^+ - N peaked at 2-4 weeks after incorporation of green manures in soil. The rate of mineralization reached its zenith at 30-35 DAT (Dey and Jain, 1997; Pramanik and Mahapatra, 1997). Green manure nitrogen mineralization, (i.e.) NH_4^+ - N release was increased until 20 DAT and then decreased sharply (Clement *et al.*, 1998).

During mineralization process, the intermediate product of NH_4^+ - N is being preferentially consumed by microorganisms (Patrick *et al.*, 1985). The kinetics of N release from organic manures indicate that the lignin to nitrogen ratio determines decomposition of plant residue in flooded soils. *S. rostrata* and *S. emerus* showed maximum mineralization at 2nd and 3rd week after incorporation respectively. The N release was peaked around 5th week after incorporation (Becker *et al.*, 1990). Combined application of manure and urea (1:1) released higher amount of N than the manure alone and this could be attributed to the application of urea upon hydrolysis released inorganic nitrogen at a much faster rate (Das *et al.*, 1998; Pathak and Sarkar, 1994).

The mineralization rate is also readily affected by environmental characteristics such as water (Miki and More, 1968; Brar and Sidhu, 1995; Dey and Jain, 1996), temperature (Ladd *et al.*, 1985) and season (Singh, 1984; Poovaradom *et al.*, 1987; Susan John and Alice Abraham, 1995).

2.2.6. Immobilization

Nitrogen release from incorporated green manure was delayed, because it had to undergo decomposition before available N was released unlike fertilizer (Nagarajah, 1987; Deka Medhi and De Datta, 1996). Carbon/nitrogen ratio is usually considered the best factor to predict N release from green manure (Sandh *et al.*, 1990). Presence of living plants may affect N mineralization in rhizosphere - residue interaction. Root exudates enhance microbial activity in the rhizosphere which can increase/decrease (microbial immobilization) release of nitrogen from organic matter (Janzan and Radder, 1989). Mineralization was greater in (field capacity) moist soil than in water saturated soil. Decomposition of sunnhemp under wetland conditions, in the absence of a rice crop, was as rapid as it was under *in-vitro* conditions (Bhardwaj and Datt, 1995). 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 C:N ratio of residue incorporated (22.4) was not favourable for its decomposition and N mineralization to match the nutrient demand of growing rice plant (DRR, 1998).

Sur *et al.* (1993) reported that for decomposition and release of nitrogen from green manure a minimum time should be allowed between burying green manure and transplanting rice. The presence of molecular oxygen which is normally absent in flooded rice soils is imperative to metabolize aromatic compounds (Zeikus, 1981) which hinder the mineralization process and immediate release of N from added green manures. Green manure application reduces the N losses more than the urea application, which raises the question of the fate of a portion of organically applied N that remains undecomposed under flooded soil condition and may be available for a subsequent crop (Becker *et al.*, 1994; Bouldin, 1988b).

Incorporation of legumes on 40 DAS and self decaying of these in monsoonic rain were not beneficial to the dual cultured rice crop. This might be due to non-decaying of legumes beyond 30 DAS as a result of lignification of the vegetative parts. The rice crop in these plots showed pale yellow discoloration (Abraham Varughese and Sushama Kumari, 1993).

Immobilization of organic carbon in soil was higher in rainy and summer seasons than in winter and addition of glucose led to maximum mineralization of organic carbon (Susan John and Alice Abraham, 1995). Incorporation of legume biomass into the soil resulted in immobilization of available soil N. This effect was presumably conditioned by seasonal cool temperature (Kleinhenz *et al.*, 1997).

To realize optimum benefits of a green manures, it is essential that it should be of young age when incorporated into the soil to ensure adequate mineralization of N before the rice seedlings actively start absorbing N (Bhuiyan and Zaman, 1996).

2.2.7. Green manures on soil fertility and properties

That incorporation of green manures improves soil fertility was reported by many researchers (Swarup, 1987; Sharma and Mitra, 1988; Kalidurai and Kannaiyan, 1992; Aktar *et al.*, 1994; Dúhan and Mahendra Singh, 1994; Sharma, 1995; Somasundaram *et al.*, 1996; Joseph, 1998). *Sesbania aculeata* recorded higher availability of organic carbon, nitrogen, phosphorus, potassium, zinc, iron and manganese (Sriramachandrasekharan *et al.*, 1996).

A study conducted at the Tamil Nadu Agricultural University farm, in a heavy clay soil, revealed that incorporation of green manures, a week prior to rice planting, sustained the release of N fraction (NH_4^+ and NO_3^- - N) upto 60 days (Sivabal, 1989). An increase in soil organic carbon and N due to green manuring was reported by several workers (Kolar *et al.*, 1993; Ventura and Watanabe, 1993; Gurung and Sherchan, 1996; Kumar *et al.*, 1999). Addition of green foliage of *Glyricidia* increased organic carbon, total N,P,K and also water holding capacity (Chaphale *et al.*, 2000).

Green manure application maintained the availability of other nutrients like P to rice under submerged condition from insoluble phosphorus sources like rock phosphate (Lekha Sreekantan, 1987). Similarly, it enhanced iron availability under submergence (Swarup, 1987). Green manuring with *Crotolaria juncea* and *S. rostrata* increased soil organic matter, CEC, available phosphorus and exchangeable potassium (Cosica, 1990).

It also increased other nutrients like iron, manganese and copper in soil (Kumar and Yadav, 1995; Bhattacharyya and Mandal, 1996).

Boparai *et al.* (1992) reported that application of green manures in wetland rice increased water stable aggregates, reduced soil bulk density and increased infiltration rate. Under rice-wheat rotation, green manuring with *S. aculeata* ushered in various improvements in soil physical properties. While profile water content and hydraulic conductivity improved, soil setting and dispersion got decreased due to green manuring (Joshi *et al.*, 1994). It improved soil structure by virtue of high aggregate stability and avoidance of soil degradation problems such as crusting and compaction (DRR, 1998).

2.2.8. Economics of green manuring

Inclusion of green manures in cropping system results in increased crop yield and soil fertility. But, farmers are reluctant to devote land and resources for growing legumes solely for green manure, because it provide no immediate income or food (Buresh and De Datta, 1991). Garrity and Flinn (1988), after reviewing the economic balance sheet of green manure in various rice environments in Asia, reported that green manuring is economically feasible and viable in rice based systems in most parts of Asia.

Combined application of green manure and recommended fertilizer N to rice produced the highest net return (Srinivasulu Reddy, 1988; Sivabal, 1989; Padmavathy, 1992). Inclusion of green manure in between two rice crops of *kharif* and *rabi* increased net returns (Siddeswaran, 1992). The net returns and B:C ratio were higher when *S. rostrata* was intercropped and incorporated with recommended level of fertilizers N (Ramanathan, 1995). The highest net income was secured by intercropping daincha and incorporating it at early stage (35 DAS) (Joseph, 1998). Highest net return of Rs.20,435 ha⁻¹ was obtained with poultry manure followed by *S. rostrata* (Rs.19,985 ha⁻¹) and chemical fertilizers (Rs.16,055 ha⁻¹) (Singh *et al.*, 1999).

The additional benefits of green manure was US \$ 260 ha⁻¹ over no N and US \$ 30 ha⁻¹ over 90 kg of N as urea (Pandey *et al.*, 1995). Bhattacharyya and Mandal

(1997) reported that the net yearly profit resulting from use of green manure ranged from US \$ 19.28 to US \$ 186.76 ha⁻¹ depending on quantum of rainfall.

2.3. Intercropping green manure in rice

Green manure intercropping in rice ecosystem is of recent origin. The main objective of green manure intercropping is to strengthen soil fertility and reap higher grain yield. Of the many green manures evaluated to find their suitability under water stagnant condition, only leguminous green manures were found to have greatest adaptability and advantage of transferring N to the main crop (Arunin *et al.*, 1988). A number of economic analysis indicated an unfavourable comparison of green manure vs. inorganic fertilizer use (Ali and Narsico, 1995). The most important economic factor affecting green manure use and the input prices were land and labour for the separate cultivation prior to rice (Ali and Narsico, 1993). The farmers were reluctant to use their land, water and other inputs for raising a crop exclusively for green manuring (Kundu *et al.*, 1993). The core reason for switching over to intercropping was farmer's reluctance to sacrifice any crop for green manure establishment because of increasing trend of cropping intensity and burgeoning demands (Zaman *et al.*, 1991).

Number of panicles per hill in monocropped rice was significantly higher than in intercropped rice with mungbean (Bering and Alba, 1982). Furoc *et al.* (1986) and Gines *et al.* (1986) suggested that *S. rostrata* be intercropped with rice to accumulate sufficient N and consequently increase rice yield. In China, Lizhi (1988) reported the benefits of intercropping daincha when 30 days old seedlings were transplanted about 30 days after transplanting rice. *S. rostrata* can also be grown successfully as an intercrop in rice in 12:1 ratio without affecting growth of rice (Palaniappan *et al.*, 1991).

Purushothaman and Padmavathy (1994) opined that intercropping *S. rostrata* in transplanted rice at 7:1 ratio contributed 16.3 kg N ha⁻¹ through 2 t biomass ha⁻¹ without causing any adverse effect on rice yield. Growth of rice was affected initially when daincha was raised concurrently as an intercrop. Later, tillering of rice increased after incorporation of green manure. The highest rice yield was obtained, when rice and daincha were grown at 2:1 ratio in 20 cm wide rows and the clonal tillers uprooted from

adjoining rice rows were planted in lines vacated by daincha. The yield was however, at par with the treatments where rice and daincha were grown in alternate rows at 15 cm spacing (Sharma and Das, 1994).

Grain yield was more when concurrent cropping of green manure with rice was adopted. It suppressed weed growth significantly (Gracy Mathew and Alexander, 1995). Intercropping green manure in rice increased grain yield by 24.5 per cent compared to no green manure intercropping (Grace *et al.*, 1999).

Mulongoy (1986) found that alley cropping of *S. rostrata* in rice provided adequate N for higher yield. Solaiappan and Veerabadran (1997) stated that intercropping green manure in *kharif* rice and incorporated before transplanting of succeeding crop (*rabi* rice) resulted in higher yield of *rabi* rice. Relaying green manure at the ripening stage of rice-rice sequence would be a potentially feasible approach. On the contrary, relaying in wet season rice was found not useful (Torres *et al.*, 1995).

Interplanting *Aeschynomene afрасpera* in direct seeded rice resulted in an N accumulation of 50 kg ha⁻¹ at 40 DAS. When incorporated *in situ*, it resulted in 24 per cent increased yield of rice relative to control (no intercropping) (Choudhary *et al.*, 1991). Concurrent sowing of both main crop (rice) and green manure and its incorporation increased the value of yield attributes and enhanced grain yield of semi-dry rice (Jayachandran and Veerabadran, 1996 b).

Wet seeded rice benefited from intercropping 20 days old *S. rostrata* seedlings at 1.5 and 0.15 m inter and intra row spacings, respectively (Jayapaul *et al.*, 1995). Among the conventional intercrops, daincha had wider adaptability including problem soils and had the ability to produce drymatter ranging from 2.8 to 9.9 t ha⁻¹ and accumulate 80 to 225 kg N ha⁻¹ at 60 DAS (Lauren *et al.*, 1996). Intercropping daincha in between two rows of rice in additive series and incorporating at 35 days proved superior to sole rice (Joseph, 1998). Similarly, Bayan (2000) recorded increased yield in intercropping *S. rostrata* in wet seeded rice compared to no intercropping with *S. rostrata*.

2.3.1. Influence of intercrop on rice

Intercropping of *Sesbania* in rice increased plant height, stem diameter, number of green leaves per plant and number of active roots per plant of rice seedlings (Dina Qianta and Wangzhuan, 1980). Purushothaman and Padmavathi (1994) found that intercropping *S.rostrata* at 7:1 ratio did not cause any adverse effect on rice yield. Intercropping *S. aculeata* and *S. rostrata* in wet seeded rice did not cause negative effect on rice yield (Joseph, 1998; Bayan, 2000). Urkurkar *et al.* (1994) found intercropping green manure in general not to be detrimental in rice.

Contrary to the above findings, intercropping reduced tiller number and number of panicles per hill in rice (Bering and Alba, 1982). In rice + cowpea intercropping, the green manure crop grew quickly and shaded the rice plants. But light intensity below the green manure canopy was always higher than the light compensation point of 1500 Lux, which implied that there was sufficient light for the rice seedlings. Their height increased under low light but this effect was neutralized towards later stages (Gracy Mathew *et al.*, 1991).

Sattar and Biswas (1991) reported that intercropping of *S. rostrata* and *S. aculeata* showed prolific growth and these suppressed rice growth and intercepted 79.62 and 83.77 per cent, respectively of radiation at reproductive stage of rice.

Dual cropping of green manure beyond 30 days resulted in competition with the rice crop for light, space, water and nutrient as evidenced by lesser number of tillers and higher plant height of legumes (Abraham Varughese and Sushama Kumari, 1993). Daincha intercropping significantly reduced grain and straw yield of *Aus* rice (Zaman *et al.*, 1996).

In direct seeded rice + *Aeschynomene afraspera* intercropping system, rice growth was initially suppressed due to shading by the green manure; but at later stage after incorporation of green manure in rice, the biomass picked up and the rice plant had a higher N concentration and recorded 24 per cent increased yield (Choudhary *et al.*, 1991) which is in line with the earlier finding by Yoshida and Parao, 1976 (Appendix I).

2.4. Green manure seed production

Among the green manure crops, *S. aculeata* and *S. rostrata* took lesser days to flowering and maturity, whereas *S. speciosa* took more days to first and fifty per cent flowering (Selvam, 1994). The highest seed yield was recorded in *S. rostrata* followed by *S. aculeata* and *S. speciosa*.

Jacqueline Selvaraj and Ramasamy (1984) stated that seeds of *S. aculeata* attained physiological and harvestable maturity around 40th and 60th day respectively. Beyond this stage, the pods started cracking and resulted in shedding of seeds. The physiological maturity of seeds coincided with colour change from green to greenish yellow (Dharmalingam and Basu, 1989).

S. aculeata is a self fertile plant and sets seeds freely. It is adapted to wet areas, heavy soils and drought conditions (Brewbaker, 1987), salinity and alkalinity (Ghai *et al.*, 1988).

Therefore, green manure crops like *S. rostrata* and *S. aculeata* are well suited for green manuring to meet increasing demand. Green manure seed requirement works out to 1.95 lakh t. Current demand and supply is far lower than this estimated requirement (Krishnasamy *et al.*, 2000). Standardization of techniques for better seed production and seed treatment to improve establishment and stand of green manure is warranted (Sankaran *et al.*, 2000).

2.4.1. Constraints in green manure seed production

Green manure is an important component in low external input sustainable agriculture. Its use by farmers is rather limited due to constraints such as availability of quality seeds, establishment and cost effectiveness of the technology (Selvam, 1994). Non-availability of good seed leads to prohibitive seed price (IRRI, 1988; Ramanathan, 1995). Non-availability of adequate quantity of green manure seeds, costly establishment and incorporation, high price of land and labour and a relatively low mineral fertilizer price are the major constraints to green manure use in low land rice production system

(Ali and Narsico, 1993; Ladha *et al.*, 1992; Garrity and Flinn, 1988; Roger and Watanabe, 1986).

Scarcity of seed is the main limiting factor for quick expansion of *Sesbania* green manuring. There is little scope of growing *Sesbania* as sole crop for seed production and fuel as most of the land is harnessed for wetland rice cultivation (Sirajul Islam *et al.*, 1999). In general, seed production potential of green manure is relatively low as compared to other field crops. The multiplication ratio in green manure is of the order of 20 to 30 times only. Sensitivity of some leguminous green manure species to photoperiod is a major constraint and merits immediate attention. Quality of seed depends upon the level of mother crop nutrition and agro-ecological conditions in which seeds are produced (Krishnasamy *et al.*, 2000).

2.4.2. Influence of season on green manure seed production

Mohamed Sherif *et al.* (1974) reported that poor yields obtained from winter sowings might be attributed to availability of minimum quantum of solar energy. According to Pathak *et al.* (1985), in *Sesbania* sp. higher efficiency of production in terms of number of pods, number of branches, root length and shoot length was more, when the crop was sown in summer season.

For seed production of *Sesbania* sp., summer season was found to be ideal (Anon, 1986-87). In contrast to the above results, Selvam (1994) observed the highest daincha seed yield during *rabi* season. Thomas and Palaniappan (1998) also stated that green manure seed production varied with season.

2.4.3. Influence of spacing on green manure seed production

Seed yield of green manure is highly influenced by crop geometry and spacing. Findings of Palaniappan and Budhar (1989) indicated that wide spacing increased green manure seed yield by 10 per cent over close spacing. Radha (1991) reported that compared to narrow spacing (60 x 15 cm), wide spacing (120 x 15 cm) recorded more number of pods in both *kharif* and *rabi* seasons.

Compared to narrow spacing, wide spacing recorded more number of seeds per pod (Palaniappan and Budhar, 1992). Selvam (1994) reported that wider spacing not only increased the yield but also improved the quality of seed. Highest seed yield was obtained in the widest spacing of 60 x 20 cm in green manure crops like pillipesara, sunnhemp and velvet bean.

2.4.4. Green manure seed production in intercropping system

Availability of seeds is a limiting factor for any crop and where seeds are not commercially available (most green manure species), farmers have to depend on their own stock of quality seeds. However, seed production is one of the most costly and labour intensive aspects of green manure production (Garrity and Becker, 1995). The scope for growing *Sesbania* as sole crop for seed and fuel was not economically viable, as most of the land being engaged for wetland rice cultivation, besides hindering cropping intensity (Sirajul Islam *et al.*, 1999).

Experiment conducted at the Central Rice Research Institute, Cuttack by Jha *et al.* (1989) on the possibility of green manure seed production in existing rice ecosystem without hindering the cropping intensity and yield of rice showed that intercropping *Sesbania* with rice gave a bonus of 360-430 kg *Sesbania* seed for green manuring and a fuel yield of 460-580 kg ha⁻¹. The sole crop of *Sesbania* exclusively for seed did not prove remunerative. Narrow ratio of rice + *Sesbania* intercropping was not desirable due to overcrowding of *Sesbania* and partial suppression of rice plants, which significantly reduced the rice grain yield. It could be overcome by widening the spacing of *Sesbania* to 3 m and 4 m, respectively in 15:1 and 20:1 ratios.

Field experiment conducted at Bangladesh by Sirajul Islam *et al.* (1999) during 1992 and 1993 on green manure seed production in rice ecosystem showed that the highest seed yield (1383 and 1344 kg ha⁻¹) was obtained from sole daincha in both the years. As intercrop, daincha seedlings transplanted at 2 x 2 m spacing gave the highest seed yield (78 and 73 kg ha⁻¹) followed by stem cutting at the same spacing (72 and 67 kg ha⁻¹) in 1992 and 1993 respectively. Similar results with *S. aculeata* was also reported by Aktar *et al.* (1994).

Border cropping of green manure crop for seed production was also evaluated to substitute the intercropping techniques to fulfil the urgent demand for quality seeds with self production in the farmers field itself. Ramanathan (1995) tried *Sesbania rostrata* as a border crop in rice for green manuring cum seed production purpose. The results showed that border cropping of *S. rostrata* apart from providing a biomass of 2.96 to 3.23 t ha⁻¹ with N accumulation of 26.3 to 28.5 kg ha⁻¹ gave an additional seed yield of 125-135 kg ha⁻¹. Though rice grain yield increase in this border cropping was only 6 per cent over sole crop, it enabled the resource-poor farmer to have his own seed for subsequent sowing.

Each plant of *Sesbania* gives about 400-600 g of seeds. For sowing one ha for green manure purpose, 50-60 kg seeds will be necessary. Hence, if about 125 to 150 vigorous plants are left among the border plants, sufficient seeds could be obtained from the plants (Palaniappan and Annadurai, 1999).

2.4.4.1. Influence of green manure crop grown for seed production on rice

Jha *et al.* (1989) reported that intercropping daincha in rice for seed production at narrow row ratio of rice + *Sesbania* as 5:1 was not desirable, as it led to overcrowding of sesbania seedlings and partial suppression of rice plants, resulting in reduced grain yield. This could be circumvent by adopting wider row ratios like 15:1 and 20:1 of rice + sesbania intercropping under lowland condition.

Intercropping of *Sesbania* for seed production in rice did not compete with rice for moisture because of its deeper root system (Sirajul Islam *et al.*, 1999).

2.4.4.2. Influence of light availability on rice + green manure (seed crop) intercropping system

Temperature and solar radiation are the major climatic factors affecting growth and grain yield of rice. Unshaded plants gave significantly higher grain yield than shaded ones. Shading 40 and 60 per cent did not show any significant differences in grain yield. The principal yield component affected by increased shading intensity was

percentage of filled spikelet, whereas 1000 grain weight remained unaffected (Chauhan, 1994).

Reduction in growth and yield of different crop species under low radiation has been reported by several workers (Nayak and Murty, 1980; Sengupta and Jadhav, 1988; Singh, 1994). At very low photon flux densities, photosynthetic rates of all genotypes were very poor due to limited interception of light (Pramod Kumar *et al.*, 2000).

Solar radiation affects grain filling and hence proportion of filled grains got reduced (Ayyangar *et al.*, 1977). Reduction of solar radiation upto 60 per cent during flowering to anthesis had less pronounced effect of 21.4 per cent yield reduction and affected only grain filling (Chauhan, 1994).

Shading during transplanting to panicle initiation stage reduced yield more than that in other stages through greater reduction in effective tillers and grains per panicle. Shading during panicle initiation to flowering stage and flowering to maturity stage decreased yield by lowering fertility of grains and their weight. Shading during all the stages caused heavy mortality of the plant, reduced the growth of the plant, made panicle the shortest with 60 per cent sterile grains and produced only 0.47 q grains and 2.16 q straw ha⁻¹ (Lenka and Misra, 1980).

Solar radiation during the period from flowering to maturity had significant effect on grain yield of rice. This might be due to the fact that grain yield in rice comes mostly from post flowering photosynthesis (Janardhan *et al.*, 1980; Khushu and Mavi, 1991). Under low light intensity, total chlorophyll, tiller mortality, plant height and spikelet sterility increased, while chlorophyll a/b ratio, dry matter yield, panicle number, spikelet number, grain number, 1000 grain weight and grain yield were markedly reduced (Roy *et al.*, 1998b).

Growth and development of economic organs suffered a greater extent than those of vegetative organs under low light stress. Partitioning of biomass from vegetative parts to economic parts (harvest index) was also impaired by shading in all crop plants investigated (Singh, 1994 and Singh, 1997).

Shading caused profound increase in the contents of protein, non protein, nitrogen and chlorophyll b. Sugar and starch contents in the stem of maize increased by shading, which may perhaps be due to poor translocation of reserve photosynthates from stem to the developing sink (grains)(Singh, 1994).

2.4.4.3. Economic advantage of green manure seed production in rice intercropping system

Among various combinations of row ratio between rice and daincha tried by Jha *et al.* (1989), *Sesbania* in the ratio of 15:1 gave higher grain equivalent values followed by 20:1 ratio giving 6 per cent higher value. Sole cropping of *Sesbania* gave the lowest values (39-28%) compared with sole rice.

Highest rice equivalent was observed when daincha seedlings were intercropped at 2 x 2 m spacing. However, sole daincha gave the lowest rice equivalent (Sirajul Islam *et al.*, 1999).

The above results indicate that farmers need not earmark a piece of land, engaging labour exclusively for raising sesbania seed crop for green manuring in subsequent season.

2.5. Nitrogen nutrition in wet seeded rice

The major breakthrough in rice production was brought about by the use of high yielding dwarf and semi dwarf rice varieties with short stem, erect leaves and non-lodging characters which helped to make the maximum use of solar energy and hence, yielded more when N was applied (Subramanian and Thangamuthu, 1981). Nitrogen fertilization is one of the key factors that affects rice production irrespective of the establishment method (Mikkelson, 1987). N is a substrate for the synthesis of proteins which are constituents of protoplasm and chloroplasts. In addition, the nutritional status of N can also be visualized from hormonal view so far as N stimulates meristematic growth and cytokinin biosynthesis (Yoshida and Oritani, 1974; Beringer, 1980).

Nitrogen accounts for 67 per cent of the total amount of fertilizers applied to rice (Prasad and De Datta, 1999). Crop yield is influenced, often decisively by the extent to which the plant requirement for N can be met. This varies greatly from crop to crop, soil to soil and from one climate to another (Green wood, 1976, 1982). Direct seeded rice showed a linear response to added nitrogen upto 180 kg ha⁻¹ (Sudhakar *et al.*, 1987). For Tamil Nadu condition, the recommended dose of nitrogen for *kharif* and *rabi* seasons in direct seeded rice are 120 and 150 kg ha⁻¹ respectively (CPG, 1999).

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

Nitrogenous fertilizer is one of the costliest and perhaps the most crucial primary nutrient which can limit rice yield. Modern rice varieties respond well to nitrogen fertilizer. Recovery of applied N is low, being between 25 and 40 per cent under varied cultural conditions, and it does not exceed 49 per cent (De Datta *et al.*, 1990). This low recovery of applied N is attributed to ammonia volatilization, denitrification, leaching, runoff, immobilization and ammonium fixation (Savant and De Datta, 1982) and also due to mismatch between crop requirement and time of N application. Among the various ways to improve nitrogen use efficiency, proper time of application makes ideal match between crop requirement at critical growth stages and on the other hand reducing various N losses (De Datta and Buresh, 1989).

Split application of N at different growth stages according to the needs of crop under weed free condition has been found to be beneficial for improving N use efficiency (Choubey *et al.*, 1985). Furoc *et al.* (1988) showed that N efficiency in rice could be enhanced by proper splitting of N and supplementation with green manures. Because, basal application of nitrogen to direct sown rice did not show any significant impact on yield compared to top dressing later. It is attributed to poor absorbing capacity of seedlings in the earlier stage (Rathi and Sharma, 1996). Many workers recommended application of first dose of N from a week after germination till maximum tillering stage, which favourably influenced yield components and yield of direct seeded rice (Ahmed and Moody, 1981; Songmuang *et al.*, 1983; Choubey *et al.*, 1985 and Veno *et al.*, 1990). When N supply to rice crop was delayed upto 16 DAT, higher grain yields were obtained due to increased tiller production and leaf N content (Thiyagarajan *et al.*, 1993).

Application of moderate level of N in three to four splits during sowing, active tillering, late tillering and panicle initiation stages to semi dwarf varieties proved beneficial (Moorthy and Mittra, 1992). Vijayalakshmi *et al.* (1992) showed that application of 100 kg N ha⁻¹ in four equal splits of 21, 35, 50 and 65 DAS increased panicle number, spikelet number and filled grain percentage which ultimately increased grain yield. Pandey *et al.* (1997a) observed that grain yield did not vary significantly due to application of N in three or four splits for drill seeded rice. Similar result was reported by Murali and Reddy (1995).

However, application of N in four equal splits, each at 10, 30, 45 and 60 DAS gave significantly higher rice yields than applying in 3 equal splits (Bhattacharyya and Singh, 1992). Sanbagavalli and Kandasamy (1998) brought out that four equal splits of recommended N was superior to three splits in wet season rice at Coimbatore. Likewise, Alagesan (1997) and Joseph (1998) recommended four equal split of N at seedling stage, AT, PI and flowering stages for increased growth and yield attributes of wet seeded rice at Coimbatore.

In contrast, split application of N (½ at 21 DAS, ¼ at 42 DAS and ¼ at 56 DAS) gave maximum grain yield in direct seeded rice during *kharif* 1996 and 1997 at Directorate of Rice Research (DRR, 1998 and DRR 1999). Thakur and Patel (1999) obtained that the highest grain yield could be recorded with application of 80 kg N ha⁻¹ in three equal splits with 5 t FYM ha⁻¹. N application in three equal splits (1/3 basal + 1/3 at active tillering 1/3 at panicle initiation) was found to be the ideal management practice for higher yield and N uptake in wet seeded rice (Malla Reddy and Bhaskar Reddy, 1999).

Sanbagavalli and Kandasamy (1998) found that five split applications of recommended dose of nitrogen was superior to four splits in dry season low land rice at Coimbatore. Similarly, Ramamoorthy *et al.* (1998) also opined that N application in five splits, seven days after transplanting, active tillering, panicle initiation, heading and flowering stages along with *Sesbania rostrata* incorporation produced the highest grain yield of 8.72 t ha⁻¹. Tillering, panicle initiation and seed setting are the critical stages

contributing the maximum impetus to yield increase. Application of fertilizer in three splits with a little more stress at panicle initiation stage is a preferred technique to increase paddy yield (Rasheed *et al.*, 1999). Many workers emphasised the need for N application before panicle initiation to ensure sufficient biomass production and increased yield (Greenwood *et al.*, 1991; Thiyagarajan *et al.*, 1994).

For wet seeded rice, application of nitrogen in four equal splits at 20, 35, 55 and 70 DAS proved promising at Coimbatore condition.

2.5.2. Nitrogen uptake and response

Nitrogen plays a great role in plant growth and metabolism thereby it increases yield determinants (Morris *et al.*, 1990) and yield (Singh *et al.*, 1990). Samantaray *et al.* (1990) reported that N uptake was high between vegetative and reproductive stages. Rao *et al.* (1994) and Das *et al.* (1994) reported that total amount of leaf, stem and root N continued to increase until flowering after which it decreased. Johnkutty (1996) observed continued uptake of N by the crop even after heading and an enhancement of N uptake after heading by late N supply. Leaf, culm and root N concentration were the highest during active tillering. N concentration in these organs declined thereafter until maturity. N uptake was 1.33-8.17, 1.52-6.03 and 0.05-1.02 kg m⁻² d⁻¹ during mid tillering, heading and dough stages respectively (Fu Qinglin *et al.*, 1999).

A gradual increase in N concentration and uptake as the level of N upto 180 kg N ha⁻¹ was reported by Sudhakara *et al.*, 1983. Kailash Kumar and Rao (1992) revealed that N concentration and its uptake by grain and straw was significantly increased by N and P levels due to increased N availability and higher dry matter accumulation, increased root growth which collectively led to effective N absorption.

De Datta *et al.* (1989) and Peng *et al.* (1996) evaluated broadcast seeded and transplanted rice under similar N management practices. With applied urea, ¹⁵N recovery was greater for broadcast seeded rice than transplanted rice due to rapid vegetative growth and absence of transplantation shock. However, Schnier *et al.* (1990a) observed

that row sown rice had a higher N demand and an inferior ability to convert high biomass production into grain yield as compared to transplanted rice.

2.5.3. SPAD values for N management

There is a strong correlation between chlorophyll and net photosynthetic rate and hence, SPAD values gave better indication of photosynthetic rate than other parameters. It is therefore possible that a constant SPAD value could be directly used as a threshold level for the timing of N top dressing for a given variety during entire growing period that could maintain high physiological efficiency required for high DMP (Sarkar *et al.*, 1988).

A minimum concentration of N in the leaves is needed to attain a higher yield level (Johnkutty and Palaniappan, 1996). The chlorophyll meter (SPAD) has been recently introduced to estimate N concentration in leaves. In rice, it has been widely used by Takebe *et al.* (1990), Peng and Cassman (1995), Johnkutty and Palaniappan (1996).

Photosynthetic rate is highly correlated with leaf area and SPAD (Peng and Cassman, 1995). SPAD can be used directly to estimate leaf N and forecast top dressing of N. Muralidharan (1996) fixed the critical SPAD value of 37 for the rice cultivar IR 50, 38 for ADT 36 and ASD 18.

In India, Janaki and Thiyagarajan (1999) showed that critical SPAD value was 37 for wet (*kharif*) season and 35-37 for dry and winter (*rabi*) season to obtain maximum yield in transplanted rice.

Liangttuan and Qin Nan (1999) observed a significant positive correlation between chlorophyll meter reading and leaf chlorophyll content at mid-tillering as well as at panicle initiation stages and also established relationship between grain yield and chlorophyll meter readings.

On-farm experiment conducted at Tamil Nadu Rice Research Institute, Aduthurai under IRRI-CREMNET programme to determine optimum SPAD threshold values for different varieties showed that during 1998 (*kuruvai*), higher grain yield was obtained for

ADT 42 at SPAD 37 and 39 with 75 and 120 kg N level ha⁻¹ respectively (Mohandoss *et al.*, 2000).

2.5.4. Integrated nitrogen management

Green manure is an important component in integrated nitrogen management (Ladha *et al.*, 1988; Singh and Dwivedi, 1996). Modern intensive farming system with increased risk of seed fertility losses and environmental pollution is a warning against intensive agriculture (Lee *et al.*, 1992). Therefore, to restore and sustain soil health and productivity in the long run in rice-rice system, integrated use of chemical fertilizer and organic manures was emphasized (Hegde, 1996). It is necessary to maintain (or) increase the soil organic matter, if better crop yields are aimed (Rovira, 1993).

In Phillippines, both 50/50 and 75/25 ratio of inorganic N and organic N combination in research farm and farmer's fields produced yields comparable to those obtained with complete inorganic form of N (Dascalsota *et al.*, 1986). In Karnataka, green manuring of *Sesbania rostrata* along with 100 per cent recommended N fertilizer gave the highest rice yield and was found to be better than 100 per cent inorganic N alone in red silty clay loam soil under irrigated condition during *kharif* and *rabi* seasons (Matiwade and Sheelavantar, 1994). Similar results regardless of seasons were also reported by several workers (Halepyati and Sheelavantar, 1990; Kalidurai and Kannaiyan, 1991; Setty and Channabasavanna, 1991; Dalel Singh *et al.*, 1991).

Combined use of fertilizer and green manure N source at 200 kg ha⁻¹ was on par with 200 kg fertilizer source alone (Budhar and Palaniappan, 1996). Integrated nitrogen management treatments were comparable with those of recommended dose in terms of net returns and cost benefit ratio (Chavan *et al.*, 1996). Some workers found that recommended N dose had to be applied through green manure and inorganic N fertilizer in equal proportion to produce higher grain yield than 100 per cent of the recommended dose of inorganic N alone (Pillai and Nair, 1995; Somasundaram *et al.*, 1996; Talukdar *et al.*, 1996). Green manure equivalence was estimated at 150 (Gines *et al.*, 1986) and 120 kg N ha⁻¹ (Tiwari *et al.*, 1995).

From the foregoing review, it is evident that limited literature is available on green manure seed production under rice intercropping system. This points to potential area for future research. Also, literature on *in situ* incorporation of green manure and timing of nitrogen application in split levels under rice intercropping system is scant. Therefore, the present study was designed to generate information on these lacunae.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Field experiments were conducted during *kharif* and *rabi* of 1999 and *kharif* 2000 in Wetland Farm of Tamil Nadu Agricultural University, Coimbatore to evaluate the effect of daincha intercropping with various nitrogen split doses for wet seeded rice and to explore the possibility of daincha seed production and its effect on wet seeded rice as an intercropping system. The experimental details, materials used and methods employed during the course of investigations are presented in this chapter.

3.1. Materials

3.1.1. Location of experimental field

Field experiments were carried out in A and D blocks of Wetland Farm of Tamil Nadu Agricultural University, Coimbatore (11° N; 77° E 426.7 MSL)

3.1.2. Weather and Climate

Normal weather conditions of Coimbatore (25 years mean) are as follows: A mean annual rainfall of 674.2 mm is received in 49 rainy days. The mean maximum and minimum temperatures are 31.5°C and 21°C respectively. Mean relative humidity ranges from 58 to 63 per cent. Mean bright sunshine hours per day is 7.3 hr with a mean solar radiation of 429.2 cal cm⁻²day⁻¹ (17.68 MJ m⁻² day⁻¹).

Minimum required agro-meteorological variables, recommended for fundamental research in rice by the World Meteorological Organization and the International Rice Research Institute (IRRI, 1980), were considered in the present study. Weather conditions that prevailed during the experimental periods are furnished in Appendix II and also illustrated in Fig.1a, b and c. In general, weather during the study was normal and congenial for crop growth.

3.1.3. Physico-chemical characteristics of the soil

Soils of the experimental fields (A₂ and D₆ blocks) are clay loam in texture and taxonomically classified as *Typic haplustalf*. Soils are low in available nitrogen,

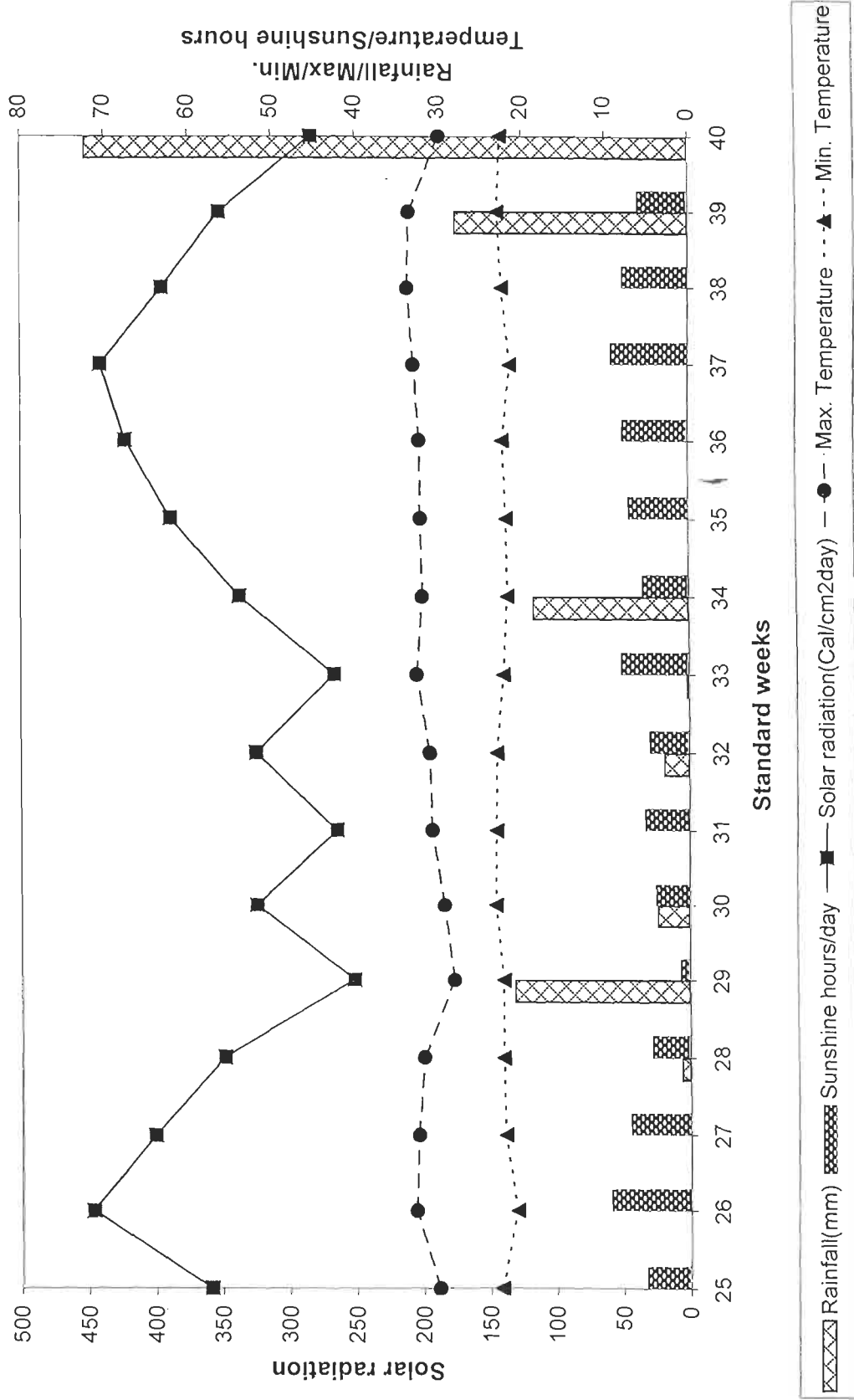


Fig.1a. Weather for the cropping period - Kharif 1999

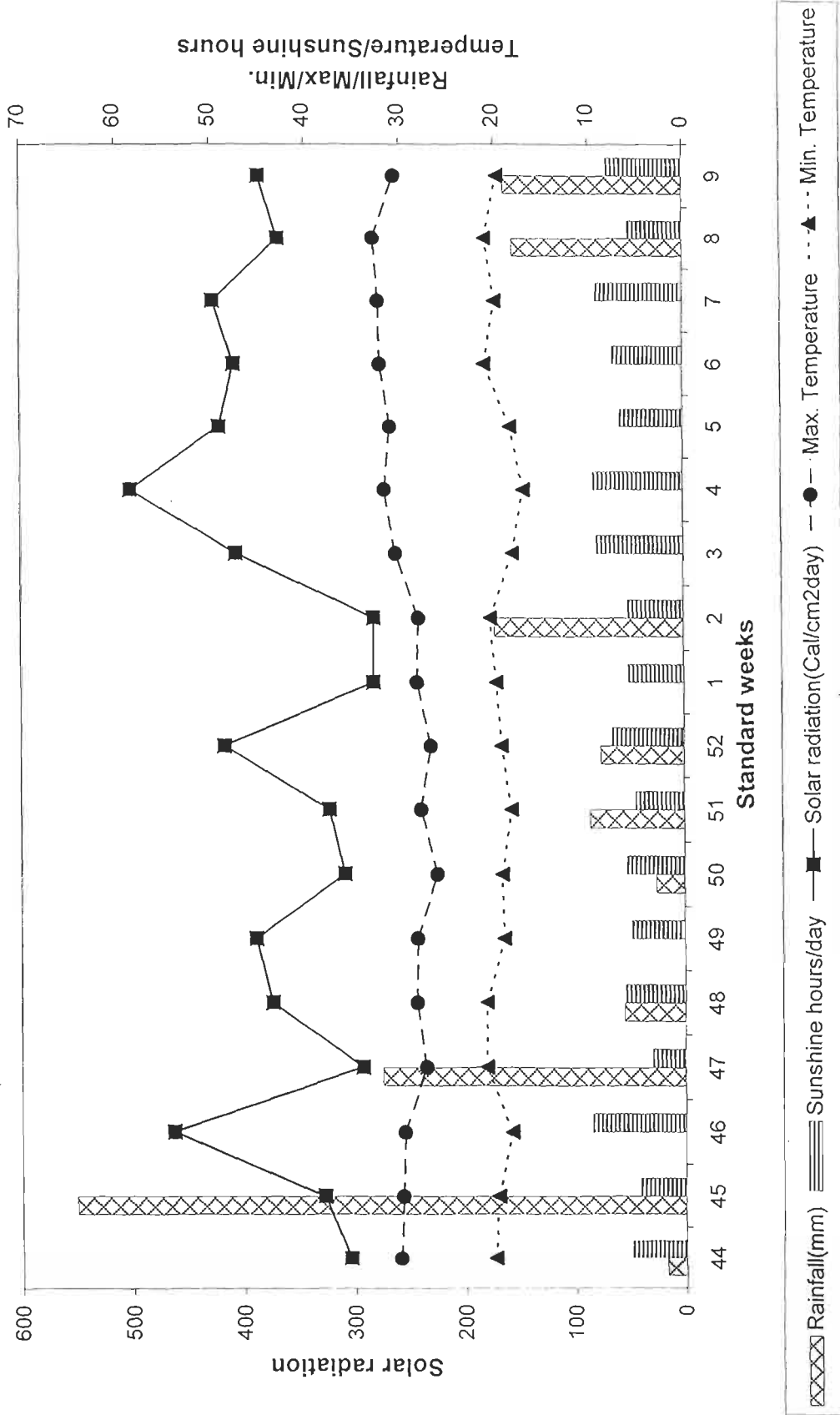


Fig.1b. Weather during the cropping season - Rabi 1999

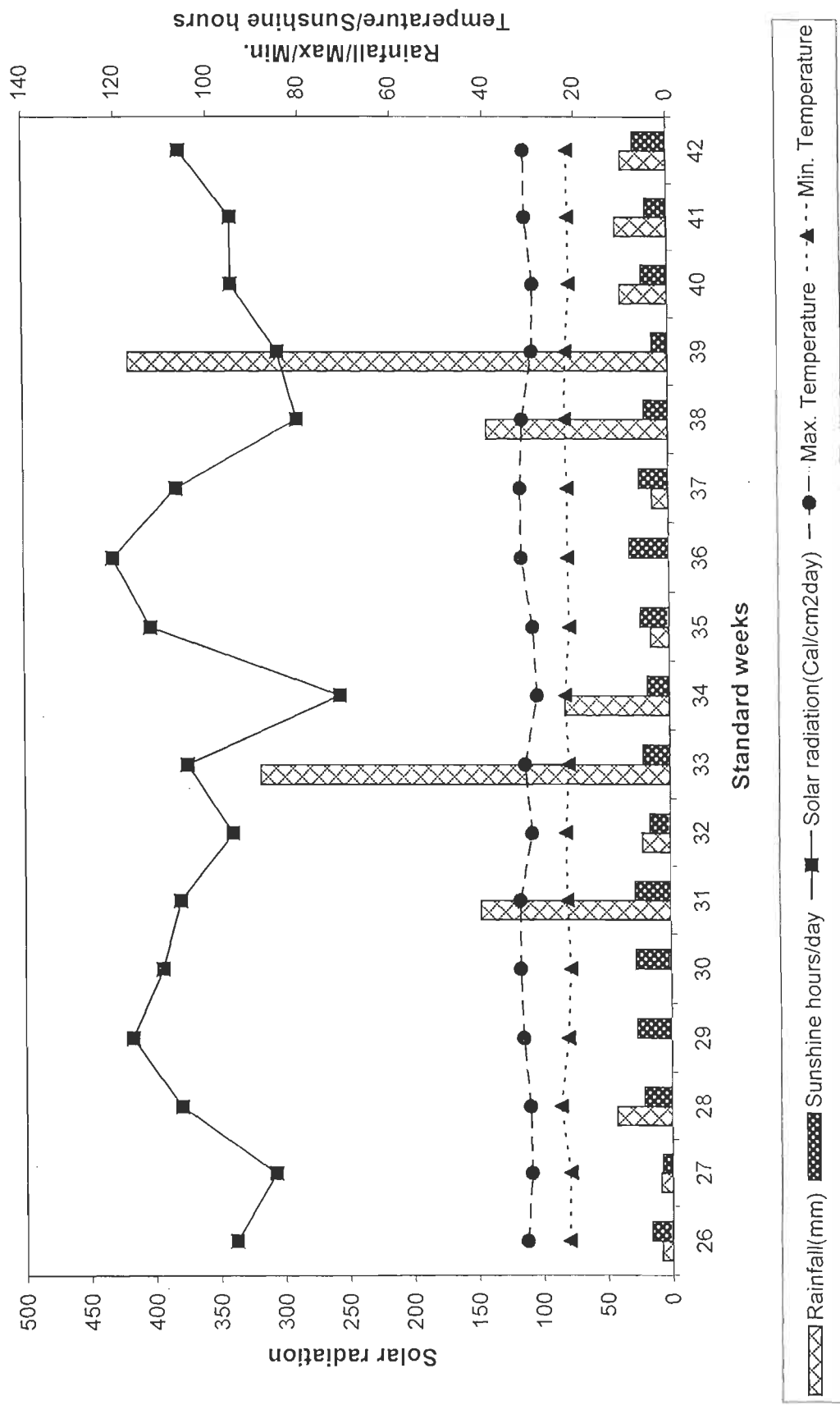


Fig. 1c. Weather during the cropping period - Kharif 2000

medium in available phosphorus and high in available potassium. Details of physico-chemical properties of the soil are given in Table 1.

Table 1. Physico-chemical properties of experimental field

Particulars	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
I. Mechanical analysis			
Clay (%)	43.8	45.6	43.7
Silt (%)	19.1	18.8	19.7
Fine sand (%)	21.4	18.3	18.9
Coarse sand (%)	15.1	16.6	17.2
Textural class	Clay loam	Clay loam	Clay loam
II. Chemical analysis			
Organic carbon (%)	0.59	0.63	0.71
Available nitrogen (kg ha ⁻¹)	189	213	237
Available phosphorus (kg ha ⁻¹)	16.2	17.3	18.9
Available potassium (kg ha ⁻¹)	538	505	514
pH (1:2 soil water suspension)	7.8	8.0	7.6
EC (d S m ⁻¹)	0.39	0.36	0.40

3.1.4. Season and cultivars

Latest, high yielding and most suited varieties for the seasons and location have been chosen as outlined below.

Short duration rice cv. ADT 43 during *kharif* (June - October) 1999 and 2000 and medium duration cv. ADT 38 during *rabi* (October - March) 1999-2000 were grown. The details of the cultivars are given in Table 2.

3.1.5. Daincha (intercrop)

Sesbania aculeata, a leguminous green manure (GM) crop was grown as intercrop as per treatment. *S. aculeata* is an indigenous and familiar green manure crop among Indian farmers. It is traditionally grown as a root nodulating, quick growing, succulent green manure, capable of producing 20 to 25 t of biomass ha⁻¹ accumulating

80-120 kg N ha⁻¹ in 55 days. It is tolerant to flooding, salinity and does not require seed scarification to increase germination.

Table 2. Characteristics of rice cultivars used in the experiment

Character	ADT 43	ADT 38
Duration (days)	110	130-135
Parentage	IR 50 x improved ponni	IR 1529 - 680 - 3 - 2/ IR 4432 - 52 - 6 - 4/ IR 7963 - 30 - 2
Grain yield (kg ha ⁻¹)	5000	6200
Test weight (g)	15.5	21.0
Habit	Semi-dwarf	Semi-dwarf, erect
Grain type	Medium slender	Long slender
Panicle	Moderately long, intermediate type and drooping	Long moderately dense

3.2. Methods

3.2.1. Treatment details

a. Main plot : Rice + daincha

Treatments	Notation
Sole rice	I ₀
Rice + Daincha (entirely for green manuring)	I ₁
Rice +Daincha (every 10 th daincha row for seed production and other rows for green manuring)	I ₂
Rice +Daincha (every 15 th daincha row for seed production and other rows for green manuring)	I ₃
Rice +Daincha (every 20 th daincha row for seed production and other rows for green manuring)	I ₄

b. Sub plot (Recommended N in split doses)

Split doses (%)	Days after sowing			
	20	37	55	70
N ₁	25	25	25	25
N ₂	25	33	21	21
N ₃	25	42	16.5	16.5

(Total N dose was constant)

c. Absolute control (no N)

Experimental design	:	Split-plot
Replication	:	3
Spacing	:	25 cm between rice rows and 12.5 cm between rice and daincha rows
Gross plot size	:	7.5 x 4.0 m
Net plot size (I ₀ , I ₁ , I ₄)	:	6.5 x 3 m
(I ₃)	:	5.25 x 3 m
(I ₂)	:	4 x 3 m

The layout plan of field experiment is shown in Fig.2.

3.3. Crop husbandry

All cultural practices and need based plant protection measures for rice other than the treatments, were followed as per recommendation of the Crop Production Guide of Directorate of Agriculture, Tamil Nadu and Tamil Nadu Agricultural University (CPG, 1999).

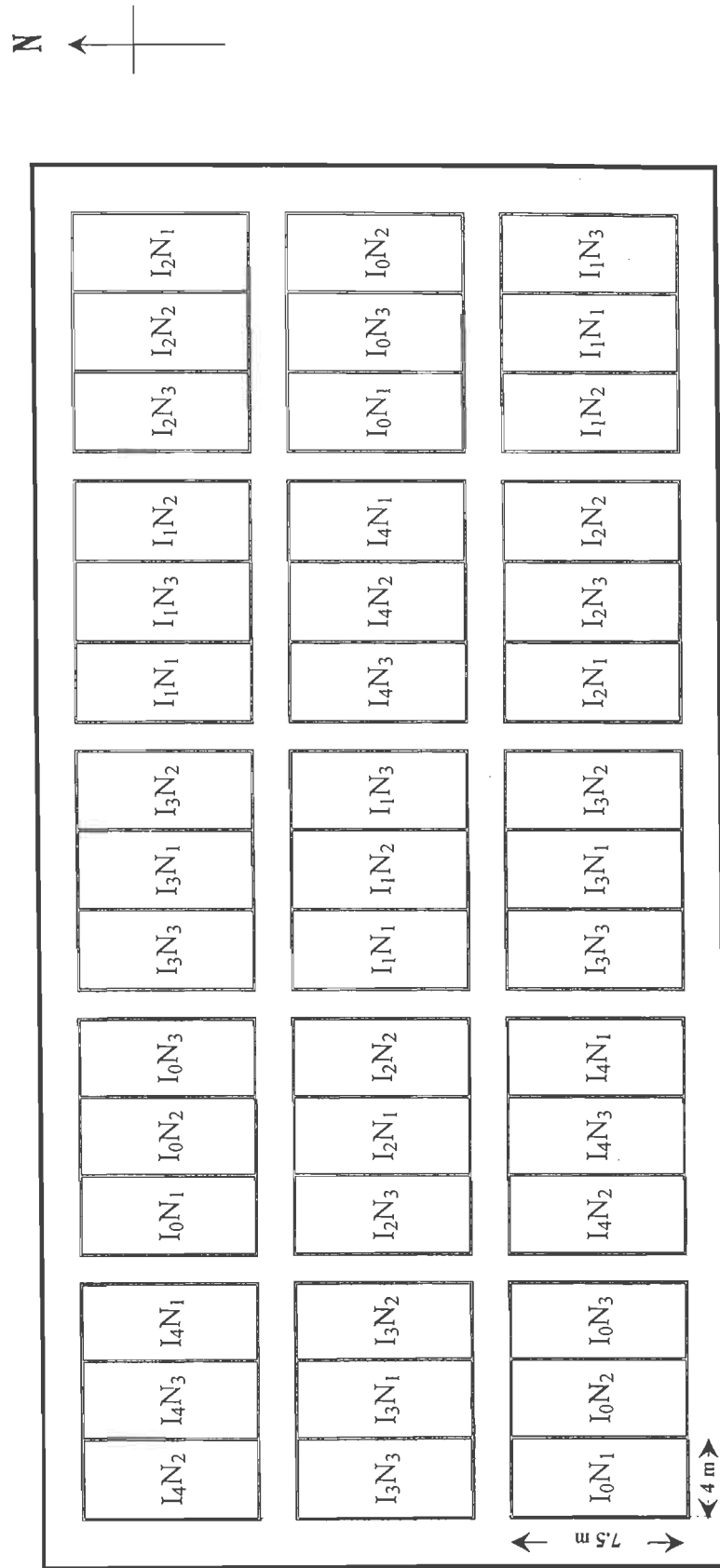
3.3.1. Field preparation

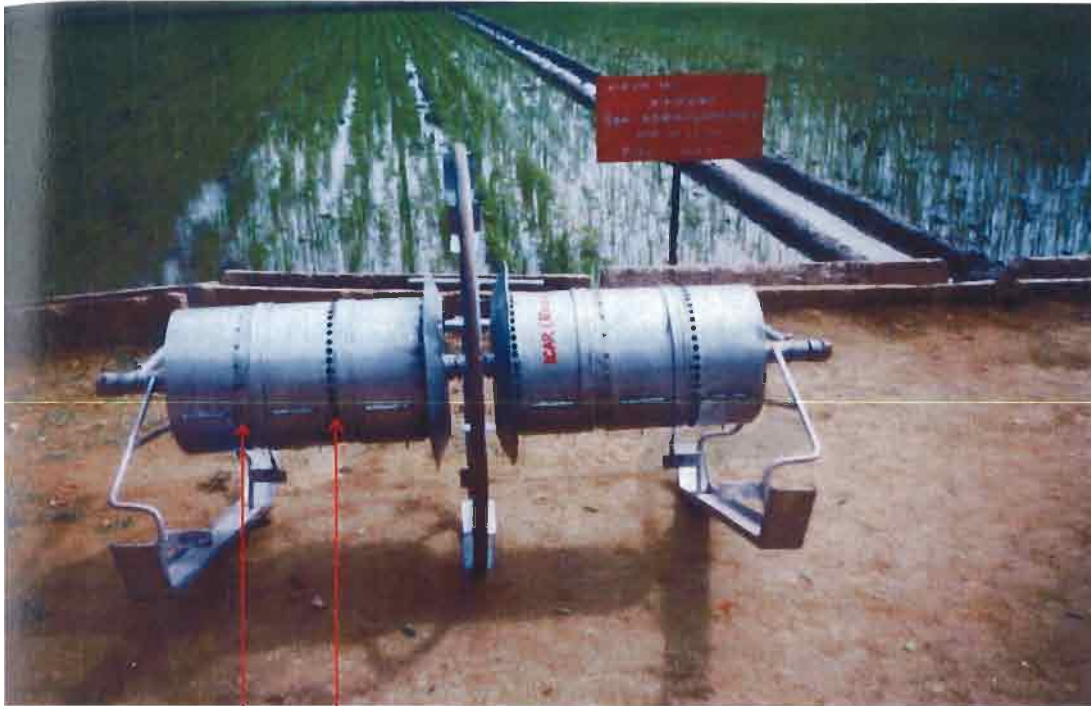
The experimental field was initially dry ploughed with tractor drawn disc harrow and then puddled with tractor drawn cage wheel. The field was levelled with wooden plank before layout. The main and subplots were laid out with irrigation and drainage channels all around the experimental field.

3.3.2. Wet seeding using drum seeder

Manually operated "Single wheel rice cum green manure seeder" developed by Tamil Nadu Agricultural University, Coimbatore was used in the study. The seeder has single wheel which is in the center and designed to sow rice and green manure (daincha) in alternate rows 12.5 cm apart, sowing 6 rows at a time 3 rows each of rice and daincha (Fig.3a and b). The seeder width is 0.75 m and the walking speed is around 1.5 km ha⁻¹. Two men will cover 0.54 ha day⁻¹ taking into account the time loss for unhooking and hooking the handle after each pass.

Fig. 2. Layout of the experimental field (same layout was followed for all the seasons)





Daincha Rice

Fig.3a Drum Seeder (Rice + Green manure)



25cm

12.5cm

Rice

Daincha

Fig.3b Rice + Daincha intercropping

Pre-germinated rice seeds (seeds soaked in water overnight and incubated for 24 hr) were used @ 75-80 kg ha⁻¹. For the intercrop *Sesbania aculeata*, the seed rate used was 40 kg ha⁻¹.

3.3.3. Weed management

Pre-emergence herbicide, butachlor @ 1.0 kg ha⁻¹ was sand mixed and broadcast 6 DAS uniformly to all plots. A thin film of water was maintained at the time of herbicide application. One hand weeding was given after incorporation of the intercropped daincha.

3.3.4. Green manure incorporation

Intercropped daincha, intended for green manuring, was *in situ* incorporated 37 DAS using IRRI “Cono weeder”. Daincha rows intended for seed production were retained intact. As such every 10th, 15th and 20th daincha rows as per treatments was earmarked for seed production (Fig.4a, b and c).

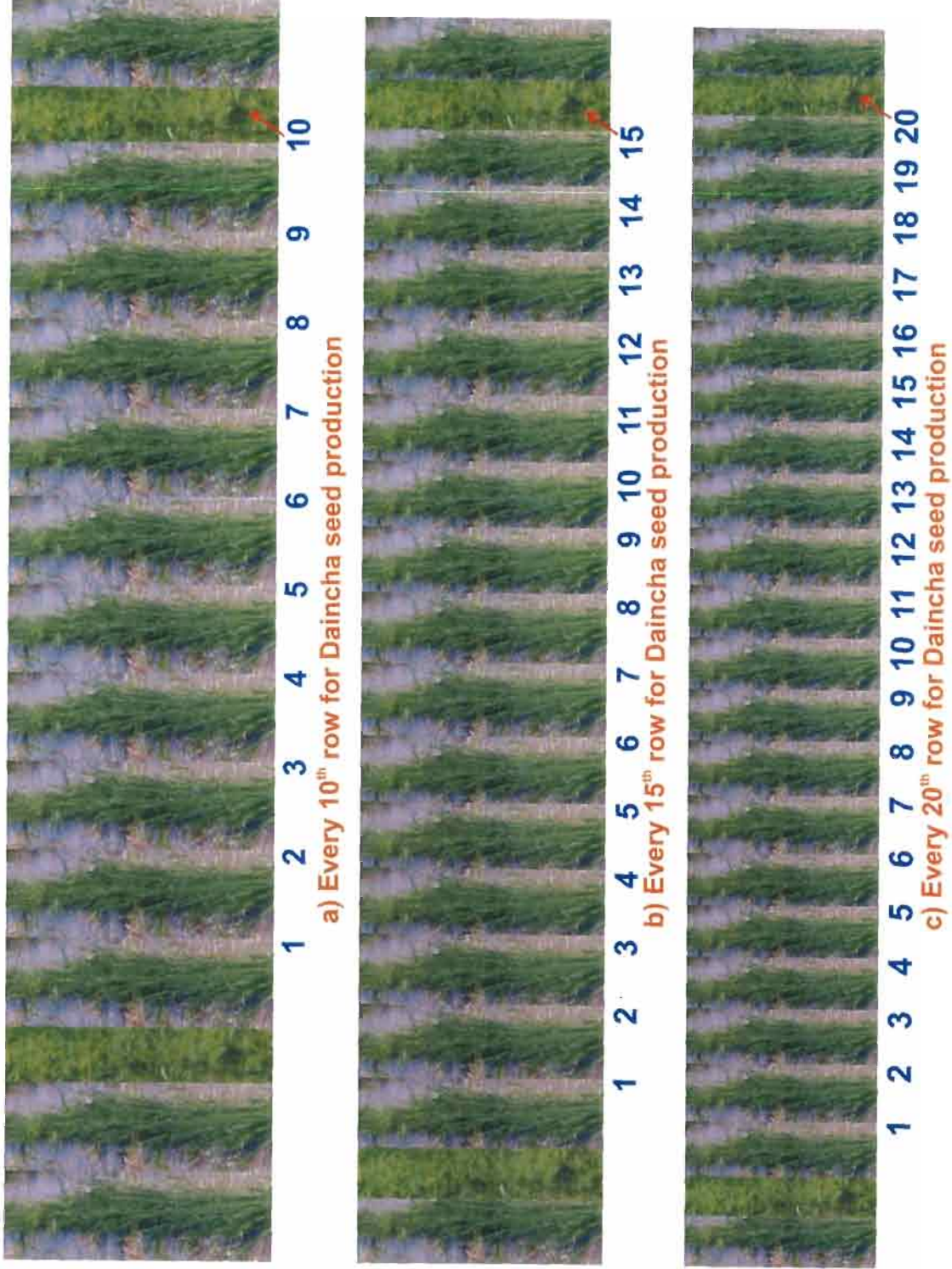
3.3.5. Fertilizer application

Recommended doses of 120:38:38 kg ha⁻¹ (*kharif*) and 150:50:50 kg ha⁻¹ (*rabi*) of nitrogen, phosphorus and potassium in the form of urea (46% N), single super phosphate (16% P₂ O₅) and muriate of potash (60% K₂O) were applied. Split application of N was done as per treatments and the entire dose of phosphorus was applied basally before sowing. Potassium was applied equally at 20, 40 and 55 DAS. Second split of N application was given after *in situ* incorporation of daincha as per treatment schedule.

3.3.6. Water management

A thin film of water was maintained at the time of drum seeding. For the next 8-10 days, irrigation and drainage of water were alternated to facilitate aeration and adequate moisture for germination of seeds and establishment of seedlings. Thereafter, the crop was irrigated to 5 cm depth at required interval when the water completely drained and irrigation was withheld 10 days prior to harvest.

Fig. 4: Daincha rows retained for seed production



3.4. Calendar of operations

The details of cropping were as follows:

a. Rice

Sl.No.	Particulars	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
(i)	Date of sowing	21.06.1999	29.10.1999	30.06.2000
(ii)	Date of harvest	05.10.1999	02.03.2000	17.10.2000
(iii)	Field duration (days)	107	127	110

b. Daincha seed crop

Sl.No.	Particulars	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
(i)	Date of sowing	21.06.1999	29.10.1999	30.06.2000
(ii)	Date of harvest	08.10.1999	20.02.2000	19.10.2000
(iii)	Field duration (days)	110	115	112

3.5. Sampling Technique

Rice and daincha samples were collected from pre-designated sampling area on either side of the plot excluding two border rows. Periodical samples were drawn from two random sampling areas of 0.25 m² each in every plot.

3.6. Studies on Rice

3.6.1. Growth parameters

3.6.1.1. Plant height

Plant height was measured from ground level to the tip of the longest leaf at tillering and flowering stages and upto tip of the panicle at maturity stage on five random plants, the average worked out and expressed in cm.

3.6.1.2. Number of tillers

Number of tillers in 0.5 m length was counted at active tillering, panicle initiation and flowering stages and converted to per m².

3.6.1.3. Leaf area index (LAI)

Ten hills in sampling area (0.25 m²) were selected at random at active tillering and flowering stages. Leaf area of all leaves was measured in a leaf area meter model

LI 3000. Leaf area index is the ratio of total leaf area to the land area occupied by it (Williams, 1946).

3.6.1.4. Leaf area duration (LAD)

LAD for the periods from sowing to active tillering and active tillering to flowering stage was computed and expressed in $\text{d m}^{-2} \text{day}^{-1}$.

$$\text{LAD} = \frac{\text{LA}_2 - \text{LA}_1}{t_2 - t_1}$$

Where, LA_1 and LA_2 are leaf areas recorded at t_1 and t_2 days and $t_2 - t_1$ is time interval in days.

3.6.1.5. Dry matter production

Plant samples drawn at active tillering, panicle initiation, flowering and maturity stages were oven dried to constant weight at 70°C and the weights extrapolated to kg ha^{-1} .

3.6.1.6. Crop growth rate (CGR)

CGR for the periods from active tillering to flowering and flowering to physiological maturity was computed following Watson (1958) and expressed in $\text{g m}^{-2} \text{day}^{-1}$.

$$\text{CGR} = \frac{W_2 - W_1}{G (t_2 - t_1)}$$

Where, W_1 and W_2 are plant dry weights recorded at t_1 and t_2 days respectively, $t_2 - t_1$ is the time interval in days and G is the ground area in which W_1 and W_2 were estimated.

3.6.1.7. Rice leaf N concentration

Chlorophyll meter (SPAD 502, Soil-plant Analysis Division, Minolta Camera Co. Ltd., Osaka, Japan) was used to record SPAD values of intact leaves as described by Peng *et al.* (1993). The SPAD meter uses light sources and detectors to measure the light transmitted by a plant leaf at two different wave lengths namely, red (650 nm) and near infra-red (950 nm). The ratio of the light transmittance at these wave lengths, in addition

to the ratio determined with number of sample is processed by the instrument to produce a reading shown on a digital display. This reading is in SPAD units which are values defined by “Minolta” to indicate the relative amount of chlorophyll content in plant leaves (Minolta Camera Co Ltd., 1989).

SPAD measurements were taken on five random plants in each plot at active tillering, panicle initiation and flowering stages.

3.7. Yield and yield components

3.7.1. Yield components

The number of panicles m^{-2} was counted in the net plot area at maturity stage. Number of filled grains panicle⁻¹, panicle length, 1000 grain weight of filled grains and per cent unfilled grains panicle⁻¹ were recorded on 5 random panicles.

3.7.2. Grain and straw yields

The grains from individual net plot were sun dried, cleaned and weighed. Results were expressed on 14 per cent moisture basis as suggested by Yoshida *et al.* (1976). Straw was sun dried for 4 days and weighed separately. Grain and straw yields were expressed in kg ha^{-1} .

3.7.3. Harvest index

From the estimated grain and straw yields, harvest index (HI) was derived using the formula suggested by Donald and Humblin (1976):

$$\text{HI} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Grain yield} + \text{Straw yield (kg ha}^{-1}\text{)}}$$

3.8. Light interception

Light intensity above the canopy and at ground level was measured during mid day at different growth stages using a hand held Lux meter. Measurement during each time was made only once at above canopy level and randomly at five places at ground level in each plot. Ground level measurements were averaged.

From the above measurements, per cent light interception by the crop canopy was calculated as under.

$$\text{Light intercepted by the crop} = \frac{\text{Light intensity on the top of the crop canopy} - \text{Average light intensity at ground level}}{\text{Light available on the top of crop canopy}} \times 100$$

3.9. Observations on intercrop (*Sesbania aculeata*)

3.9.1. Population

Population stand was counted in two sample areas in each plot at the time of incorporation (37 DAS) and expressed as number of plants m⁻².

3.9.2. Plant height

Height of intercrop was measured from ground level to growing point at the time of incorporation on five random plants and the mean height given in cm.

3.9.3. Biomass production

Total biomass of the plant chosen for population count in 0.5 m² area in each plot was weighed and the fresh biomass expressed in t ha⁻¹. The samples were oven dried at 70°C to constant weight and the dry weights expressed in t ha⁻¹.

3.10. Observations on daincha seed crop

After incorporation of daincha grown for *in situ* green manuring, the rows for daincha seed production purpose were retained as per the treatment schedule. Uniform population was maintained in the seed production rows with intra row spacing of 30 cm.

3.10.1. Plant height (cm)

Height of the plant was measured before harvest of the seed crop. Randomly five plants/plot were taken and height was measured from ground level to tip of the plant and the mean value worked out.

3.10.2. Branches/plant

Number of branches/plant was counted from the randomly pre-designated five plants in each treatment.

3.10.3. Canopy cover

Extent of canopy coverage on either side of the paddy row was measured by considering the middle portion of the daincha crop. The width covered by the top was taken into account as canopy cover.

3.10.4. Number of pods plant⁻¹

On the pre-designated five plants, the number of pods was counted at different portion of the crop (bottom, middle and top) and the mean values were expressed in units.

3.10.5. Number of seeds pod⁻¹

Five pods from each of the position were selected at random and the number of seeds pod⁻¹ was counted and the mean values were expressed.

3.10.6. Pod length

Five pods from each of the plant were selected portion wise (bottom, middle and top) at random, the length of the pod, excluding the stalk was measured and expressed in cm.

3.10.7. Seed and haulm yields

Pods from the rows, allowed for green manure seed production, were harvested when maximum number of pods reached physiological maturity. Colour change from greenish to yellowish was the indication of physiological maturity. Harvested plants were sun-dried for three to four days and the dried plants were thrashed for separating seeds.

3.10.8. Seed weight

Seeds from different portions were pooled and 100 seeds were taken for test weight and the weight expressed in g.

3.11. Observation on adjacent rows of rice from daincha seed crop

Following observations were made to assess yield reduction if any in rice crop particularly adjacent rice rows due to competition of green manure crop earmarked for seed.

3.11.1. Yield components

Number of panicles m^{-2} , filled grains panicle⁻¹ and 1000 grain weight of filled grains and per cent of unfilled grains were recorded separately in the adjoining 3 rows of rice.

3.11.2. Grain and straw yields

Yields were separately recorded by harvesting the adjoining 3 rice rows separately from others in each plot, then it was pooled together to work out the net plot yield.

3.11.3. Light interception

Daincha seed crop and its shade on adjoining three rows of rice crop was measured using the lux meter. Light available at top of the daincha seed crop and light available at top of rice crop were recorded. Light available at the bottom of the rice crop was also recorded at panicle initiation, flowering and milky stages of rice crop. Light interception was calculated as under para 3.8.

3.12. Chemical Analysis

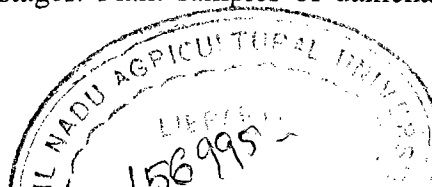
3.12.1. Soil analysis

Pre-experimental composite samples were collected from 0-20 cm depth using core samples to determine the physical properties. Air dried samples were used for estimating available N, P and K and organic carbon. Soil samples collected after *in situ* incorporation of daincha were drawn to estimate organic carbon, available nitrogen and phosphorus at active tillering, panicle initiation and flowering stages.

Post harvest soil samples were collected plotwise from a depth of 20 cm for estimating available N, P, K and organic carbon content. Methods adopted for the analysis of the soil samples are indicated in Table 3.

3.12.2. Plant analysis

Plant samples collected to assess dry matter production were ground to a fine powder in a Wiley Mill and used for chemical analysis to assess the uptake of N, P and K at active tillering, flowering and maturity stages. Plant samples of daincha seed crop



were also collected at maturity to assess N, P and K uptake as per the standard procedures (Table 3). Nutrient content of the samples was multiplied with their respective DMP to calculate nutrient uptake and expressed in kg ha^{-1} . N content of *Sesbania aculeata* was estimated at the time of incorporation and expressed in kg ha^{-1} .

Table 3. Details of analytical methods employed in soil and plant analysis

Name and estimation	Reference	Methodology
I. Soil analysis		
Organic carbon	Walkley and Black (1934)	Chromic acid wet digestion method.
Available nitrogen	Subbaiah and Asija (1956)	Alkaline permanganate method
Available phosphorus	Olsen <i>et al.</i> (1954)	Ascorbic acid method in ERMA colorimeter using red filter (660 nm)
Available potassium	Stanford and English (1949)	Flame photo metric method (neutral normal ammonium acetate extraction) using potassium filter.
II. Plant analysis		
Nitrogen	Humphries (1956)	Kjeldahl method
Phosphorus	Jackson (1973)	Triacid digestion with colorimetric estimation
Potassium	Jackson (1973)	Triacid digestion with flame photo metric method.

3.13. Nitrogen use efficiency

Absolute control (No N) was maintained separately in the experimental field to work out the N use efficiency. Recommended dose of N applied through fertilizer N (120 kg N ha^{-1} in *kharif* and 150 kg N in *rabi* seasons) and additional N supplied from the intercropped daincha were accounted for total N applied to work out different nitrogen use efficiencies. Various parameters used to study the use efficiency of N are as follows.

3.13.1. Agronomic efficiency (AE)

Agronomic efficiency i.e. the response in yield for unit input as indicated by kg of grain per kg of applied N was computed following Yoshida (1981).

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

3.13.2. Apparent recovery (AR)

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

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

Where,

Y_t = Uptake of N in particular treatment (kg ha^{-1})

Y_o = Uptake of N in unfertilized plot (kg ha^{-1})

N_t = Quantity of N applied to the treatment (kg ha^{-1})

3.13.3. Partial Factor Productivity

Cassman *et al.* (1996) introduced the term Partial Factor Productivity of N which is determined by the expression given below:

$$\text{Partial Factor Productivity (PFP)} = \frac{Y_f}{N_a}$$

Where,

Y_f = Yield from N fertilized plot (kg ha^{-1})

N_a = N applied (kg ha^{-1})

3.14. Rice yield equivalents

Rice yield equivalent was worked out by converting the economic yield of daincha seeds in terms of rice grain yield on the basis of marketable price ratio.

3.15. Economic Analysis

Crop wise economic evaluation was done by calculating the gross return, net return and cost of cultivation. Benefit cost ratio (BCR) based on the present market rate was also worked out using the formula,

$$\text{BCR} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

Income from daincha seed was also included to workout the BCR. Detailed cost of cultivation is given in Appendices III to VI.

3.16. Statistical Analysis

Data on various characters studied during investigation were subjected to an analysis of variance (F-test) as per the methods suggested by Gomez and Gomez (1984). Wherever statistical significance was observed, critical difference (CD) at 0.05 level of probability was worked out for comparison. Non significant comparisons were indicated as NS. For some attributes, data were not statistically analysed due to limited variables.

RESULTS

CHAPTER IV

RESULTS

Results of the field experiments conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* and *rabi* 1999 and *kharif* 2000 seasons to study the influence of daincha intercropping in wet seeded rice for *in situ* green manuring cum seed production and split application of N on growth, crop uptake, rice yield, soil fertility, light interception, green manure crop seed yield and economics are presented in this Chapter.

4.1. Growth characters of intercrop (daincha) at the time of incorporation (37 DAS) (Table 4 and 5)

4.1.1. Plant population (m^{-2})

Among the rice + daincha intercropping treatments (I_1 to I_4), daincha population m^{-2} was almost similar in all the seasons (73.5-75.1 in *kharif* 1999, 81.8-83.6 in *rabi* 1999 and 67.8-69.5 in *kharif* 2000 respectively).

4.1.2. Plant height (cm)

Plant height of *S. aculeata* in all the treatments was almost optimum and did not vary significantly due to seasons (53.0-54.5 cm in *kharif* 1999, 46.1-47.5 cm in *rabi* 1999 and 55.3-57.1 cm in *kharif* 2000 respectively) under study.

4.1.3. Biomass

Biomass production of *S. aculeata* was greatly influenced by the various intercropping treatments. The treatment intended entirely for green manuring purpose (I_1) added more biomass of 14.35, 12.87 and 15.80 $t\ ha^{-1}$ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. The next best treatment was allowing every 20th daincha row for seed production and remaining rows for green manuring (I_4). Lowest biomass (12.15, 10.50 and 13.25 $t\ ha^{-1}$ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) was recorded in the treatment with every 10th daincha row for seed production and remaining rows for green manuring (I_2).

Table 4. Plant population (No.m⁻²) and plant height of daincha at the time of incorporation (37 DAS)

Treatments	Plant population (No.m ⁻²)				Plant height (cm)				
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping									
I ₁ = Rice + daincha (entirely for GM alone)	73.50	82.10	69.50	53.80	46.10	56.80	53.80	46.10	56.80
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	74.30	83.60	68.10	54.50	47.30	55.30	54.50	47.30	55.30
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	75.10	81.80	67.80	53.00	46.80	56.00	53.00	46.80	56.00
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	74.70	83.00	68.60	54.10	47.50	57.10	54.10	47.50	57.10
SEd	2.22	1.98	1.41	1.97	1.23	1.42	1.97	1.23	1.42
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N split dose (%)									
N ₁ = 25:25:25:25	73.80	81.80	67.50	53.10	46.10	57.10	53.10	46.10	57.10
N ₂ = 25:33:21:21	74.40	82.60	68.40	53.90	46.90	56.40	53.90	46.90	56.40
N ₃ = 25:42:16.5:16.5	75.00	83.50	69.60	54.60	47.80	55.50	54.60	47.80	55.50
SEd	1.83	1.57	1.96	1.44	1.45	1.27	1.44	1.45	1.27
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

GM: Green manure; SP: Seed production

Table 5. Biomass ($t\ ha^{-1}$) and N accumulation of daincha at the time of incorporation (37 DAS)

Treatments	Biomass ($t\ ha^{-1}$)				N accumulation ($kg\ ha^{-1}$)			
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Rabi</i> 1999	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Rabi</i> 2000
GM Intercropping								
I ₁ = Rice + daincha (entirely for GM alone)	14.35	12.87	15.80	77.50	65.60	81.20		
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	12.15	10.50	13.25	65.60	53.60	68.10		
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	12.95	11.48	14.15	69.90	58.60	72.70		
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	13.47	12.15	14.75	72.70	63.10	75.80		
SEd	0.16	0.13	0.17	0.98	1.10	1.23		
CD (P=0.05)	0.38	0.33	0.41	2.40	2.70	3.00		
N split dose (%)								
N ₁ = 25:25:25:25	13.34	11.57	14.25	72.00	60.30	73.40		
N ₂ = 25:33:21:21	13.09	11.98	14.45	70.60	59.00	74.30		
N ₃ = 25:42:16.5:16.5	13.27	11.71	14.77	71.70	61.40	75.70		
SEd	0.17	0.26	0.28	1.28	1.07	1.34		
CD (P=0.05)	NS	NS	NS	NS	NS	NS		

GM: Green manure; SP: Seed production

Nitrogen split applications did not have any impact on daincha biomass production since the nitrogen management treatments were imposed only after *in situ* incorporation (37 DAS) of intercropped daincha.

4.1.4. N accumulation

Intercrop of daincha was incorporated *in situ* 37 DAS irrespective of season. The nitrogen content in the daincha at the time of incorporation was 2.70, 2.55 and 2.57 per cent (dry weight basis) in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. N accumulation in daincha was significantly more (77.5, 65.6 and 81.2 kg N ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 season respectively) under daincha grown exclusively for green manuring (I₁) than under the remaining treatments. Every 20th daincha row for seed production and remaining rows for green manuring (I₄) stood next (72.7, 63.1 and 75.8 kg N ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) in terms of N accumulation. The lowest N accumulation was recorded in the treatment every 10th daincha row for seed production and remaining rows for green manuring (65.6, 53.6 and 68.1 kg N ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

4.2. Influence of daincha intercropping and N splits on rice

4.2.1. Growth components

4.2.1.1. Plant height (Table 6 and 7)

At active tillering stage, sole rice had a significant influence on plant height (37.4, 39.8 and 43.6 cm in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) compared to other treatments. However, there was no variation in plant height among the daincha intercropping treatments.

No significant influence on plant height was discernible under split applications of nitrogen except during *rabi* 1999. Maximum plant height of 39.1 cm was recorded under treatments of N₃ and N₂ compared to four equal split applications of N (N₁).

Significant difference in plant height was noticed in rice + daincha intercropping entirely for green manuring (I₁) at panicle initiation, flowering and maturity stages.

Table 6. Influence of daincha intercropping/seed production and N split doses on plant height of rice (cm)

Treatments	At active tillering stage			At panicle initiation stage		
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping						
I ₀ = Sole rice	37.40	39.80	43.60	51.90	60.30	54.80
I ₁ = Rice + daincha (entirely for GM alone)	35.60	38.00	41.20	55.40	65.00	59.10
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	34.80	36.70	40.50	54.10	63.30	57.40
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	35.20	37.00	40.80	54.60	63.90	57.70
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	35.10	37.60	41.00	55.00	64.30	58.30
SEd	0.73	0.90	0.58	0.82	1.28	1.04
CD (P=0.05)	1.70	2.07	1.33	1.89	2.95	2.40
N split dose (%)						
N ₁ = 25:25:25:25	34.90	36.80	40.80	53.00	61.80	55.80
N ₂ = 25:33:21:21	35.40	37.60	41.30	54.10	63.60	57.50
N ₃ = 25:42:16.5:16.5	36.60	39.10	42.20	55.60	64.70	59.10
SEd	0.80	0.91	0.82	1.20	1.33	1.49
CD (P=0.05)	NS	1.91	NS	2.51	2.77	3.10

GM: Green manure; SP: Seed production

Table 7. Influence of daincha intercropping/seed production and N split doses on plant height of rice (cm)

Treatments	At flowering stage			At maturity stage		
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping						
I ₀ = Sole rice	72.40	81.60	75.80	77.90	85.80	80.10
I ₁ = Rice + daincha (entirely for GM alone)	77.10	85.90	81.60	84.70	92.40	86.60
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	74.90	84.30	78.80	81.30	89.50	83.90
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	75.30	84.90	79.90	82.80	90.70	85.10
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	76.00	84.80	80.90	83.50	91.80	86.00
SEd	1.01	1.09	1.27	1.46	1.27	1.16
CD (P=0.05)	2.33	2.51	2.93	3.37	2.93	2.68
N split dose (%)						
N ₁ = 25:25:25:25	75.30	84.20	79.20	84.00	92.30	86.30
N ₂ = 25:33:21:21	77.10	85.80	80.60	83.10	90.80	85.10
N ₃ = 25:42:16.5:16.5	73.00	82.90	78.40	79.00	87.00	81.60
SEd	1.50	1.38	1.06	1.93	1.06	1.45
CD (P=0.05)	3.13	2.87	2.21	4.03	2.21	3.02

GM: Green manure; SP: Seed production

However, it was on par with other treatments except sole rice (I_0) at panicle initiation and flowering stages. At maturity stage, daincha grown for green manuring alone (I_1) was on par with rice + daincha intercropping and allowing 20th and 15th daincha row for seed production (I_4 and I_3). The lowest plant height was observed in sole rice (I_0).

Split applications of N were found to markedly increase plant height at panicle initiation, flowering and maturity stages. At panicle initiation stage, both the treatments 42 per cent N (N_3) and 33 per cent N (N_2) application at the time of daincha incorporation (N_3) recorded maximum plant height.

At flowering stage, application of 33 per cent N at the time of daincha incorporation (N_2) and four equal split applications of N imparted almost similar influence on plant height compared to N_3 (42 per cent N application at the time daincha incorporation) irrespective of the season. The latter treatment recorded least plant height.

At maturity stage, four equal split applications of N (N_1) had a pronounced effect on plant height. However, it was comparable with the treatment of 33 per cent N application at the time of daincha incorporation irrespective of season. Plant height was least in the treatment, 42 per cent N application at the time of daincha incorporation (N_3).

4.2.1.2. Number of tillers m^{-2} (Table 8 and 9)

Number of tillers m^{-2} at active tillering stage varied significantly among the treatments. During *kharif* 1999 and *kharif* 2000, sole rice (I_0) performed better in terms of tiller production (343 and 362 m^{-2}) whereas, the other treatments did not have significant influence on number of tillers and were at par with each another.

Split applications of nitrogen did not have significant influence on number of tillers during *kharif* 1999 and 2000. However, a significant influence of nitrogen was noticed during *rabi* 2000 crop. Maximum number of tillers was registered in 42 per cent N (N_3) and 33 per cent N (N_2) applications at the time of daincha incorporation.

Number of tillers at panicle initiation and flowering stages was significantly influenced by intercropping treatments. Among the treatments, more number of tillers

Table 8. Influence of daincha intercropping/seed production and N split doses on number of tillers of rice (m^{-2})

Treatments	At active tillering stage			At panicle initiation stage		
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping						
I_0 = Sole rice	343	395	362	404	467	421
I_1 = Rice + daincha (entirely for GM alone)	332	387	350	428	501	445
I_2 = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	325	378	346	417	483	432
I_3 = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	326	380	347	421	488	436
I_4 = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	329	383	350	425	495	439
SEd	4.4	5.9	4.9	4.7	6.2	5.3
CD (P=0.05)	10.1	13.6	11.3	10.9	14.3	12.2
N split dose (%)						
N_1 = 25:25:25:25	327	378	347	411	477	428
N_2 = 25:33:21:21	331	385	350	419	488	433
N_3 = 25:42:16.5:16.5	335	391	356	427	495	443
SEd	5.2	4.4	6.8	7.4	8.1	6.3
CD (P=0.05)	NS	9.2	NS	15.4	16.9	13.1

GM: Green manure; SP: Seed production

Table 9. Influence of daincha intercropping/seed production and N split doses on number of tillers (m^{-2}) of rice at flowering stage

Treatments		<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping				
I_0	= Sole rice	479	557	501
I_1	= Rice + daincha (entirely for GM alone)	517	603	539
I_2	= Rice + daincha (every 10 th daincha row for SP and other rows for GM)	498	572	519
I_3	= Rice + daincha (every 15 th daincha row for SP and other rows for GM)	504	584	526
I_4	= Rice + daincha (every 20 th daincha row for SP and other rows for GM)	510	592	531
SEd		7.4	6.2	7.3
CD (P=0.05)		17.1	14.3	16.8
N split dose (%)				
N_1	= 25:25:25:25	492	574	516
N_2	= 25:33:21:21	500	579	522
N_3	= 25:42:16.5:16.5	513	592	532
SEd		5.7	5.9	4.7
CD (P=0.05)		11.9	12.3	9.8

GM: Green manure; SP: Seed production

was recorded in the intercropped daincha entirely for green manuring (I_1) purpose. Number of tillers m^{-2} was 428,517 in *kharif* 1999, 501, 603 in *rabi* 1999 and 445, 539 in *kharif* 2000 at panicle initiation and flowering stages respectively. Least number of tillers was observed in sole rice (I_0). The treatment where daincha was grown entirely for green manuring (I_1) purpose was on par with 20th and 15th daincha row for seed production and remaining rows for green manuring (I_4 and I_3) during *kharif* 1999 and 2000 at flowering stage. In *rabi* 1999 season, daincha grown entirely for green manuring was on par with 20th daincha row for seed production and remaining rows for green manuring (I_4).

At panicle initiation stage the different N splits behaved almost similarly. During flowering stage, the treatment 42 per cent N application at the time of daincha incorporation was found to be superior to other treatments (513, 592 and 532 tillers m^{-2} during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) and less number of tillers was observed in the four equal split applications of N (N_1) in all the seasons.

4.2.1.3. Leaf area index (LAI)(Table 10)

During active tillering stage, LAI was significantly more under sole rice (I_0) than under daincha intercropped treatments in both *kharif* seasons. Eventhough sole rice recorded higher LAI, it was equally effective with rice + daincha grown entirely for green manuring (I_1) during *rabi* 1999.

Split application of nitrogen at tillering stage of crop did not influence LAI during both *kharif* seasons. In *rabi* 1999 season, 42 per cent N application at the time of daincha incorporation (N_3) significantly influenced the LAI which was on par with the treatment 33 per cent N application at the time of daincha incorporation (N_2). The least values were noticed in the four equal split applications of N (N_1).

At flowering stage, LAI was significantly promoted by the daincha intercropping treatments compared to sole rice irrespective of the season. Sole rice (I_0) registered least LAI but it was on par with 10th daincha row for seed production and remaining rows for green manuring (I_2) in *kharif* 1999 and *rabi* 1999 seasons. Whereas during *kharif* 2000, it

Table 10. Influence of daincha intercropping/seed production and N split doses on leaf area index of rice

Treatments	At active tillering stage				At flowering stage			
	Kharif 1999	Rabi 1999	Kharif 2000	Kharif 1999	Rabi 1999	Kharif 1999	Rabi 1999	Kharif 2000
GM Intercropping								
I ₀ = Sole rice	2.46	2.97	2.78	4.31	4.96	4.80		
I ₁ = Rice + daincha (entirely for GM alone)	2.27	2.83	2.63	4.76	5.37	5.23		
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	2.16	2.72	2.56	4.51	5.11	4.89		
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	2.18	2.78	2.58	4.60	5.21	5.05		
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	2.23	2.80	2.60	4.68	5.30	5.13		
SEd	0.06	0.07	0.05	0.08	0.07	0.08		
CD (P=0.05)	0.13	0.16	0.11	0.19	0.16	0.19		
N split dose (%)								
N ₁ = 25:25:25:25	2.22	2.77	2.59	4.47	5.07	4.91		
N ₂ = 25:33:21:21	2.26	2.82	2.64	4.57	5.19	5.01		
N ₃ = 25:42:16.5:16.5	2.31	2.88	2.66	4.68	5.31	5.13		
SEd	0.05	0.05	0.04	0.10	0.11	0.09		
CD (P=0.05)	NS	0.10	NS	0.20	0.22	0.18		

GM: Green manure; SP: Seed production

recorded lower LAI than the treatment 10th daincha row for seed production and remaining rows for green manuring (I₂).

Split applications of N had a significant influence on LAI. Application of 42 per cent N at the time of daincha incorporation (N₃) recorded higher LAI of 4.68, 5.30 and 5.13 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively than four equal splits of N (N₁) but it was on par with the treatment 33 per cent N at the time of daincha incorporation (N₂) in all the seasons.

4.2.1.4. Leaf area duration (LAD) (Table 11)

In respect of the LAD from sowing to active tillering stage, sole rice (I₀) registered higher values of 5.59, 5.60 and 5.91 d m² day⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. Different daincha intercropping treatments (I₂ to I₄) failed to influence LAD relative to sole rice (I₀) and also there was no significant difference between the various daincha intercropping treatments during sowing to active tillering stage.

N splits failed to influence LAD between sowing and active tillering stage in any of the season

During active tillering to flowering stage, daincha intercropping treatments (I₁ to I₄) had appreciable effect on LAD compared to sole rice (I₀). Daincha intercropping entirely meant for green manuring (I₁) had higher LAD (8.03, 6.05 and 8.13 d m² day⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than other treatments, except the treatment every 20th daincha row for seed production and remaining rows for green manuring (I₄) in all the three seasons. The treatment (I₄) was on par with every 15th daincha row for seed production and remaining rows for green manuring (I₃) irrespective of season. Least leaf area duration was noticed in sole rice (I₀) of 5.97, 4.74 and 6.31 d m² day⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively relative to daincha intercropping treatments.

Split applications of N had a significant influence on LAD from active tillering to flowering stage. Application of 42 per cent N at the time of daincha incorporation had a

Table 11. Influence of daincha intercropping/seed production and N split doses on leaf area duration (LAD) of rice ($\text{d m}^{-2} \text{day}^{-1}$)

Treatments	Sowing to active tillering			Active tillering to flowering		
	Kharif 1999	Rabi 1999	Kharif 2000	Kharif 1999	Rabi 1999	Kharif 2000
GM Intercropping						
I ₀ = Sole rice	5.59	5.60	5.91	5.97	4.74	6.31
I ₁ = Rice + daincha (entirely for GM alone)	5.16	5.34	5.60	8.03	6.05	8.13
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	4.91	5.13	5.45	7.58	5.69	7.28
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	4.95	5.25	5.49	7.81	5.79	7.72
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	5.07	5.28	5.53	7.90	5.95	7.91
SEd	0.11	0.10	0.08	0.09	0.11	0.17
CD (P=0.05)	0.26	0.22	0.18	0.21	0.25	0.38
N split dose (%)						
N ₁ = 25:25:25:25	5.05	5.23	5.51	7.26	5.48	7.25
N ₂ = 25:33:21:21	5.14	5.32	5.62	7.45	5.64	7.41
N ₃ = 25:42:16.5:16.5	5.25	5.43	5.66	7.65	5.79	7.72
SEd	0.15	0.13	0.09	0.16	0.15	0.20
CD (P=0.05)	NS	NS	NS	0.24	0.30	0.42

GM: Green manure; SP: Seed production

greater influence on LAD with 7.65, 5.79 and 7.72 d m² day⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively than four equal split applications of N (N₁). Treatment N₃ was on par with N₂ (33 per cent N application at the time of daincha incorporation).

4.2.1.5. SPAD value of rice leaf (Table 12 and 13)

Chlorophyll meter (SPAD) reading clearly indicated that intercropping treatment did not influence SPAD values at active tillering stage in *kharif* seasons. In *rabi* season, the intercropping treatments (I₁ to I₄) possessed higher effect on chlorophyll meter readings than sole rice (I₀).

Split application of N had significant effect on SPAD values at active tillering stage. Application of 42 per cent N at the time of daincha incorporation (N₃) had superiority over N₁ (38.7, 39.9 and 40.5 SPAD values during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). But this treatment (N₃) was comparable with 33 per cent N application at the time of daincha incorporation (N₂) in all the seasons. Least values were noticed under N application at four equal splits (N₁).

At panicle initiation and flowering stages, intercropping with daincha (I₁) recorded higher SPAD values than sole rice in all the seasons except *kharif* 2000. In *kharif* 2000, daincha grown purely for green manuring (I₁) proved superior to other treatments, except the treatment every 20th daincha row for seed production and remaining rows for green manuring (I₄). In general daincha grown entirely for green manuring had shown superiority over the remaining treatments in terms of SPAD values in all the seasons. Invariably the lowest SPAD values were recorded in the sole rice (I₀).

At panicle initiation stage, split applications of N exhibited significant variation in SPAD values except during *rabi* 1999. The treatment of 33 per cent N application at the time of daincha incorporation (N₂) was comparable with four equal split applications of N (N₁). In all the seasons at panicle initiation stage, 42 per cent of N application at the time of daincha incorporation (N₃) recorded significantly higher SPAD values than the remaining treatments (41.2, 40.2 and 42.8 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

Table 12. Influence of daincha intercropping/seed production and N split doses on SPAD values of rice at active tillering and panicle initiation stages

Treatments	At active tillering				At panicle initiation stage			
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 1999	<i>Kharif</i> 2000	
GM Intercropping								
I ₀ = Sole rice	37.3	36.8	38.7	36.7	34.9	37.3	37.3	
I ₁ = Rice + daincha (entirely for GM alone)	38.5	40.0	40.3	40.5	39.3	41.5	41.5	
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	37.0	38.3	38.7	38.8	37.5	39.7	39.7	
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	37.3	38.6	39.5	39.5	38.3	40.3	40.3	
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	37.7	39.3	39.8	39.7	38.8	41.1	41.1	
SEd	0.68	0.75	0.7	0.83	0.80	0.87	0.87	
CD (P=0.05)	NS	1.72	NS	1.91	1.85	2.01	2.01	
N split dose (%)								
N ₁ = 25:25:25:25	36.5	37.1	38.0	36.8	35.3	37.1	37.1	
N ₂ = 25:33:21:21	37.5	38.9	39.7	39.1	37.9	40.0	40.0	
N ₃ = 25:42:16.5:16.5	38.7	39.9	40.5	41.2	40.2	42.8	42.8	
SEd	0.94	0.86	0.81	0.97	1.01	1.31	1.31	
CD (P=0.05)	1.97	1.80	1.69	2.03	2.11	2.73	2.73	

GM: Green manure; SP: Seed production

Table 13. Influence of daincha intercropping/seed production and N split doses on SPAD values of rice at flowering stage

Treatments	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping			
I ₀ = Sole rice	36.7	35.9	36.1
I ₁ = Rice + daincha (entirely for GM alone)	42.0	41.0	40.7
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	40.3	39.0	38.1
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	40.7	39.5	38.7
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	41.5	40.3	39.5
SEd	0.9	1.0	0.8
CD (P=0.05)	2.1	2.3	1.8
N split dose (%)			
N ₁ = 25:25:25:25	41.2	40.0	39.5
N ₂ = 25:33:21:21	40.1	39.1	38.5
N ₃ = 25:42:16.5:16.5	39.3	38.4	37.9
SEd	0.7	0.8	0.8
CD (P=0.05)	1.4	1.6	1.7

GM: Green manure; SP: Seed production

At flowering stage, split applications of N exhibited significant effect on SPAD values. Application of N in four equal splits (N_1) and 33 per cent N application at the time of daincha incorporation (N_2) recorded higher SPAD values. Invariably, the lowest SPAD values were registered by 42 per cent of N application at the time of daincha incorporation (N_3) irrespective of season (39.3, 38.4 and 37.9 SPAD values during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

4.2.1.6. Dry matter production (DMP) (Table 14, 15 and 16)

At active tillering stage, the DMP was significantly higher in sole rice (2873, 3871 and 3386 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively), than the remaining treatments which were at par with one another.

Influence of N application on DMP at active tillering stage was not consistent. Except during *rabi* 1999 season, there was no significant effect on DMP. Although the treatment 42 per cent N application at the time of daincha incorporation recorded higher DMP during *rabi* 1999 season, the increase was meagre.

At panicle initiation stage, daincha intercropping treatments recorded more DMP compared to sole rice in all the seasons. Whereas daincha intercropping treatments behaved similarly among them irrespective of the season.

DMP varied greatly between the different N split applications at panicle initiation stage. Application of 42 per cent N at the time of daincha incorporation (N_3) significantly produced maximum DMP of 4738, 5874 and 5188 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively, which was followed by 33 per cent N application at the time of daincha incorporation and four equal split applications of N (N_2 and N_1).

At flowering, difference in DMP was greater, due to intercropping treatments. Among the treatments, intercropped daincha entirely for green manuring (I_1) exerted a greater influence on DMP (8286, 9339 and 8878 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). The lowest DMP was recorded in sole rice (I_0) in all the seasons.

Table 14. Influence of daincha intercropping/seed production and N split doses on dry matter production by rice (kg ha^{-1}) at active tillering and panicle initiation stages

Treatments	At active tillering stage			At panicle initiation stage		
	<i>Khariif 1999</i>	<i>Rabi 1999</i>	<i>Khariif 2000</i>	<i>Khariif 1999</i>	<i>Rabi 1999</i>	<i>Khariif 2000</i>
GM Intercropping						
I_0 = Sole rice	2873	3871	3386	4227	5393	4718
I_1 = Rice + daincha (entirely for GM alone)	2641	3702	3184	4684	5837	5137
I_2 = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	2562	3547	3043	4541	5622	4953
I_3 = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	2579	3588	3072	4590	5690	5013
I_4 = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	2603	3640	3144	4637	5781	5085
SEd	48	71	64	63	94	82
CD (P=0.05)	110	163	147	146	217	188
N split dose (%)						
N_1 = 25:25:25:25	2608	3601	3110	4348	5456	4774
N_2 = 25:33:21:21	2644	3683	3168	4522	5663	4981
N_3 = 25:42:16.5:16.5	2703	3725	3219	4738	5874	5188
SEd	48	47	54	66	88	98
CD (P=0.05)	100	98	113	138	184	204

GM: Green manure; SP: Seed production

Table 15. Influence of daincha intercropping/seed production and N split doses on dry matter production (kg ha⁻¹) by rice at flowering stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	7428	7251	7043	7241	8162	7953	7745	7953	7873	7617	7424	7638
I ₁ = Rice + daincha (entirely for GM alone)	8063	8284	8512	8286	9168	9381	9467	9339	8689	8918	9027	8878
I ₂ = Rice + daincha (every 10 th daincha row for SP)	7369	7582	7794	7582	8534	8701	8832	8689	7845	8078	8296	8073
I ₃ = Rice + daincha (every 15 th daincha row for SP)	7618	7749	7982	7783	8718	8896	9006	8873	8168	8344	8583	8365
I ₄ = Rice + daincha (every 20 th daincha row for SP)	7784	7903	8213	7967	8869	9017	9113	9000	8363	8476	8869	8569
Mean	7652	7754	7909	7690	8690	8790	8833	8188	8286	8440		
N split dose (%) : N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	81.90	189.00	88.00	203.00	88.00	203.00	99.40	229.20	99.40	229.20	99.40	229.20
I at N	112.20	234.00	67.60	141.00	67.60	141.00	74.90	156.20	74.90	156.20	74.90	156.20
Nat I	208.10	454.90	189.90	415.00	189.90	415.00	154.90	338.60	154.90	338.60	154.90	338.60
	164.90	344.00	175.50	366.00	175.50	366.00	145.60	303.60	145.60	303.60	145.60	303.60

Table 16. Influence of daincha intercropping/seed production and N split doses on dry matter production by rice (kg ha⁻¹) at maturity stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	13210	12673	12182	12688	12579	12181	11894	12218	13422	12798	12267	12829
I ₁ = Rice + daincha (entirely for GM alone)	14326	14556	13614	14165	14376	14639	13841	14285	14573	15036	13974	14528
I ₂ = Rice + daincha (every 10 th daincha row for SP)	13497	13701	12217	13138	13213	13581	12813	13202	13517	13889	13181	13529
I ₃ = Rice + daincha (every 15 th daincha row for SP)	13708	13892	12683	13428	13731	13910	13288	13643	13888	14263	13462	13871
I ₄ = Rice + daincha (every 20 th daincha row for SP)	14007	14201	13367	13858	14070	14332	13584	13995	14216	14635	13831	14227
Mean	13750	13805	12813	13594	13729	13084	13923	14124	13343			
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	170.10	392.30	129.20	297.90	147.70	340.60	197.90	412.60	219.30	203.50	276.70	604.90
I at N	276.70	604.90	193.50	423.00	217.30	475.40	277.20	578.20	190.50	397.20	277.20	578.20
Nat I												

Among the different N splits, application of 42 per cent N (N_3) and 33 per cent N (N_2) at the time of daincha incorporation registered the maximum DMP. Application of N in four equal splits (N_1) produced lowest DMP in all the seasons.

Interaction effect between intercropping and N split applications was significant at flowering stage. Daincha intercropping entirely for green manuring along with 44 per cent N application at the time of daincha incorporation (I_1N_3) registered the maximum DMP of 8512, 9467 and 9027 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. The former combination was closely followed by 20th daincha row for seed production with 44 per cent N application at the time of daincha incorporation (I_4N_3). Sole rice with 42 per cent N application at daincha incorporation (I_0N_3) recorded the lowest DMP of 7043, 7745 and 7424 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 seasons respectively.

At maturity, daincha grown entirely for green manuring in I_1 significantly increased the DMP (14165, 14285 and 14528 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) over rest of the treatments excluding 20th row for seed production (I_4) alone in *kharif* 1999 and *rabi* 1999 crops. Treatments I_3 and I_2 (every 15th and 10th daincha row for seed production) which were proved superior to I_0 (sole rice).

Application of 33 per cent N at the time of daincha incorporation (N_2) and four equal split applications of N registered the higher DMP compared to 42 per cent N at time daincha incorporation (N_3)

Interaction effect between different intercropping treatments and split applications of N was significant in all the seasons at maturity. Daincha grown entirely for green manuring along with 33 per cent N at the time of daincha incorporation (I_1N_2) registered maximum DMP of 14556, 14639 and 15036 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. However, this combination was on par with the treatment consisting entirely grown for green manuring along with four equal split applications of N (I_1N_1) followed by 20th daincha row for seed production with 33 per cent N at the time

of daincha incorporation (I_4N_2). Poorest combined effect was noticed in sole rice with 42 per cent N at the time of daincha incorporation (I_0N_3) in all the seasons.

4.2.1.7. Crop growth rate (CGR) (Table 17)

Intercropping treatments had significant influence on CGR at both stages (active tillering to flowering and flowering to maturity).

Intercropped daincha meant for green manuring alone (I_1) recorded higher CGR of 17.11, 12.81 and 17.79 $g\ m^{-2}day^{-1}$ in all the seasons respectively than other treatments, except 20th daincha row for seed production and remaining rows for green manuring (I_4) in both *kharif* seasons. In *rabi* season, the treatment (I_1) was on par with I_4 and I_3 (20th and 15th daincha row for seed production and remaining rows for green manuring).

CGR did not vary under N split applications during active tillering to flowering stage in all the seasons.

At flowering to maturity stage, maximum growth rate was observed under daincha grown entirely for green manuring (I_1) (18.27, 14.46 and 16.83 $g\ m^{-2}day^{-1}$ in all the three seasons respectively).

Nitrogen management practices had a significant influence on CGR in all the seasons at flowering to maturity stage. Application of 33 per cent N at the time of daincha incorporation (N_2) proved to be superior (18.93, 14.37 and 17.40 $g\ m^{-2}day^{-1}$ over the seasons respectively) over 42 per cent N application at the time of daincha incorporation (N_3), but it was (N_2) on par with the four equal split applications of N in all the seasons (N_1).

4.2.2. Nutrient uptake by rice

4.2.2.1. Nitrogen uptake (Table 18 to 20)

Nutrient uptake was proportional to the DMP (Table 14, 15 and 16) and nutrient concentration in the plant. N uptake was similar in different intercropping treatments except sole rice (I_0). Highest N uptake was recorded in sole rice (I_0) with values of 48.6,

Table 17. Influence of daincha intercropping/seed production and N split doses on crop growth rate of rice ($\text{g m}^{-2} \text{ day}^{-1}$)

Treatments	At active tillering - Flowering				At flowering - Maturity			
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping								
I ₀ = Sole rice	13.24	9.28	13.29	16.79	12.33	15.30		
I ₁ = Rice + daincha (entirely for GM alone)	17.11	12.81	17.79	18.27	14.46	16.83		
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	15.21	11.69	15.72	17.16	13.10	16.19		
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	15.77	12.01	16.54	17.67	13.91	16.35		
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	16.25	12.18	16.95	18.12	14.31	16.71		
SEd	0.49	0.38	0.53	0.61	0.77	0.57		
CD (P=0.05)	1.14	0.87	1.23	1.41	1.77	1.32		
N split dose (%)								
N ₁ = 25:25:25:25	14.98	11.27	15.77	18.99	14.22	17.15		
N ₂ = 25:33:21:21	15.48	11.51	16.12	18.93	14.37	17.40		
N ₃ = 25:42:16.5:16.5	16.08	12.01	16.34	14.87	12.29	14.28		
SEd	0.64	0.41	0.69	1.00	1.05	0.91		
CD (P=0.05)	NS	NS	NS	2.08	2.18	1.90		
GM: Green manure; SP: Seed production								

Table 18. Influence of daincha intercropping/seed production and N split doses on nitrogen uptake (kg ha^{-1}) by rice at active tillering stage

Treatments	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping			
I ₀ = Sole rice	48.6	61.6	57.6
I ₁ = Rice + daincha (entirely for GM alone)	43.6	57.0	52.5
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	42.3	54.6	50.2
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	42.6	55.3	50.7
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	43.0	56.1	51.9
SEd	0.8	1.2	1.0
CD (P=0.05)	1.8	2.7	2.4
N split dose (%)			
N ₁ = 25:25:25:25	43.3	55.8	51.3
N ₂ = 25:33:21:21	43.9	57.1	52.6
N ₃ = 25:42:16.5:16.5	44.8	57.9	53.8
SEd	0.8	0.9	1.2
CD (P=0.05)	1.7	1.9	NS

GM: Green manure; SP: Seed production

Table 19. Influence of daincha intercropping/seed production and N split doses on nitrogen uptake (kg ha^{-1}) by rice at flowering stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	69.1	67.4	64.5	67.0	68.6	67.1	64.8	66.8	75.4	72.2	69.7	72.4
I ₁ = Rice + daincha (entirely for GM alone)	76.5	79.4	80.9	78.9	80.5	81.9	83.4	81.9	85.4	88.8	89.9	88.0
I ₂ = Rice + daincha (every 10 th daincha row for SP)	69.9	72.5	73.9	72.1	74.1	76.3	77.5	76.0	77.8	80.9	83.2	80.6
I ₃ = Rice + daincha (every 15 th daincha row for SP)	72.2	74.1	75.7	74.0	75.7	78.1	79.8	77.9	82.1	83.6	86.1	83.9
I ₄ = Rice + daincha (every 20 th daincha row for SP)	73.8	75.7	78.0	75.8	77.0	78.4	80.9	78.8	83.1	84.3	88.3	85.2
Mean	72.3	73.8	74.6	75.2	75.2	76.4	77.3	78.7	80.7	82.0	83.4	
N split dose (%) : N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	0.85	1.95	0.95	2.20	0.95	2.20	0.99	2.29	0.99	2.29	1.47	3.43
I at N	1.09	2.27	0.61	1.27	0.61	1.27	0.70	1.47	0.70	1.47	1.57	3.06
Nat I	1.76	3.85	1.71	3.73	1.71	3.73	1.57	3.43	1.57	3.43	1.47	3.06
	1.68	3.51	1.58	3.29	1.58	3.29	1.47	3.06	1.47	3.06		

Table 20. Influence of daincha intercropping/seed production and N split doses in on nitrogen uptake (kg ha^{-1}) by rice at maturity stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	104.4	100.1	95.0	99.8	96.9	92.6	90.4	93.3	108.7	103.7	98.1	103.5
I ₁ = Rice + daincha (entirely for GM alone)	110.3	113.1	100.7	108.0	107.8	109.8	102.4	106.7	113.7	115.8	107.6	112.3
I ₂ = Rice + daincha (every 10 th daincha row for SP)	103.9	105.5	94.1	101.2	99.1	101.9	94.8	98.6	105.4	108.3	101.5	105.1
I ₃ = Rice + daincha (every 15 th daincha row for SP)	105.6	107.0	96.4	103.0	102.7	104.3	98.7	101.9	108.3	111.3	105.0	108.2
I ₄ = Rice + daincha (every 20 th daincha row for SP)	107.9	109.4	101.6	106.3	105.5	107.5	100.5	104.5	110.8	114.2	106.7	110.6
Mean	106.4	107.0	97.6	102.4	103.2	97.4	109.4	110.7	103.8			
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	1.80	4.14	1.72	3.97	1.86	4.30	1.86	4.30	1.86	4.30	1.86	4.30
I at N	1.47	3.06	1.40	2.92	1.10	2.30	1.10	2.30	1.10	2.30	1.10	2.30
Nat I	2.84	6.21	2.54	5.56	2.75	6.02	2.75	6.02	2.75	6.02	2.75	6.02
	3.08	6.43	3.13	6.53	2.47	5.16	2.47	5.16	2.47	5.16	2.47	5.16

61.6 and 57.6 kg N ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively at active tillering stage.

Split applications of N did not influence N uptake significantly in both *kharif* season crops. Whereas during *rabi* season, 42 per cent N application at the time of daincha incorporation (N₃) recorded highest N uptake (57.9 kg N ha⁻¹) than other treatments.

As growth advanced, the amount of N uptake by rice also increased (Table 19 and 20). At flowering stage the daincha intercropping had a marked influence on N uptake in all the seasons. Among the different treatments, growing daincha in rice for green manuring (I₁) proved superior to other treatments (78.9 kg in *kharif* 1999, 81.9 kg in *rabi* 1999 and 88.0 kg ha⁻¹ in *kharif* 2000). Next best treatment was 20th daincha row for seed production and remaining rows for green manuring (I₄) and it was closely followed by 15th daincha row for seed production and remaining rows for green manuring (I₃) in both *kharif* season crops.

Nitrogen split applications had a significant influence on N uptake at flowering stage in all seasons. Both the split levels N₃ and N₂ (42 per cent and 33 per cent N at the time of daincha incorporation) registered higher N uptake. The lowest N uptake was registered with four equal split applications of N (N₁).

Interaction between intercropping and N splits was evident in all the seasons at flowering stage. Daincha intercrop grown entirely for green manuring along with 42 per cent N application at the time of daincha incorporation (I₁N₃) registered more N uptake of 80.9, 83.4 and 89.9 kg N ha⁻¹ over respective seasons, which was closely followed by the treatment I₁N₂. Lowest N uptake was seen in sole rice with 42 per cent N at the time of daincha incorporation (I₀N₃).

At maturity, daincha intercrop entirely grown for green manuring (I₁) recorded a N uptake of 108.0, 106.7 and 112.3 kg ha⁻¹ in respective seasons, which was on par with 20th daincha row for seed production and remaining rows for green manuring (I₄) in *rabi* 1999 and *kharif* 2000 seasons. Whereas in *kharif* 1999 season both I₄ and I₃ (20th and

15th daincha row for seed production and remaining rows for green manuring) were on par with the above treatment (I₁). Lowest N uptake of 99.8, 93.3 and 103.5 kg N ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively was seen in sole rice (I₀)

In nitrogen split applications, both N₂ and N₁ (33 per cent N application at the time of daincha incorporation and four equal splits) recorded higher N uptake. Least N uptake was noticed in treatment N₃ (42 per cent N application at daincha incorporation).

Combination of intercropping with N split applications had exhibited a substantial influence on N uptake in all the seasons at maturity. Daincha intercropping meant entirely for green manuring along with 33 per cent N application at the time of daincha incorporation (I₁N₂) had a superiority over (113.1, 109.8 and 115.8 kg N ha⁻¹ in respective seasons) other treatments, which was closely followed by I₁N₁ and I₄N₂. In intercropping treatments, nitrogen application both N₂ and N₁ had almost similar effect on nitrogen uptake .

4.2.2.2. Phosphorus uptake (Table 21 to 23)

During initial stage (at active tillering) there was little effect on P uptake by different intercropping treatments. In general intercropping of daincha failed to influence P uptake relative to sole rice (I₀). The treatment sole rice (I₀) was significantly superior to other treatments (10.0, 12.2 and 11.0 in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). The remaining treatments did not show significant influence on P uptake (I₁ to I₄) in any of the season.

P uptake did not vary due to split applications of N at active tillering stage.

Intercropping treatments had a substantial influence on P uptake at flowering and maturity stages . Daincha grown entirely for green manuring (I₁) exerted a greater influence on P uptake of 21.8, 23.7, 21.8 kg P ha⁻¹ at flowering and 24.7, 24.1 and 26.1 kg P ha⁻¹ at maturity stages during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. However, the P uptake was on par with 20th daincha row for seed production and remaining rows for green manuring (I₄) in all the seasons. The lowest uptake was noticed

Table 21. Influence of daincha intercropping/seed production and N split doses on phosphorus uptake (kg ha^{-1}) by rice at active tillering stage

Treatments	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping			
I ₀ = Sole rice	10.0	12.2	11.0
I ₁ = Rice + daincha (entirely for GM alone)	8.9	11.3	9.6
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	8.5	10.8	9.2
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	8.7	10.9	9.3
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	8.8	11.0	9.6
SEd	0.21	0.30	0.33
CD (P=0.05)	0.49	0.69	0.75
N split dose (%)			
N ₁ = 25:25:25:25	8.7	10.8	9.4
N ₂ = 25:33:21:21	9.0	11.2	9.8
N ₃ = 25:42:16.5:16.5	9.2	11.7	10.0
SEd	0.34	0.43	0.48
CD (P=0.05)	NS	NS	NS

GM: Green manure; SP: Seed production

Table 22. Influence of daincha intercropping/seed production and N split doses on phosphorus uptake (kg ha^{-1}) by rice at flowering stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	19.3	18.6	17.4	18.4	19.6	18.3	17.2	18.4	18.1	17.5	16.8	17.5
I ₁ = Rice + daincha (entirely for GM alone)	21.0	21.8	22.6	21.8	22.5	23.9	24.8	23.7	20.9	21.7	22.7	21.8
I ₂ = Rice + daincha (every 10 th daincha row for SP)	18.3	19.3	20.1	19.2	20.3	21.2	22.2	21.2	18.7	19.6	20.4	19.6
I ₃ = Rice + daincha (every 15 th daincha row for SP)	19.2	19.9	20.7	19.9	20.8	21.9	23.1	21.9	19.2	19.8	21.0	20.0
I ₄ = Rice + daincha (every 20 th daincha row for SP)	20.1	20.7	21.9	20.9	21.8	22.5	23.7	22.7	20.1	20.8	21.9	20.9
Mean	19.6	20.1	20.5	20.5	21.0	21.6	22.2	21.6	19.4	19.9	20.6	20.6

N split dose (%): N₁ = 25:25:25; N₂ = 25:33:21:21; N₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
I	0.62	1.42	0.58	1.34	0.52	1.21
N	0.36	0.83	0.54	1.13	0.51	1.07
I at N	0.78	1.70	0.74	1.61	0.78	1.70
Nat I	0.98	NS	1.19	NS	1.08	NS

Table 23. Influence of daincha intercropping/seed production and N split doses on phosphorus uptake (kg ha^{-1}) by rice at maturity stage.

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	22.5	21.0	19.8	21.1	21.4	20.7	19.3	20.5	24.2	23.0	21.1	22.8
I ₁ = Rice + daincha (entirely for GM alone)	25.2	25.6	23.4	24.7	24.4	24.9	23.1	24.1	26.2	27.1	25.1	26.1
I ₂ = Rice + daincha (every 10 th daincha row for SP)	22.9	23.3	20.8	22.3	22.5	23.1	21.7	22.4	23.9	24.7	23.2	23.9
I ₃ = Rice + daincha (every 15 th daincha row for SP)	24.7	25.0	22.7	24.1	23.3	23.7	22.0	23.0	25.1	25.7	24.0	24.9
I ₄ = Rice + daincha (every 20 th daincha row for SP)	24.9	25.0	23.1	24.3	24.9	24.4	23.1	24.1	25.6	26.0	24.2	25.3
Mean	24.0	24.0	22.0	23.3	23.3	23.4	21.8	24.1	25.0	25.3	23.5	24.5
N split dose (%) : N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	0.76	1.75	0.68	1.57	0.68	1.57	0.68	1.57	0.49	1.13	0.49	1.13
I at N	0.61	1.27	0.64	1.34	0.64	1.34	0.64	1.34	0.71	1.47	0.71	1.47
Nat I	0.96	2.10	0.93	2.04	0.93	2.04	0.93	2.04	0.72	1.58	0.72	1.58
	1.34	NS	1.56	NS	1.56	NS	1.56	NS	1.55	NS	1.55	NS

in the sole rice (I_0) with 21.1, 20.5 and 22.8 kg P ha⁻¹ at maturity stage in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Application of N in splits, had a greater influence on P uptake at flowering and maturity stages. Among split applications both N_3 and N_2 registered higher P uptake at flowering stage irrespective of the season. Whereas at maturity stage, 33 per cent N application at the time of daincha incorporation (N_2) proved significantly better (24.0, 23.3 and 25.3 kg P ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than 42 per cent N at the time of daincha incorporation (N_3) in all the seasons. This treatment (N_3) recorded lower P uptake of 22.0, 21.8 and 23.5 kg P ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively in all the three seasons at maturity stage.

With regard to interaction effect of the treatments, daincha intercrop entirely grown for green manuring with 42 per cent N application at the time of daincha incorporation (I_1N_3) performed superior, and it was closely followed by I_1N_2 at flowering stage in all seasons. Whereas at maturity stage, the split applied N had influenced the same treatment (I_1) in a different manner. This treatment (I_1) in combination with 33 per cent N application at the time of daincha incorporation (I_1N_2) proved superior with 25.6, 24.9 and 27.1 kg of P uptake ha⁻¹ in the seasons respectively to 42 per cent N application at the time of daincha incorporation (N_3) in all the seasons. This treatment combination (I_1N_2) was closely followed by I_1N_1 , I_4N_2 , I_4N_1 in all the seasons. Lowest P uptake was noticed in sole rice with 42 per cent N application at the time of daincha incorporation (I_0N_3) with 19.8, 19.3 and 21.1 kg P ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

In general, split applications of N at intercropping treatment combinations (N at I) did not exert any significant influence on P uptake both at flowering and maturity stages irrespective of season.

4.2.2.3. Potassium uptake (Table 24 to 26)

Potassium uptake was significantly higher in sole rice (I_0) than in intercropping treatments at active tillering stage in all the seasons. The remaining treatments behaved almost similar with one another in this stage irrespective of season.

Nitrogen application did not exhibit significant influence on K uptake at active tillering stage in all the three crops.

During flowering, intercropping daincha exclusively for green manuring (I_1) proved superior (78.9, 90.4 and 85.8 kg K ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) over other treatments, but the treatment 20th daincha row for seed production and remaining rows for green manuring (I_4) performed comparable with former treatment during *kharif* 1999 alone. Lowest K uptake was discernible in sole rice (I_0). Statistically it differed from the remaining intercropping treatments at flowering and maturity stages irrespective of the season.

Split application of N resulted a change in K uptake over the seasons. Application of 42 per cent N application at the time of daincha incorporation (N_3) registered higher K uptake in all the seasons (75.2, 85.5 and 81.5 kg K ha⁻¹ with respective seasons) but, it was equally effective with the treatment 33 per cent N application at daincha incorporation (N_2). However, this had been remarkably changed at maturity stage. Both the treatments N_2 and N_1 registered higher K uptake. At maturity stage lowest uptake was recorded under 42 per cent N application at daincha incorporation (N_3).

Interaction was evident between intercropping and N split applications. The combined influence of daincha raised entirely for green manuring along with 33 per cent N applied at the time of daincha incorporation (I_1N_2) had the highest K uptake of 142.8, 158.4 and 155.4 kg K ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively compared to remaining treatments and it was closely followed by I_1N_1 in both *kharif* seasons. Lowest uptake was seen in sole rice irrespective of the N splits at maturity stage in all the three seasons.

Table 24. Influence of daincha intercropping/seed production and N split doses on potassium uptake (kg ha^{-1}) by rice at active tillering stage

Treatments	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping			
I ₀ = Sole rice	21.3	26.3	23.7
I ₁ = Rice + daincha (entirely for GM alone)	19.5	25.2	22.3
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	19.0	24.1	21.3
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	19.1	24.4	21.3
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	19.3	24.8	22.0
SEd	0.35	0.48	0.45
CD (P=0.05)	0.81	1.11	1.03
N split dose (%)			
N ₁ = 25:25:25:25	19.3	24.5	21.8
N ₂ = 25:33:21:21	19.7	25.0	22.1
N ₃ = 25:42:16.5:16.5	20.0	25.4	22.5
SEd	0.35	0.69	0.81
CD (P=0.05)	NS	NS	NS

GM: Green manure; SP: Seed production

Table 25. Influence of daincha intercropping/seed production and N split doses on K uptake (kg ha^{-1}) by rice at flowering stage.

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	70.3	68.6	66.5	68.5	78.5	76.6	74.7	76.6	75.6	73.2	71.3	73.4
I ₁ = Rice + daincha (entirely for GM alone)	76.6	78.9	81.2	78.9	88.6	90.8	91.9	90.4	83.8	86.2	87.4	85.8
I ₂ = Rice + daincha (every 10 th daincha row for SP)	69.7	71.9	74.0	71.9	82.2	84.1	85.5	83.9	75.4	77.8	80.1	77.8
I ₃ = Rice + daincha (every 15 th daincha row for SP)	72.0	73.6	76.3	74.0	84.1	86.0	87.3	85.8	78.6	80.5	82.9	80.7
I ₄ = Rice + daincha (every 20 th daincha row for SP)	73.8	75.1	78.2	75.7	85.6	87.2	88.3	87.0	80.5	81.8	85.8	82.7
Mean	72.5	73.6	75.2		83.8	84.9	85.5		78.8	79.9	81.5	
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	0.98	2.25	0.84	1.94	0.93	2.14	0.91	1.90	0.93	2.14	0.91	1.90
I at N	0.88	1.83	0.82	1.71	0.91	1.90	1.23	2.68	1.23	2.68	1.23	2.68
Nat I	1.29	2.81	1.11	2.43	1.23	2.68	2.19	4.56	2.19	4.56	2.19	4.56
	2.21	NS	1.97	NS	2.19	4.56						

Table 26. Influence of daincha intercropping/seed production and N split doses on K uptake (kg ha^{-1}) by rice at maturity stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	128.7	123.1	117.9	123.2	134.7	130.1	126.8	130.5	137.6	130.8	124.9	131.1
I ₁ = Rice + daincha (entirely for GM alone)	140.4	142.8	133.0	138.7	155.3	158.4	149.2	154.3	150.3	155.4	143.7	149.8
I ₂ = Rice + daincha (every 10 th daincha row for SP)	131.7	134.0	123.4	129.7	141.9	146.2	137.4	141.8	138.7	142.8	135.0	138.8
I ₃ = Rice + daincha (every 15 th daincha row for SP)	133.9	135.8	123.2	131.0	147.4	150.0	143.3	146.9	142.8	146.9	138.1	142.6
I ₄ = Rice + daincha (every 20 th daincha row for SP)	137.0	137.1	130.4	134.8	151.8	154.8	146.2	151.0	146.4	151.0	142.1	146.5
Mean	134.4	134.6	125.6		146.2	147.9	140.6		143.2	145.4	136.8	
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	1.70	3.93	1.49	3.43	1.63	3.75	1.01	2.10	2.15	4.69	2.22	4.62
I at N	2.08	4.34	1.21	2.52	1.01	2.10	2.15	4.69	2.22	4.62	2.22	4.62
N at I	2.52	5.50	2.20	4.80	2.15	4.69	2.22	4.62	2.22	4.62	2.22	4.62
N at I	2.91	6.07	2.70	5.64	2.70	5.64	2.70	5.64	2.70	5.64	2.70	5.64

In general, interaction between split applications of N and intercropping (N at I) was non-significant during flowering stage during *kharif* 1999 and *rabi* 1999.

4.2.3. Yield components

4.2.3.1. Panicles m^{-2} (Table 27)

Intercropping treatments greatly influenced the number of ear bearing tillers (panicles) in all the seasons. Daincha intercrop entirely grown for green manuring (I_1) was significantly superior over sole rice in terms of panicles production (442, 432 and 461 m^{-2}) in pertinent seasons. Treatment, I_1 was on par with I_4 and I_3 (every 20th and 15th daincha row for seed production and remaining rows for green manuring) in all the seasons. Less number of panicles was produced in sole rice (I_0), with the tune of 402, 389 and 420 m^{-2} in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Application of N in splits, greatly influenced the panicles production. Application of 33 per cent N at the time of daincha incorporation (N_2) significantly outyielded (433, 417 and 449 m^{-2} in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) 42 per cent N application at the time of daincha incorporation (N_3) in terms of number of panicles and it was on par with the treatment comprising four equal splits (N_1) in all the seasons.

Conjoint influence of daincha intercropping with N splits showed a marked effect on panicle numbers in all the seasons. Daincha intercrop entirely meant for green manuring along with 33 per cent N application at the time of daincha incorporation (I_1N_2) favoured more number of panicles m^{-2} in the order of 453, 441 and 472 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. It was closely followed by daincha intercropping purely for green manuring with four equal splits (I_1N_1) and 20th daincha row for seed production and remaining rows for green manuring along with 33 per cent N application at the time of daincha incorporation (I_4N_2) in all the seasons. Lowest number of panicles m^{-2} was noticed in sole rice along with 42 per cent N application at daincha incorporation (I_0N_3) (392, 380 and 406 m^{-2} in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

Table 27. Influence of daincha intercropping/seed production and N split doses on number of panicles m⁻² of rice

Treatments	Kharif 1999						Rabi 1999						Kharif 2000					
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean		
I ₀ = Sole rice	413	400	392	402	399	387	380	389	435	418	406	420	435	418	406	420		
I ₁ = Rice + daincha (entirely for GM alone)	441	453	431	442	435	441	421	432	462	472	450	461	462	472	450	461		
I ₂ = Rice + daincha (every 10 th daincha row for SP)	421	428	413	421	408	413	392	404	436	444	420	433	436	444	420	433		
I ₃ = Rice + daincha (every 15 th daincha row for SP)	428	436	419	428	412	416	400	409	447	452	429	443	447	452	429	443		
I ₄ = Rice + daincha (every 20 th daincha row for SP)	432	447	424	434	420	426	408	418	454	461	442	452	454	461	442	452		
Mean	427	433	416	416	415	417	400	418	447	449	429	442	447	449	429	442		

N split dose (%): N₁ = 25:25:25:25; N₂ = 25:33:21:21; N₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
I	4.6	10.7	6.0	13.8	5.6	12.8
N	3.5	7.4	5.4	11.3	7.8	16.3
I at N	5.9	12.8	7.9	17.2	8.3	18.2
N at I	7.8	16.2	8.9	18.6	9.7	20.2

4.2.3.2. Filled grains per panicle (Table 28)

Filled grains per panicle was substantially influenced by intercropping treatments as well as N splits irrespective of the season. Daincha intercrop grown exclusively for green manuring (I_1) had significant effect on number of filled grains per panicle (120, 105 and 112 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than other treatments. Least number of filled grains of 90, 81 and 84 panicle⁻¹ was noticed in sole rice (I_0) during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Among the N splits, application of 33 per cent N at the time of daincha incorporation (N_2) and four equal splits of N (N_1) had recorded more number of filled grains compared to 42 per cent N application at the time of daincha incorporation (N_3) irrespective of season.

Interaction effect was found to be greater in all the seasons. Maximum number of filled grains per panicle was due to interaction effect of the daincha intercrop exclusively grown for green manuring along with 33 per cent N application at the time of daincha incorporation (I_1N_2) to the tune of 129, 111 and 119 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. Similar effect was also seen in I_1N_1 (daincha grown entirely for green manuring along with four equal split application of N).

In general, I_1 favourably influenced filled grains per panicle under both split levels of 33 per cent N application at the time of daincha incorporation (N_2) and four equal N split applications (N_1) treatments. Lowest mean filled grains per panicle (79 numbers) over three seasons was evident in sole rice with 42 per cent N application at daincha incorporation (I_0N_3).

4.2.3.3. Percentage of illfilled grains (Table 29)

Percentage of illfilled grains per panicle varied significantly with intercropping treatments. Higher values of 14.22, 14.82 in *kharif* 1999 and *rabi* 1999 were recorded in the treatment 10th daincha row for seed production and remaining rows for green manuring (I_2) but in *kharif* 2000 sole rice (I_0) and I_2 registered more number of illfilled grains per panicle. Lower percentage of illfilled grains was noticed in the daincha

Table 28. Influence of daincha intercropping/seed production and N split doses on number of filled grains panicle⁻¹ of rice

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	96	91	84	90	87	81	75	81	89	85	79	84
I ₁ = Rice + daincha (entirely for GM alone)	121	129	111	120	106	111	98	105	113	119	104	112
I ₂ = Rice + daincha (every 10 th daincha row for SP)	106	111	95	104	91	94	84	90	97	101	88	95
I ₃ = Rice + daincha (every 15 th daincha row for SP)	112	116	103	110	95	99	88	94	102	106	94	101
I ₄ = Rice + daincha (every 20 th daincha row for SP)	116	122	107	115	101	104	95	100	108	113	99	107
Mean	110	114	100		96	98	88		102	105	93	
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	2.0	4.6	1.5	3.4	1.5	3.4	2.1	4.9	2.1	4.9	2.1	4.9
I at N	2.4	5.1	1.4	3.0	1.4	3.0	2.0	4.1	2.0	4.1	2.0	4.1
Nat I	3.0	6.6	2.0	4.3	2.0	4.3	2.8	6.2	2.8	6.2	2.8	6.2
	3.9	8.1	2.3	4.9	2.3	4.9	3.5	7.4	3.5	7.4	3.5	7.4

Table 29. Influence of daincha intercropping/seed production and N split doses on percentage of illfilled grains of rice

Treatments	Kharif 1999			Rabi 1999			Kharif 2000					
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	11.30	13.67	15.33	13.44	12.67	13.50	14.67	13.61	12.40	14.66	16.33	14.33
I ₁ = Rice + daincha (entirely for GM alone)	9.49	8.67	10.33	9.50	10.33	10.00	11.66	10.64	10.67	10.33	11.66	10.87
I ₂ = Rice + daincha (every 10 th daincha row for SP)	13.67	13.30	15.67	14.22	14.00	14.67	15.80	14.82	13.67	13.66	15.10	14.14
I ₃ = Rice + daincha (every 15 th daincha row for SP)	12.50	12.30	14.30	13.05	12.33	12.50	14.66	13.16	12.60	12.70	14.30	13.20
I ₄ = Rice + daincha (every 20 th daincha row for SP)	11.01	10.67	12.67	11.45	11.66	10.90	12.50	11.87	11.33	11.40	12.40	11.71
Mean	11.60	11.73	13.67		12.20	12.31	13.86		12.13	12.55	13.95	
N split dose (%) : N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	0.18	0.41	0.29	0.67	0.23	0.54	0.29	0.61	0.29	0.61	0.29	0.61
I at N	0.22	0.46	0.39	0.82	0.32	0.69	0.39	0.86	0.32	0.69	0.39	0.86
Nat I	0.44	0.93	0.39	0.86	0.32	0.69	0.39	0.86	0.32	0.69	0.39	0.86
	0.49	1.02	0.82	1.72	0.63	1.32	0.82	1.72	0.63	1.32	0.82	1.72

intercrop purely allotted for green manuring alone (I_1) (9.50 in *kharif* 1999, 10.64 in *rabi* 1999 and 10.87 in *kharif* 2000).

Regarding split applications of N, 42 per cent N application at the time of daincha incorporation (N_3) recorded substantially higher percentage of illfilled grains of 13.67, 13.86 and 13.95 in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively than other treatments (N_2 and N_1). Treatments N_1 (four equal splits) and 33 per cent N application at the time of daincha incorporation (N_2) registered lowest percentage of illfilled grains .

Treatment combinations displayed a significant interaction effect on percentage of illfilled grains per panicle in all the seasons. Lowest number of illfilled grain was recorded in daincha grown entirely for green manuring with four equal splits of N (I_1N_1). Higher percentage of illfilled grains was observed in the treatment 10th daincha row for seed production along with 42 per cent N application at the time of daincha incorporation (I_2N_3) in *kharif* 1999 and *rabi* 1999 seasons; in *kharif* 2000 sole rice with 42 per cent N at the time of daincha incorporation resulted in higher percentage of illfilled grains (I_0N_3).

4.2.3.4. Panicle length (Table 30)

Panicle length was substantially influenced by intercropping treatments. Growing daincha entirely for green manuring (I_1) registered lengthier panicles of 22.9, 21.1 and 21.4 cm in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively and at the same time, it was comparable with I_4 (every 20th daincha row for seed production and remaining rows for green manuring) in all the seasons. In sole rice, shorter panicles were noticed with a length of 20.5, 18.6 and 19.7 cm in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively, but it was on par with every 10th daincha row for seed production and remaining rows for green manuring (I_2) during both the *kharif* season crops.

Application of N in splits did not have a significant influence on panicle length irrespective of season.

4.2.3.5. Test weight (Table 31)

Thousand grain weight did not differ significantly due to different intercropping as well as N split applications in any of the season.

Table 30. Influence of daincha intercropping/seed production and N split doses on panicle length (cm) of rice

Treatments		<i>Kharif 1999</i>	<i>Rabi 1999</i>	<i>Kharif 2000</i>
GM Intercropping				
I ₀	= Sole rice	20.5	18.6	19.7
I ₁	= Rice + daincha (entirely for GM alone)	22.9	21.1	21.4
I ₂	= Rice + daincha (every 10 th daincha row for SP and other rows for GM)	22.0	19.8	20.3
I ₃	= Rice + daincha (every 15 th daincha row for SP and other rows for GM)	22.4	20.2	20.8
I ₄	= Rice + daincha (every 20 th daincha row for SP and other rows for GM)	22.7	20.5	21.1
SEd		0.26	0.34	0.29
CD (P=0.05)		0.60	0.79	0.68
N split dose (%)				
N ₁	= 25:25:25:25	22.2	20.6	21.1
N ₂	= 25:33:21:21	23.0	20.8	21.5
N ₃	= 25:42:16.5:16.5	21.2	18.7	19.3
SEd		0.83	1.21	0.98
CD (P=0.05)		NS	NS	NS

GM: Green manure; SP: Seed production

Table 31. Influence of daincha intercropping/seed production and N split doses on test weight (g) of rice

Treatments		<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping				
I ₀	= Sole rice	16.13	20.3	16.47
I ₁	= Rice + daincha (entirely for GM alone)	17.31	21.6	17.21
I ₂	= Rice + daincha (every 10 th daincha row for SP and other rows for GM)	16.37	20.5	16.80
I ₃	= Rice + daincha (every 15 th daincha row for SP and other rows for GM)	16.85	20.7	16.95
I ₄	= Rice + daincha (every 20 th daincha row for SP and other rows for GM)	17.20	21.0	17.15
SEd		0.54	0.61	0.38
CD (P=0.05)		NS	NS	NS
N split dose (%)				
N ₁	= 25:25:25:25	17.14	21.48	17.48
N ₂	= 25:33:21:21	16.75	20.87	16.88
N ₃	= 25:42:16.5:16.5	16.43	20.11	16.39
SEd		0.41	0.63	0.49
CD (P=0.05)		NS	NS	NS

GM: Green manure; SP: Seed production

4.2.3.6. Grain yield (Table 32)

There was appreciable differences in rice grain yield due to the intercropping treatments in all the seasons. Growing daincha entirely for green manuring (I_1) outyielded other treatments in terms of grain yield (6295, 5387 and 6467 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). Next best treatment was allowing every 20th daincha row for seed production and remaining rows for green manuring (I_4). Lowest grain yield was recorded in sole rice (I_0) compared to intercropping treatments in all seasons (5030, 4303 and 5349 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). In *rabi* season, daincha grown for seed production at every 20th (I_4) and 15th (I_3) row after incorporation of other daincha rows for green manuring produced similar grain yield.

Split applications of N had an augmentative effect on grain yield irrespective of season. Application of 33 per cent N at the time of daincha incorporation (N_2) recorded significantly higher grain yield of 6021 kg ha⁻¹ in *kharif* 1999. During *rabi* 1999 and *kharif* 2000, split application of 33 per cent N during daincha incorporation (N_2) and four equal N splits (N_1) recorded higher grain yield. Treatment with 42 per cent N application had least influence on grain yield (5237, 4494 and 5441 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 seasons respectively).

Interaction effect was significant between daincha intercropping and N split applications in all seasons. The best treatment combination in terms of maximum grain yield was growing daincha entirely for green manuring along with 33 per cent N application during daincha incorporation (I_1N_2) (6761, 5718 and 6810 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 seasons respectively). Next best treatment combination was retaining every 20th row of daincha for seed production along with 33 per cent N application at the time of daincha incorporation (I_4N_2). Significantly least effect was evident in I_0 with 42 per cent N at the time of daincha incorporation (I_0N_3) with grain yields of 4616, 3949 and 4986 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Table 32. Influence of daincha intercropping/seed production and N split doses on grain yield of rice

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	5438	5036	4616	5030	4647	4312	3949	4303	5713	5348	4986	5349
I ₁ = Rice + daincha (entirely for GM alone)	6306	6761	5817	6295	5438	5718	5006	5387	6583	6810	6007	6467
I ₂ = Rice + daincha (every 10 th daincha row for SP)	5373	5760	4956	5363	4606	4843	4240	4563	5523	5714	5040	5426
I ₃ = Rice + daincha (every 15 th daincha row for SP)	5713	6125	5270	5703	4883	5135	4495	4838	5885	6088	5370	5781
I ₄ = Rice + daincha (every 20 th daincha row for SP)	5992	6423	5526	5980	5193	5461	4781	5145	6359	6578	5803	6247
Mean	5764	6021	5237		4953	5094	4494		6013	6108	5441	
N split dose (%) : N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	57	132	71	163	69	159	69	159	69	159	69	159
I at N	78	163	68	143	85	176	85	176	85	176	85	176
Nat I	114	250	141	308	138	301	138	301	138	301	138	301
	172	360	150	312	186	387	186	387	186	387	186	387

Table 32a. Influence of daincha intercropping/seed production and N split doses on grain yield (kg ha^{-1}) of rice (pooled mean yield).

Treatments	Kharif 1999	Rabi 1999	Kharif 2000	Pooled mean*
GM Intercropping				
I ₀ = Sole rice	5030	4303	5349	4894
I ₁ = Rice + daincha (entirely for GM alone)	6295	5387	6467	6050
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	5363	4563	5426	5117
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	5703	4838	5781	5441
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	5980	5145	6247	5791
SEd	57	71	69	-
CD (P=0.05)	132	163	159	-
N split dose (%)				
N ₁ = 25:25:25:25	5764	4953	6013	5577
N ₂ = 25:33:21:21	6021	5094	6108	5741
N ₃ = 25:42:16.5:16.5	5237	4494	5441	5057
SEd	78	68	85	-
CD (P=0.05)	163	143	176	-

GM: Green manure; SP: Seed production

*Data statistically not analysed.

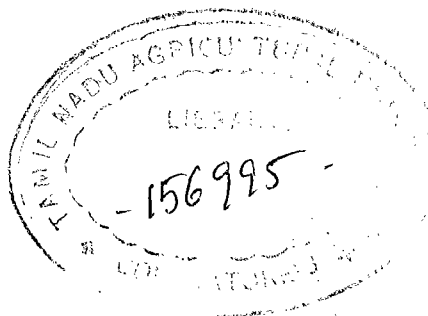


Table 32. Influence of daincha intercropping/seed production and N split doses on grain yield of rice (kg ha⁻¹)

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	5438	5036	4616	5030	4647	4312	3949	4303	5713	5348	4986	5349
I ₁ = Rice + daincha (entirely for GM alone)	6306	6761	5817	6295	5438	5718	5006	5387	6583	6810	6007	6467
I ₂ = Rice + daincha (every 10 th daincha row for SP)	5373	5760	4956	5363	4606	4843	4240	4563	5523	5714	5040	5426
I ₃ = Rice + daincha (every 15 th daincha row for SP)	5713	6125	5270	5703	4883	5135	4495	4838	5885	6088	5370	5781
I ₄ = Rice + daincha (every 20 th daincha row for SP)	5992	6423	5526	5980	5193	5461	4781	5145	6359	6578	5803	6247
Mean	5764	6021	5237	5764	4953	5094	4494	5145	6013	6108	5441	5764
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	57	132	71	163	69	159	69	159	69	159	69	159
I at N	78	163	68	143	85	176	85	176	85	176	85	176
Nat I	114	250	141	308	138	301	138	301	138	301	138	301
	172	360	150	312	186	387	186	387	186	387	186	387

4.2.3.7. Straw yield (Table 33)

Growing daincha as intercrop in rice entirely for green manuring (I_1) excelled other treatments in terms of straw yield (7622, 7908 and 7969 kg in the three seasons in that order). Lowest straw yield was recorded in sole rice (I_0) (6631, 6881 and 7034 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 season respectively).

Greater straw yield was recorded in 33 per cent N application at the time of daincha incorporation (N_2) (7381, 7541 and 7683 kg ha⁻¹ in three seasons). Lowest straw yield was observed in 42 per cent N application at the time of daincha incorporation (N_3).

Interaction effect of intercropping and N split applications had a remarkable influence on straw yield. Combined effect of daincha intercrop grown for green manuring with 33 per cent N application at the time of daincha incorporation (I_1N_2) had maximum straw yield of 7881, 8104 and 8264 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. The treatment entirely meant for green manuring along with four equal N splits (I_1N_1) also resulted in comparably similar straw yield with the former treatment. Interaction effect was least in sole rice with 42 per cent N at the time of daincha incorporation (I_0N_3) (6088, 6487 and 6543 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

4.2.3.8. Harvest index (Table 34)

Intercropping of daincha as well as different N splits did not influence the harvest index in any of the season.

4.2.3.9. Rice grain yield equivalent (Table 35 and 36)

The various intercropping treatments with N split levels had a greater influence on rice yield equivalent in all the seasons.

Among the intercropping systems, rice + daincha for green manuring cum seed production (every 20th row for seed production) (I_4) gave higher rice yield equivalent of 6454, 5467 and 6756 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively than other treatments and this was closely followed by rice + daincha entirely grown for

Table 33. Influence of daincha intercropping/seed production and N split doses on straw yield of rice (kg ha⁻¹)

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	7086	6719	6088	6631	7238	6919	6487	6881	7439	7120	6543	7034
I ₁ = Rice + daincha (entirely for GM alone)	7634	7881	7352	7622	7942	8104	7678	7908	7986	8264	7658	7969
I ₂ = Rice + daincha (every 10 th daincha row for SP)	6704	7068	6456	6743	6926	7164	6603	6898	7108	7341	6732	7060
I ₃ = Rice + daincha (every 15 th daincha row for SP)	7116	7448	6869	7144	7313	7577	6994	7295	7487	7713	7092	7431
I ₄ = Rice + daincha (every 20 th daincha row for SP)	7452	7789	7198	7480	7487	7939	7332	7586	7697	7975	7458	7710
Mean	7198	7381	6793		7381	7541	7019		7543	7683	7097	
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	69	158	80	184	85	196						
I at N	69	143	60	126	63	131						
Nat I	131	287	152	333	162	355						
	154	321	133	278	138	288						

Table 34. Influence of daincha intercropping/seed production and N split doses on harvest index of rice

Treatments	<i>Kharif 1999</i>	<i>Rabi 1999</i>	<i>Kharif 2000</i>
GM Intercropping			
I ₀ = Sole rice	0.43	0.38	0.43
I ₁ = Rice + daincha (entirely for GM alone)	0.45	0.41	0.45
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	0.44	0.40	0.43
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	0.44	0.40	0.44
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	0.44	0.41	0.45
SEd	0.013	0.017	0.015
CD (P=0.05)	NS	NS	NS
N split dose (%)			
N ₁ = 25:25:25:25	0.44	0.40	0.43
N ₂ = 25:33:21:21	0.45	0.40	0.44
N ₃ = 25:42:16.5:16.5	0.43	0.39	0.43
SEd	0.012	0.014	0.011
CD (P=0.05)	NS	NS	NS

GM: Green manure; SP: Seed production

Table 35. Influence of daincha intercropping/seed production and N split doses on rice grain yield, daincha seed yield and rice yield equivalent

Treatments	Rice grain yield (kg ha ⁻¹)		Daincha seed yield (kg ha ⁻¹)		Rice equivalent yield (kg ha ⁻¹)		
	<i>Kharif</i> 99	<i>Rabi</i> 99	<i>Kharif</i> 00	<i>Rabi</i> 99	<i>Kharif</i> 00	<i>Rabi</i> 99	<i>Kharif</i> 00
GM intercropping							
I ₀ = Sole rice	5030	4303	5349	-	-	4303	5349
I ₁ = Rice + daincha (entirely for GM alone)	6295	5387	6467	-	-	5387	6467
I ₂ = Rice + daincha (every 10 th daincha row for SP)	5363	4563	5426	170	132	5137	6222
I ₃ = Rice + daincha (every 15 th daincha row for SP)	5703	4838	5781	137	97	5260	6412
I ₄ = Rice + daincha (every 20 th daincha row for SP)	5980	5145	6247	109	74	5467	6756
N splits (%)							
N ₁ = 25:25:25:25	5764	4953	6013	136	98	5379	6648
N ₂ = 25:33:21:21	6021	5094	6108	139	101	5533	6752
N ₃ = 25:42:16.5:16.5	5237	4494	5441	141	104	4946	6098

GM: Green manure; SP: Seed production; 1 kg daincha seed = 4.35 kg paddy grain; Data statistically not analysed.

Table 36. Combined influence of daincha intercropping with N split doses on rice grain yield, daincha seed yield and rice yield equivalent (kg ha⁻¹)

Treatments	Rice grain yield (kg ha ⁻¹)			Daincha seed yield (kg ha ⁻¹)			Rice grain equivalent yield (kg ha ⁻¹)		
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
I ₀ N ₁	5438	4647	5713	-	-	-	5438	4647	5713
I ₀ N ₂	5036	4312	5348	-	-	-	5036	4312	5348
I ₀ N ₃	4616	3949	4986	-	-	-	4616	3949	4986
I ₁ N ₁	6306	5438	6583	-	-	-	6306	5438	6583
I ₁ N ₂	6761	5718	6810	-	-	-	6761	5718	6810
I ₁ N ₃	5817	5006	6007	-	-	-	5817	5006	6007
I ₂ N ₁	5373	4606	5523	173	127	179	6126	5158	6302
I ₂ N ₂	5760	4843	5714	171	132	184	6504	5417	6514
I ₂ N ₃	4956	4240	5040	166	137	186	5678	4836	5849
I ₃ N ₁	5713	4883	5885	134	94	143	6296	5292	6507
I ₃ N ₂	6125	5135	6088	138	96	144	6725	5553	6714
I ₃ N ₃	5270	4495	5370	139	101	148	5875	4934	6014
I ₄ N ₁	5992	5193	6359	105	73	116	6449	5511	6864
I ₄ N ₂	6423	5461	6578	110	75	116	6901	5787	7083
I ₄ N ₃	5526	4781	5803	112	74	119	6013	5103	6321

1 kg rice grain = Rs.5.75

1 kg daincha seed = Rs.25.00

1 kg of daincha seed = 4.35 kg of rice grain

green manuring (I_1) in all the seasons. Lowest rice yield equivalent was recorded in sole rice (I_0) with 5030, 4303 and 5349 kg ha⁻¹ in respective seasons.

Split applications of N resulted in greater influence on rice yield equivalent irrespective of season. Application of 33 per cent N at the time of daincha incorporation gave higher rice yield equivalent of 6626, 5533 and 6752 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively than N_3 and N_1 . Lowest rice yield equivalent was recorded in 42 per cent N application during daincha incorporation (N_3) (5850, 4946 and 6098 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

Combined effect of rice + daincha for green manuring cum seed production (every 20th daincha row for seed production along with 33 per cent N application at the time of daincha incorporation) (I_4N_2) registered higher rice yield equivalent of 6901, 5787 and 7083 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively and it was followed by I_1N_2 during *kharif* 1999, *rabi* 1999 whereas in *kharif* 2000, it was closely followed by I_4N_1 . Lowest rice yield equivalent was registered in sole rice with 42 per cent N application at the time of daincha incorporation (I_0N_3) in all seasons. Application of 42 per cent N at daincha incorporation (N_3) with intercropping treatments registered least rice yield equivalent.

4.2.4. Nitrogen use efficiency

4.2.4.1. Agronomic efficiency (Table 37)

Agronomic efficiency, was highest in sole rice (I_0) (16.6 and 16.8 kg grain kg⁻¹ N added) compared to daincha intercropping treatments during *kharif* 1999 and *kharif* 2000 respectively. In *rabi* 1999 daincha intercropping exclusively grown for green manuring (I_1) recorded higher production efficiency of N (12.4 kg grain kg⁻¹ N added), which was closely followed by sole rice (I_0) (10.7). The lowest agronomic efficiency was noticed in the treatment meant for seed production at every 10th daincha row (I_2) in all seasons.

Among N split doses, application of 33 per cent N at the time of daincha incorporation (N_2) gave higher production efficiency of N (16.8, 11.9 and

Table 37. Influence of daincha intercropping/seed production and N split doses on agronomic efficiency (kg grain/kg N)

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	20.0	16.6	13.1	16.6	12.8	10.6	8.8	10.7	19.9	16.8	13.8	16.8
I ₁ = Rice + daincha (entirely for GM alone)	16.5	18.8	14.1	16.5	12.6	13.9	10.6	12.4	16.2	17.3	13.3	15.6
I ₂ = Rice + daincha (every 10 th daincha row for SP)	12.6	14.7	10.3	12.5	9.2	10.4	7.5	9.0	11.7	12.7	9.1	11.2
I ₃ = Rice + daincha (every 15 th daincha row for SP)	14.1	16.3	11.7	14.0	10.4	11.6	8.5	10.2	13.3	14.3	10.6	12.7
I ₄ = Rice + daincha (every 20 th daincha row for SP)	15.3	17.6	12.9	15.3	11.6	12.8	9.7	11.3	15.5	16.6	12.6	14.9
Mean	15.7	16.8	12.4	15.3	11.3	11.9	9.0	11.3	15.3	15.5	11.9	11.9

Grain yield of absolute control (No N): 3039, 2723 and 3328 kg ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

N split dose (%): N₁ = 25:25:25:25; N₂ = 25:33:21:21; N₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production

Data statistically not analysed.

15.5 kg grain kg^{-1} N added during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) which was closely followed by four equal splits of N (N_1). With increase in N application at the time of daincha to 42 per cent (N_3) lowest agronomic efficiency was recorded.

4.2.4.2. Apparent recovery (Table 38)

Sole rice (I_0) recorded highest apparent recovery of 41.7, 32.0 and 42.4 per cent in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively, whereas lowest apparent recovery was with all the daincha intercropping treatments. The greater reduction in apparent recovery was noticed in the treatment of allowing every 10th row for daincha seed production in rice (I_2).

N split application had a remarkable influence on apparent recovery of applied N. Application of 33 per cent during daincha incorporation resulted in greater influence on apparent recovery of 33.0, 29.3 and 33.1 per cent over respective seasons. This treatment was closely followed by four equal splits of N (N_1). Least apparent recovery of 27.7, 26.5 and 29.2 per cent respectively for the seasons was observed in 42 per cent N application at the time of daincha incorporation (N_3).

4.2.4.3. Partial factor productivity (Table 39)

Daincha intercropping failed to increase grain yield per unit of total N applied compared to sole rice (I_0) (41.9, 28.7 and 44.6 kg grain kg^{-1} N applied over *kharif* 1999, *rabi* 2000 and *kharif* 2001 respectively). Among the different intercropping treatments, daincha grown for both *in situ* green manuring and retaining every 10th row for seed production (I_2) recorded lesser productivity per unit of N application (28.9, 22.4 and 28.9 kg grain kg^{-1} N applied respectively for the seasons).

Among the various N split doses, 33 per cent N application at the time of daincha incorporation (N_2) proved superior (34.6, 25.8 and 34.8 kg grain kg^{-1} N applied in respective seasons) over 42 per cent N application at the time of daincha incorporation (N_3) of 30.2, 22.8 and 31.2 kg grain kg^{-1} N applied during *kharif* 1999, *rabi* 2000 and

Table 38. Influence of daincha intercropping/seed production and N split doses on apparent recovery (%)

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	45.5	41.9	37.7	41.7	34.4	31.5	30.1	32.0	46.8	42.6	37.9	42.4
I ₁ = Rice + daincha (entirely for GM alone)	30.6	32.1	25.8	29.5	29.0	29.9	26.5	28.5	30.4	31.4	27.3	29.7
I ₂ = Rice + daincha (every 10 th daincha row for SP)	29.1	30.0	23.8	27.6	26.4	27.8	24.3	26.2	28.1	29.6	26.0	27.9
I ₃ = Rice + daincha (every 15 th daincha row for SP)	29.4	30.1	24.5	28.0	27.5	28.3	25.6	27.1	28.9	30.5	27.2	28.9
I ₄ = Rice + daincha (every 20 th daincha row for SP)	30.2	30.9	26.9	29.3	28.2	29.2	25.9	27.8	29.7	31.5	27.6	29.6
Mean	33.0	33.0	27.7	29.1	29.3	26.5	26.5	32.8	33.1	29.2		

N uptake from absolute control (No N): 49.8, 45.3 and 53.6 kg N ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

N split dose (%): N₁ = 25:25:25:25; N₂ = 25:33:21:21; N₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production

Data statistically not analysed.

Table 39. Influence of daincha intercropping/seed production and N split doses on partial factor productivity (kg grain/kg N)

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	45.3	42.0	38.5	41.9	31.0	28.7	26.3	28.7	47.6	44.6	41.6	44.6
I ₁ = Rice + daincha (entirely for GM alone)	31.9	34.2	29.5	31.9	25.2	26.5	23.2	25.0	32.7	33.8	29.9	32.1
I ₂ = Rice + daincha (every 10 th daincha row for SP)	28.9	31.0	26.7	28.9	22.6	23.8	20.8	22.4	29.4	30.4	26.8	28.9
I ₃ = Rice + daincha (every 15 th daincha row for SP)	30.1	32.3	27.8	30.1	23.4	24.6	21.5	23.2	30.5	31.6	27.9	30.0
I ₄ = Rice + daincha (every 20 th daincha row for SP)	31.1	33.3	28.7	31.0	24.4	25.6	22.4	24.1	32.5	33.6	29.6	31.9
Mean	33.5	34.6	30.2	31.0	25.3	25.8	22.8	24.8	34.5	34.8	31.2	31.2

N split dose (%) : N₁ = 25:25:25:25; N₂ = 25:33:21:21; N₃ = 25:42:16.5:16.5; GM: Green manure, SP: Seed production
Data statistically not analysed.

kharif 2000 respectively. In general, both N_2 and N_1 (four equal split) performed equally well in all the seasons.

4.2.5. Soil fertility

4.2.5.1. Organic Carbon (Table 40 and 41)

The various intercropping treatments failed to improve organic carbon status of soil at active tillering stage during both *kharif* seasons. In *rabi* 2000 season, intercropping daincha (I_1 to I_4) recorded a slight improvement in organic carbon status relative to sole rice (I_0). At panicle initiation, flowering and maturity stages, the intercropping treatments registered a substantial improvement in organic carbon relative to sole rice (I_0). There was no remarkable difference among the intercropping treatments (I_1 to I_4) in any of the seasons. Sole rice (I_0) failed to improve organic carbon in the soil.

Split applications of N did not influence organic carbon status, at active tillering stage during *kharif* 1999. In *rabi* 1999 and *kharif* 2000 crop significant difference was observed by application of N in different splits. Application of 42 per cent N at the time of daincha incorporation recorded higher level of organic carbon status in the soil at active tillering stage. Application of four equal splits of N resulted in low organic carbon status at this stage.

At panicle initiation, flowering and maturity stages, N application in different split levels had a marked effect on soil organic carbon status in all seasons. Application of four equal splits of N (N_1) recorded higher level of organic carbon in the soil compared to 42 per cent N application at the time of daincha incorporation (0.68, 0.73 and 0.77 per cent at panicle initiation, 0.71, 0.75 and 0.79 per cent at flowering and 0.73, 0.77 and 0.82 per cent at maturity stage during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively), but the former treatment was on par with 33 per cent N application at the time of daincha incorporation (N_2).

There was no interaction effect between different intercropping treatments with N split levels on organic carbon content in the soil.

Table 40. Influence of daincha intercropping/seed production and N split doses on soil organic carbon content (%) at active tillering and panicle initiation stages

Treatments	At active tillering stage			At panicle initiation stage		
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping						
I ₀ = Sole rice	0.60	0.65	0.71	0.61	0.64	0.70
I ₁ = Rice + daincha (entirely for GM alone)	0.63	0.70	0.73	0.68	0.73	0.76
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	0.63	0.68	0.72	0.66	0.70	0.74
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	0.62	0.69	0.72	0.67	0.72	0.75
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	0.63	0.70	0.73	0.67	0.72	0.76
SEd	0.015	0.014	0.017	0.017	0.022	0.013
CD (P=0.05)	NS	0.032	NS	0.04	0.05	0.03
N split dose (%)						
N ₁ = 25:25:25:25	0.60	0.66	0.70	0.68	0.73	0.77
N ₂ = 25:33:21:21	0.62	0.68	0.72	0.66	0.70	0.74
N ₃ = 25:42:16.5:16.5	0.64	0.71	0.74	0.64	0.67	0.71
SEd	0.017	0.013	0.016	0.018	0.019	0.024
CD (P=0.05)	0.035	0.028	0.037	0.038	0.04	0.05

GM: Green manure; SP: Seed production

Table 41. Influence of daincha intercropping/seed production and N split doses on soil organic carbon content (%) at flowering and maturity stages

Treatments	At flowering stage			At maturity stage		
	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping						
I ₀ = Sole rice	0.63	0.65	0.72	0.61	0.64	0.70
I ₁ = Rice + daincha (entirely for GM alone)	0.71	0.75	0.79	0.73	0.76	0.82
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	0.69	0.73	0.77	0.69	0.73	0.78
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	0.70	0.74	0.78	0.71	0.75	0.80
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	0.70	0.75	0.78	0.72	0.75	0.81
SEd	0.022	0.017	0.020	0.017	0.022	0.022
CD (P=0.05)	0.05	0.04	0.046	0.04	0.051	0.051
N split dose (%)						
N ₁ = 25:25:25:25	0.71	0.75	0.79	0.73	0.77	0.82
N ₂ = 25:33:21:21	0.69	0.72	0.77	0.69	0.72	0.78
N ₃ = 25:42:16.5:16.5	0.66	0.71	0.74	0.65	0.69	0.75
SEd	0.019	0.014	0.022	0.024	0.034	0.029
CD (P=0.05)	0.04	0.03	0.046	0.05	0.071	0.06

GM: Green manure; SP: Seed production

4.2.5.2. Available soil N (Table 42 to 44)

Available N at active tillering stage was influenced to a greater extent by intercropping treatments (I_1 to I_4) than by sole rice (I_0) during *rabi* 1999 and *kharif* 2000. In *kharif* 1999, the intercropping treatments did not exercise any significant influence on N status in soil

Application of N in splits had a favourable influence on available N status both at active tillering (except *kharif* 1999) and panicle initiation stages in all the seasons. Application of 42 per cent N at the time of daincha incorporation (N_3) had a marked influence on available N status comparable to four equal split applications (N_1). The treatment N_3 was closely followed by 33 per cent N application at the time of daincha incorporation (N_2) at panicle initiation stage in all the seasons.

During panicle initiation stage, daincha intercrop exclusively grown for green manuring (I_1) recorded a substantial increase in soil N status but it was on par with rest of the daincha intercropping treatments (I_4 , I_3 and I_2). Least soil available N was recorded in sole rice (I_0).

At flowering and maturity stages, daincha exclusively for green manuring (I_1) exerted a positive effect on soil available N status (242, 244 and 267 kg N ha⁻¹ at flowering and 237, 234 and 256 kg N ha⁻¹ at maturity stage during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. Retaining every 20th daincha row for seed production and remaining rows for green manuring (I_4) registered the next best soil N status at flowering and maturity stages in all seasons. The lowest available soil N status was noticed in sole rice (I_0).

Split applications of N made a significant influence on the available soil N at flowering and maturity stages in all the three seasons. Application of four equal splits had a superior effect on available N status both at flowering and maturity stages as 229, 233, 251 and 224, 227 and 244 kg N ha⁻¹ over *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively, which was on par with the treatment consisting of 33 per cent N application at the time of daincha incorporation (N_2) at flowering stage alone, but highly significant difference was noticed among N split treatments at maturity stage in all seasons.

Table 42. Influence of daincha intercropping/seed production and N split doses on available soil N (kg ha^{-1}) at active tillering and panicle initiation stages.

Treatments	At active tillering stage			At panicle initiation stage		
	Khariif 1999	Rabi 1999	Khariif 2000	Khariif 1999	Rabi 1999	Khariif 2000
GM Intercropping						
I ₀ = Sole rice	213	221	242	215	219	237
I ₁ = Rice + daincha (entirely for GM alone)	216	230	246	234	246	259
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	213	228	243	226	237	252
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	214	228	244	229	240	255
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	216	229	244	231	242	256
SEd	1.8	2.7	1.7	2.3	2.6	2.1
CD (P=0.05)	NS	6.2	3.9	5.3	6.0	4.9
N split dose (%)						
N ₁ = 25:25:25:25	212	224	241	223	232	246
N ₂ = 25:33:21:21	214	226	244	228	237	252
N ₃ = 25:42:16.5:16.5	217	232	248	232	241	257
SEd	2.8	2.3	2.9	3.2	2.3	3.0
CD (P=0.05)	NS	4.8	6.0	6.7	4.8	6.3

GM: Green manure; SP: Seed production

13. Influence of daincha intercropping/seed production and split doses on available soil N (kg ha^{-1}) at flowering stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	213	206	201	207	213	218	209	213	235	229	221	228
I ₁ = Rice + daincha (entirely for GM alone)	244	243	238	242	247	244	240	244	271	268	263	267
I ₂ = Rice + daincha (every 10 th daincha row for SP)	223	222	218	221	230	227	222	227	243	241	237	240
I ₃ = Rice + daincha (every 15 th daincha row for SP)	229	227	223	226	235	232	227	231	248	247	242	246
I ₄ = Rice + daincha (every 20 th daincha row for SP)	234	231	229	232	238	235	231	235	256	254	248	253
Mean	229	226	222	222	233	231	226	226	251	248	242	242
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	2.3	5.2	2.7	6.2	2.4	5.5	2.4	5.5	2.4	5.0	2.4	5.0
I at N	1.8	3.7	2.01	4.2	3.0	6.6	3.0	6.6	3.0	6.6	3.0	6.6
Nat I	3.0	6.5	3.4	7.4	3.9	8.2	4.2	8.8	5.1	10.6	5.1	10.6

Table 44. Influence of daincha intercropping/seed production and N split doses on available soil N (kg ha⁻¹) at maturity stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	213	201	197	204	213	208	202	208	229	218	211	219
I ₁ = Rice + daincha (entirely for GM alone)	241	237	230	237	240	237	226	234	261	256	252	256
I ₂ = Rice + daincha (every 10 th daincha row for SP)	218	213	207	213	221	218	212	217	237	234	226	232
I ₃ = Rice + daincha (every 15 th daincha row for SP)	223	218	211	217	227	223	215	222	243	240	235	239
I ₄ = Rice + daincha (every 20 th daincha row for SP)	227	223	218	223	232	227	218	226	249	245	241	245
Mean	224	218	213	227	227	223	215	224	244	239	233	
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	1.7	3.9	2.0	4.6	2.2	5.1	1.9	4.0	3.8	4.0	3.8	8.2
I at N	2.1	4.4	1.8	3.8	3.8	8.2	3.2	7.1	4.1	4.1	3.8	8.5
Nat I	3.1	6.9	3.2	7.1	3.9	8.5	3.9	8.1	4.1	4.1	3.8	8.5
Nat I	4.6	9.6	3.9	8.1	4.1	8.5	3.9	8.1	4.1	4.1	3.8	8.5

Lowest available N status was observed in 42 per cent N application at the time of daincha incorporation (N_3).

Interaction effect on soil available N was observed at flowering and maturity stages. Treatment combination of daincha entirely grown for green manuring with four equal split applications of N (I_1N_1) recorded higher N in soil during all the seasons. At maturity stage, the combined effect of I_1N_1 was highly significant compared to rest of the treatments (241, 240 and 261 kg available N ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). Lowest available N in soil was recorded in sole rice with 42 per cent N application at daincha incorporation (I_0N_3) as 197, 202 and 211 kg N ha⁻¹ at all seasons.

4.2.5.3. Available soil P (Table 45 to 47)

Intercropping treatments brought out favourable effect on available P in soil compared to sole rice (I_0) at active tillering stage irrespective of the seasons, but among the intercropping treatments (I_1 to I_4) there was no significant difference in respect of P status. During panicle initiation stage, treatments I_1 and I_4 registered higher available P in soil, whereas during *kharif* and *rabi* 1999 treatments I_1 , I_4 and I_3 were on par. Invariably the lowest available P status in soil was evident in sole rice treatments in all seasons.

Split application of N had shown significant influence on available P in soil during *rabi* season alone at active tillering stage, whereas during both *kharif* seasons, there was no significant influence. Among various split applications, N_3 registered higher available P status in soil during panicle initiation stage.

At flowering and maturity stages, the daincha intercropped entirely for green manuring (I_1) recorded significantly higher available P in soil than other treatments in all seasons (23.6, 22.7 and 23.1 kg P ha⁻¹ at flowering and 21.6, 20.8 and 20.3 kg P ha⁻¹ at maturity stages during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). Retaining every 20th row of daincha (after *in situ* incorporation of daincha for green manuring) for seed production (I_4) was the next best among the other intercropping treatments. Invariably, least available soil P was noticed in sole rice (I_0) of 17.8, 16.0 and

Table 45. Influence of daincha intercropping/seed production and N split doses on available soil P (kg ha^{-1}) at active tillering and panicle initiation stages

Treatments	At active tillering stage			At panicle initiation stage		
	Khariif 1999	Rabi 1999	Khariif 2000	Khariif 1999	Rabi 1999	Khariif 2000
GM Intercropping						
I ₀ = Sole rice	19.0	18.4	20.1	17.1	17.7	18.9
I ₁ = Rice + daincha (entirely for GM alone)	21.2	22.4	21.8	24.2	25.8	25.2
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	20.8	20.7	20.9	21.2	21.0	21.6
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	20.9	21.2	21.0	22.0	22.0	22.5
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	21.0	21.9	21.6	22.8	23.1	23.6
SEd	0.6	0.8	0.5	0.6	0.8	0.7
CD (P=0.05)	1.4	1.8	1.2	1.4	1.9	1.7
N split dose (%)						
N ₁ = 25:25:25:25	20.2	19.9	20.6	19.8	20.2	20.9
N ₂ = 25:33:21:21	20.5	20.8	20.9	21.4	21.9	22.3
N ₃ = 25:42:16.5:16.5	21.0	22.0	21.7	23.2	23.7	23.9
SEd	0.7	0.5	0.6	0.7	0.6	0.5
CD (P=0.05)	NS	1.0	NS	1.5	1.2	1.1

GM: Green manure; SP: Seed production

Table 46. Influence of daincha intercropping/seed production and N split doses on available soil P (kg ha⁻¹) at flowering stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	18.3	18.0	17.1	17.8	16.4	16.0	15.7	16.0	18.7	18.0	17.3	18.0
I ₁ = Rice + daincha (entirely for GM alone)	24.1	23.7	23.0	23.6	23.5	22.8	21.9	22.7	23.7	23.0	22.7	23.1
I ₂ = Rice + daincha (every 10 th daincha row for SP)	19.4	19.1	19.0	19.2	18.1	17.8	17.1	17.7	19.7	19.3	18.6	19.2
I ₃ = Rice + daincha (every 15 th daincha row for SP)	21.6	21.0	20.7	21.1	19.6	19.1	18.5	19.1	21.0	20.7	19.8	20.5
I ₄ = Rice + daincha (every 20 th daincha row for SP)	22.9	22.1	21.8	22.3	22.0	21.4	21.1	21.5	22.4	21.8	21.2	21.8
Mean	21.3	20.8	20.3	19.9	19.9	19.4	18.9	19.7	21.1	20.6	19.9	

N split dose (%): N₁ = 25:25:25; N₂ = 25:33:21:21; N₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
I	0.47	1.08	0.52	1.21	0.46	1.07
N	0.47	NS	0.53	NS	0.59	NS
I at N	0.62	1.35	0.80	1.75	0.64	1.39
Nat I	1.04	NS	1.18	NS	1.30	NS

Table 47. Influence of daincha intercropping/seed production and N split doses on available soil P (kg ha⁻¹) at maturity stage

Treatments	Kharif 1999				Rabi 1999				Kharif 2000			
	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean	N ₁	N ₂	N ₃	Mean
I ₀ = Sole rice	16.9	16.0	15.8	16.2	15.8	15.3	15.1	15.4	17.6	16.7	16.4	16.9
I ₁ = Rice + daincha (entirely for GM alone)	22.1	21.6	21.0	21.6	21.6	20.5	20.3	20.8	21.0	20.2	19.8	20.3
I ₂ = Rice + daincha (every 10 th daincha row for SP)	17.2	16.6	16.0	16.6	17.0	16.2	15.6	16.3	17.6	17.0	16.7	17.1
I ₃ = Rice + daincha (every 15 th daincha row for SP)	18.5	18.0	17.2	17.9	18.3	17.6	17.1	17.7	19.0	18.2	17.8	18.3
I ₄ = Rice + daincha (every 20 th daincha row for SP)	19.8	19.1	18.4	19.1	19.4	18.9	18.3	18.9	20.0	19.6	19.3	19.6
Mean	18.9	18.3	17.7	18.4	17.7	17.3	17.3	18.3	19.0	18.3	18.0	18.0
N split dose (%): N ₁ = 25:25:25:25; N ₂ = 25:33:21:21; N ₃ = 25:42:16.5:16.5; GM: Green manure; SP: Seed production												
I	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
N	0.50	1.15	0.48	1.10	0.45	1.03	0.45	1.03	0.58	NS	0.59	1.29
I at N	0.63	NS	0.59	NS	0.58	NS	0.59	NS	1.28	NS	1.28	NS
Nat I	0.69	1.50	0.65	1.43	0.59	1.29	0.59	1.29	1.28	NS	1.28	NS
Nat I	1.38	NS	1.31	NS	1.28	NS	1.28	NS	1.28	NS	1.28	NS

18.0 kg ha⁻¹ at flowering and 16.2, 15.4 and 16.9 kg P ha⁻¹ at maturity stages during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively over other treatments.

N split applications failed to have a positive effect on available P status in soil both at flowering and maturity stages.

Interaction effect on available P in soil was observed in all seasons. Combined effect of various intercropping treatments with N splits had significant influences on available P status. N splits on different intercropping had no effect on available P status in soil both at flowering and maturity stages in all seasons.

4.2.5.4. Available soil K (Table 48)

Available soil K was markedly influenced by different intercropping systems in all seasons. The status of post harvest available soil K was higher in sole rice (526, 498 and 502 kg K ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than in the various intercropping treatments (I₁ to I₄) in all the seasons. Available soil K in treatments for seed production (I₂ to I₄) were on par with each other in all seasons. Lowest available K was noticed in 10th daincha row for seed production and remaining rows for green manuring (I₂) (498, 466 and 471 kg K ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). Growing daincha and incorporating entirely for green manuring (I₁) was the next best to sole rice (I₀) and it was on par with I₃ and I₄ during *rabi* 1999 and *kharif* 2000 and I₄ during *kharif* 1999 season.

Nitrogen split applications did not significantly influence available K in any season.

4.2.6. Light interception (%) (Table 49 to 51)

Daincha intercropping treatments, intercepted higher sun light than sole rice before daincha incorporation. This trend was reversed immediately after incorporation of daincha. At active tillering stage, there was low light interception by intercropped treatments (I₁ to I₄) whereas higher light was intercepted in sole rice (I₀) in all the seasons.

Table 48. Influence of daincha intercropping/seed production and N split doses on post harvest K in soil (kg ha^{-1})

Treatments	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping			
I ₀ = Sole rice	526	498	502
I ₁ = Rice + daincha (entirely for GM alone)	514	481	489
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	498	466	471
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	503	472	477
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	508	475	483
SEd	4.6	4.0	5.6
CD (P=0.05)	10.7	9.2	12.9
N split dose (%)			
N ₁ = 25:25:25:25	516	484	490
N ₂ = 25:33:21:21	509	477	484
N ₃ = 25:42:16.5:16.5	504	474	479
SEd	6.4	5.4	6.7
CD (P=0.05)	NS	NS	NS

GM: Green manure; SP: Seed production

Table 49. Influence of daincha intercropping/seed production and N split doses on light interception (%) before GM incorporation

Treatments	<i>Kharif</i> 1999	<i>Rabi</i> 1999	<i>Kharif</i> 2000
GM Intercropping			
I ₀ = Sole rice	30.5	33.1	26.8
I ₁ = Rice + daincha (entirely for GM alone)	73.8	78.3	68.1
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	74.0	79.4	67.3
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	72.7	77.9	68.7
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	72.1	76.0	66.8
SEd	0.9	1.1	0.9
CD (P=0.05)	2.1	2.5	2.0
N split dose (%)			
N ₁ = 25:25:25:25	63.7	67.8	58.3
N ₂ = 25:33:21:21	64.3	69.1	60.7
N ₃ = 25:42:16.5:16.5	65.9	69.9	59.4
SEd	1.3	1.1	1.2
CD (P=0.05)	NS	NS	NS

GM: Green manure; SP: Seed production

Table 50. Influence of daincha intercropping/seed production and N split doses on light interception by rice (%) at active tillering and panicle initiation stages

Treatments	At active tillering			At panicle initiation stage		
	Kharif 1999	Rabi 1999	Kharif 2000	Kharif 1999	Rabi 1999	Kharif 2000
GM Intercropping						
I ₀ = Sole rice	33.5	44.3	29.5	62.8	72.5	58.3
I ₁ = Rice + daincha (entirely for GM alone)	29.3	46.0	26.1	67.4	84.4	63.8
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	29.1	41.2	25.0	59.0	73.5	55.4
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	29.8	42.6	25.4	63.0	77.2	58.1
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	29.5	44.1	25.7	65.2	81.0	60.7
SEd	0.5	0.69	0.52	0.91	1.42	1.05
CD (P=0.05)	1.2	1.58	1.2	2.1	3.27	2.43
N split dose (%)						
N ₁ = 25:25:25:25	29.6	42.7	25.6	62.3	76.5	58.0
N ₂ = 25:33:21:21	30.1	43.4	26.4	63.5	77.8	59.3
N ₃ = 25:42:16.5:16.5	31.0	44.8	27.0	64.6	78.8	60.4
SEd	0.73	1.03	0.71	1.10	1.20	0.86
CD (P=0.05)	NS	NS	NS	NS	NS	NS

GM: Green manure; SP: Seed production

Table 51. Influence of daincha intercropping/seed production and N split doses on light interception of rice (%) at flowering and milky stages

Treatments	Flowering stage				Milky stage		
	Kharif 1999		Rabi 1999		Kharif 2000		Kharif 1999
	Kharif 1999	Rabi 1999	Kharif 1999	Rabi 1999	Kharif 2000	Rabi 1999	Kharif 2000
GM Intercropping							
I ₀ = Sole rice	86.6	89.1	84.3	89.8	87.8	89.6	87.8
I ₁ = Rice + daincha (entirely for GM alone)	93.0	94.5	91.7	95.1	93.1	95.8	93.1
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows for GM)	70.2	68.0	65.3	64.7	61.3	64.2	61.3
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows for GM)	74.7	73.1	70.1	69.2	65.8	68.7	65.8
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows for GM)	78.1	76.9	74.8	73.1	70.4	72.5	70.4
SEd	1.44	1.59	1.29	1.56	1.30	1.34	1.30
CD (P=0.05)	3.31	3.67	2.97	3.60	3.00	3.10	3.00
N split dose (%)							
N ₁ = 25:25:25:25	80.8	80.4	77.4	78.8	75.9	78.3	75.9
N ₂ = 25:33:21:21	81.6	81.5	78.2	79.3	76.7	79.2	76.7
N ₃ = 25:42:16.5:16.5	79.2	79.1	76.1	77.0	74.4	77.0	74.4
SEd	1.17	1.30	1.06	1.49	1.25	1.10	1.25
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

GM: Green manure; SP: Seed production

Invariably, the split applications of N exhibited significant difference in light interception at all stages irrespective of season.

During panicle initiation stage, the treatment daincha grown entirely for green manuring (I_1) proved superior to other treatments (67.4, 84.4 and 63.8 per cent light interception in respective seasons). The next best treatment was allowing every 20th row of daincha for seed production (I_4). Least light interception was recorded in sole rice (I_0) (62.8, 72.5 and 58.3 per cent during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

The intercropping treatments were highly significant between one another. Daincha exclusively grown for green manuring recorded superiority over other treatments in terms of light interception with 93.0, 94.5 and 91.7 at flowering and 95.1, 95.8 and 93.1 per cent at milky stages. Next best treatment was sole rice (I_0) with 86.6, 89.1 and 84.3 per cent at flowering and 89.8, 89.6 and 87.8 per cent at milky stages over *kharif* 1999, *rabi* 1999 and *kharif* 2000 season respectively. Lowest light interception was recorded in the treatment 10th daincha row for seed production and remaining rows for green manuring (I_2) along with 70.2, 68.0 and 65.3 per cent at flowering and 64.7, 64.2 and 61.3 per cent at milky stages during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. In general, daincha seed production treatment (I_2 to I_4) brought out a drastic reduction in light interception relative sole rice in all the seasons.

4.2.8. Economics evaluation (Table 52 and 53)

Net income and benefit cost ratio (BCR) were greatly influenced by daincha intercropping and N split applications in all the seasons.

a. Net Income

Intercropping of daincha for *in situ* green manuring cum seed production in 20:1 ratio (I_4) produced higher net income of Rs.28214, 23036 and Rs.30048 ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 seasons respectively. Rice + daincha grown entirely for green manuring (I_1) was next best. The lowest net income was from sole rice (I_0) with Rs.20390, 16843 and Rs.22386 ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Table 52. Influence of daincha intercropping/seed production and N split doses on net income (Rs.ha⁻¹) and benefit cost ratio (BCR) of rice

Treatments	Kharif 1999		Rabi 1999		Kharif 2000	
	Net income (Rs.ha ⁻¹)	BCR	Net income (Rs.ha ⁻¹)	BCR	Net income (Rs.ha ⁻¹)	BCR
GM intercropping						
I ₀ = Sole rice	20390	2.82	16843	2.58	22386	3.00
I ₁ = Rice + daincha (entirely for GM)	27232	3.27	22664	2.98	28359	3.36
I ₂ = Rice + daincha (every 10 th daincha row for SP and other rows GM)	25785	3.08	20784	2.76	26635	3.15
I ₃ = Rice + daincha (every 15 th daincha row for SP and other rows GM)	27143	3.21	21672	2.85	28350	3.31
I ₄ = Rice + daincha (every 20 th daincha row for SP and other rows GM)	28214	3.32	23036	2.98	30048	3.47
N split dose (%)						
N ₁ = 25:25:25:25	26277	3.19	21592	2.88	27985	3.33
N ₂ = 25:33:21:21	27862	3.31	22509	2.96	28618	3.38
N ₃ = 25:42:16.5:16.5	23119	2.92	18898	2.65	24863	3.07

GM: Green manure; SP: Seed production

Table 53. Combined influence of intercropping with N split doses on net income (Rs.ha⁻¹) and benefit cost ratio (BCR) of rice

Treatments	<i>Kharif 1999</i>		<i>Rabi 1999</i>		<i>Kharif 2000</i>	
	Net income (Rs.ha ⁻¹)	BCR	Net income (Rs.ha ⁻¹)	BCR	Net income (Rs.ha ⁻¹)	BCR
I ₀ N ₁	22918	3.05	18965	2.78	24641	3.20
I ₀ N ₂	20460	2.83	16912	2.59	22414	3.00
I ₀ N ₃	17792	2.59	14652	2.38	20102	2.80
I ₁ N ₁	27302	3.27	22969	3.00	29034	3.42
I ₁ N ₂	30016	3.50	24644	3.15	30452	3.54
I ₁ N ₃	24377	3.03	20379	2.78	25591	3.13
I ₂ N ₁	25900	3.09	20916	2.77	27111	3.19
I ₂ N ₂	28223	3.28	22501	2.90	28430	3.30
I ₂ N ₃	23232	2.88	18935	2.60	24364	2.97
I ₃ N ₁	27099	3.21	21863	2.86	28477	3.32
I ₃ N ₂	29705	3.42	23470	3.00	29761	3.43
I ₃ N ₃	24625	3.01	19683	2.68	26811	3.19
I ₄ N ₁	28164	3.32	23246	3.00	30662	3.52
I ₄ N ₂	30907	3.54	25019	3.15	32033	3.64
I ₄ N ₃	25570	3.10	20843	2.79	27449	3.26

Application of N in different splits, had a marked influence on net income in all the seasons. Application of 33 per cent N at the time of daincha incorporation (N_2) registered higher net income of Rs.27862, 22509 and Rs.28618 ha^{-1} in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. Lowest net income was fetched in 42 per cent N application at the time of daincha incorporation (N_3) with Rs.23119, 18898 and 24863 ha^{-1} of net income during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Combination of daincha intercropping for green manuring as well as daincha seed production at every 20th row (20:1) in rice along with 33 per cent N application at the time of daincha incorporation (I_4N_2) gave higher net income of Rs.30907, 25019 and Rs.32033 ha^{-1} *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively, This was closely followed by daincha grown entirely for green manuring with 33 per cent N application at the time of daincha incorporation (I_1N_2) and I_4N_1 in all seasons. Least net income was recorded in sole rice with 42 per cent N application at the time of daincha incorporation (I_0N_3) (Rs.17792, 14652 and Rs.20102 of net income ha^{-1} in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

b. Benefit cost ratio (BCR)

From the standpoint of BCR also a trend similar to net income was evident. BCR was higher from rice + daincha seed crop (every 20th daincha row for SP) (I_4) with Rs.3.32, 2.98 and Rs.3.47 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. The next best treatment was I_1 (entirely for green manuring). Least BCR was recorded in sole rice with Rs.2.82, 2.58 and Rs.3.00 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Application of 33 per cent N at the time of daincha incorporation gave higher BCR of 3.31, 2.96 and 3.38 in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. Lowest BCR was recorded in 42 per cent N application at the time of daincha incorporation (N_3) with Rs.2.92, 2.65 and 3.07 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Combination of daincha intercropping for green manuring cum seed production for every 20th row (20:1) in rice with 33 per cent N application at the time of daincha incorporation (I₄N₂) gave higher BCR of 3.54, 3.15 and 3.64. Sole rice with 42 per cent N application at the time of daincha incorporation (I₀N₃) registered least BCR of Rs.2.83, 2.59 and 3.0 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

4.3. Influence of treatments on daincha seed crop

Intercropping of daincha in wet seeded rice for *in situ* green manuring and retaining few daincha rows for seed production (every 10th, 15th and 20th daincha row) with N split applications for rice and its influence on daincha seed crop was documented.

4.3.1. Plant height (Table 54)

Intercropping of daincha for seed production at every 20th daincha row (after *in situ* incorporation of remaining rows) produced taller plants (220, 191 and 233 cm during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). Shortest plant was noticed in I₂ (every 10th daincha for seed production). Application of 42 per cent N at the time of daincha incorporation resulted in taller plants (220, 191 and 237 in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than rest of the N splits.

Plant height greatly differed among seasons. Daincha grown during *kharif* 2000 recorded taller plants (233 to 238 cm) than *rabi* 1999 and *kharif* 1999.

4.3.2. Branches plant⁻¹ (Table 54)

Branches plant⁻¹ were more in the treatment retaining every 20th row for seed production (I₄) during *kharif* 2000 and *rabi* 1999 (16 and 10) whereas during *kharif* 1999 season, 15th daincha row for seed production and remaining rows for green manuring (I₃) recorded more number of branches plant⁻¹. But the treatmental influence on number of branches was meagre. More number of branches (10 to 16) over different seasons was observed in 42 per cent N application at daincha incorporation (N₃).

Seasonal influence on branches plant⁻¹ was pronounced irrespective of treatments. More number of branches was observed during *kharif* 2000 (13-16) followed by *kharif* 1999. Lesser number of branches was noticed in *rabi* season (9-10).

Table 54. Influence of daincha intercropping/seed production and N split doses for rice on plant height, branches plant¹ and canopy coverage of daincha seed crop

Treatments	Plant height (cm)		Branches plant ¹			Canopy cover (cm) at flowering stage			
	<i>Kharif</i> 99	<i>Rabi</i> 99	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> 99	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> 99	<i>Kharif</i> 00
Daincha Seed Crop									
I ₂ = Rice + Daincha (every 10 th row for SP)	214	189	235	11	9	14	131	107	137
I ₃ = Rice + Daincha (every 15 th row for SP)	217	187	238	13	7	13	136	105	135
I ₄ = Rice + Daincha (every 20 th row for SP)	220	191	233	12	10	16	134	110	143
N split dose (%)									
N ₁ = 25:25:25:25	215	187	234	10	8	13	131	104	136
N ₂ = 25:33:21:21	217	189	235	12	8	14	134	108	139
N ₃ = 25:42:16.5:16.5	220	191	237	14	10	16	136	110	141

GM: Green manure; SP: Seed production
Data statistically not analysed.

4.3.3. Canopy cover at flowering stage (Table 54)

Canopy covered by daincha seed crop was not greatly influenced by the treatments. But broader canopy coverage was recorded in retaining every 20th row for seed production. Less canopy coverage was observed in retaining every 10th row for seed production in all the seasons.

Daincha canopy coverage was (seed crop) broader, when 42 per cent N application at the time of daincha incorporation (N₃) for rice. In general, split application of N did not exercise appreciable influence on canopy coverage.

Among the seasons, *kharif* 2000 green manure crop recorded broader canopy coverage (135-143 cm) than *kharif* 1999 (131-136 cm) and *rabi* 1999 (105-110 cm) season.

4.3.4. Pods plant⁻¹ (Table 55)

Among the various intercropping treatments, retaining every 20th daincha row for seed production had more number of pods plant⁻¹ (134.0, 105.7 and 147.1 in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than 15th and 10th daincha row for seed production and remaining rows for green manuring (I₃ and I₂). Application of 42 per cent N at the time of daincha incorporation (N₃) registered more number of pods plant⁻¹ than other treatments (N₁ and N₂).

kharif 2000 season crop performed better (139.9-147.1) than *rabi* 1999 and *kharif* 1999 seasons.

4.3.5. Seeds pod⁻¹ (Table 55)

Growing daincha at every 20th row for seed production and remaining rows for green manuring (I₄) produced more number of seeds pod⁻¹ during *kharif* 1999 and *kharif* 2000 (27.1 and 26.3) whereas during *rabi* 1999 season, 15th daincha row for seed production and remaining rows for green manuring recorded more number of seeds pod⁻¹ (24.1). Split applications of N had no substantial influence on pod number in any of the season.

Table 55. Influence of daincha intercropping/seed production and N split doses for rice on yield attributes of daincha seed crop

Treatments	No. of pods / plant				No. of seeds / Pod				Pod length (cm)			
	<i>Kharif</i> 99	<i>Rabi</i> 99	<i>Kharif</i> 00	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> 99	<i>Kharif</i> 00	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> 99	<i>Kharif</i> 00	
Daincha Seed Crop												
I ₂ = Rice + Daincha (every 10 th row for SP)	129.3	101.9	139.9	139.9	25.6	19.8	22.9	22.9	22.7	20.3	23.6	
I ₃ = Rice + Daincha (every 15 th row for SP)	133.1	103.1	141.3	141.3	26.3	24.1	23.7	23.7	22.1	20.6	23.9	
I ₄ = Rice + Daincha (every 20 th row for SP)	134.0	105.7	147.1	147.1	27.1	21.7	26.3	26.3	23.2	19.8	22.7	
N split dose (%)												
N ₁ = 25:25:25:25	129.3	101.3	139.7	139.7	25.9	21.5	23.9	23.9	22.5	19.9	23.0	
N ₂ = 25:33:21:21	132.4	103.8	142.9	142.9	26.1	21.8	24.2	24.2	22.6	20.3	23.5	
N ₃ = 25:42:16.5:16.5	134.7	105.7	145.7	145.7	27.0	22.3	24.8	24.8	22.9	20.7	23.8	

GM: Green manure; SP: Seed production
Data statistically not analysed.

Among the seasons, *kharif* 2000 registered more number of seeds pod^{-1} (22.7 to 23.9) than *rabi* 1999 and *kharif* 1999 season. Less number of pods plant^{-1} was noticed during *rabi* 1999 season (19.8 to 20.6).

4.3.6. Pod length (Table 55)

Pod length was not influenced either by intercropping or by split applications of N in all the seasons.

Seasonal influence revealed that *kharif* 2000 recorded longer pod of 23.0 to 23.8 cm than *rabi* and *kharif* 1999 seasons. Lesser length of pod was observed during *rabi* 1999 (19.9 to 20.7 cm).

4.3.7. Seed yield (Table 56)

Retaining daincha every 10th row for seed production and remaining rows for green manuring (I_2) gave higher seed yield (170, 132 and 183 kg ha^{-1} during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than 15th and 20th daincha row for seed production and remaining rows for green manuring. Lowest seed yield of 109, 74 and 117 kg ha^{-1} was recorded in 20th daincha row for seed production and remaining rows for green manuring (I_4) during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

Split application at 42 per cent of N at the time of daincha incorporation (N_3) gave higher seed yield of 141, 104 and 151 kg ha^{-1} during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively, but the difference due to the treatments was almost negligible.

Season had greater influence on daincha seed yield. During *kharif* 2000, higher seed yield of 183 kg ha^{-1} was recorded in 10th daincha row for seed production and remaining rows for green manuring (I_2). During *kharif* 1999, it was 170 kg ha^{-1} and in *rabi* 1999 it was 132 kg ha^{-1} . Similarly, in other treatments 15th and 20th daincha row for seed production and remaining rows for green manuring in *kharif* 2000 season outyielded other seasons.

Table 56. Influence of daincha intercropping/seed production and N split doses for rice on seed and haulm yield and test weight of daincha seed crop

Treatments	Seed yield (kg ha ⁻¹)			Haulm yield (kg ha ⁻¹)			100 seed weight (gm)		
	<i>Kharif</i> 99	<i>Rabi</i> '99	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> '99	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> '99	<i>Kharif</i> 00
Daincha Seed Crop									
I ₂ = Rice + Daincha (every 10 th row for SP)	170	132	183	1825	1584	2010	2.04	1.91	1.98
I ₃ = Rice + Daincha (every 15 th row for SP)	137	97	145	1572	1178	1642	2.10	1.87	1.95
I ₄ = Rice + Daincha (every 20 th row for SP)	109	74	117	1313	926	1368	2.08	1.86	2.04
N split dose (%)									
N ₁ = 25:25:25:25	136	98	146	1551	1222	1663	2.05	1.85	1.95
N ₂ = 25:33:21:21	139	101	148	1571	1229	1670	2.07	1.88	1.98
N ₃ = 25:42:16.5:16.5	141	104	151	1588	1237	1687	2.10	1.90	2.03

GM: Green manure; SP: Seed production
Data statistically not analysed.

4.3.8. Haulm yield (Table 56)

Haulm yield was greatly influenced by the treatments. More haulm yield was recorded in the treatment of retaining every 10th daincha row for seed production and remaining rows for green manuring (I₂) (1825, 1584 and 2010 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively) than other treatments. Low haulm yield was noticed in 20th daincha row for seed production and remaining rows for green manuring (I₄) (1313, 926 and 1368 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

Split applications of N in general had meagre influence on haulm yield. However, higher haulm yield was recorded in 42 per cent N application at the time of daincha incorporation (1588, 1237 and 1687 kg ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively).

Seasonal influence on haulm yield was marked. Higher haulm yield was recorded during *kharif* 2000 than during *rabi* 1999 and *kharif* 1999. In general, *kharif* 2000 performed better than *rabi* 1999 and *kharif* 1999 seasons. Lowest haulm yield was recorded during *rabi* 1999 season.

4.3.9. 100 seed weight (Table 56)

Test weight of daincha seed crop was not influenced by intercropping or N split treatments. However, seasonal influence was noticed. Higher test weight was recorded during *kharif* 1999 (2.04 to 2.10 g) than during *rabi* 1999 and *kharif* 2000.

4.3.10. Nutrient uptake (Table 57)

Higher NPK uptake was recorded in the 10th daincha row for seed production and remaining rows for green manuring irrespective of season (26.73, 21.64 and 31.13 kg N ha⁻¹; 9.25, 7.30 and 11.0 kg P ha⁻¹ and 33.17, 27.14 and 35.74 kg K ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). Lowest uptake of NPK was recorded in 20th daincha row for seed production and remaining rows for green manuring (I₄) in all the seasons. Split application of N did not show much influence on uptake of NPK in any of the seasons.

Table 57. Influence of daincha intercropping/seed production and N split doses for rice on NPK uptake (kg ha^{-1}) of daincha seed crop at maturity stage

Treatments	N						P			K		
	<i>Kharif</i> 99	<i>Rabi</i> '99	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> '99	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> '99	<i>Kharif</i> 00	<i>Kharif</i> 99	<i>Rabi</i> '99	<i>Kharif</i> 00
Daincha Seed Crop												
I ₂ = Rice + Daincha (every 10 th row for SP)	26.73	21.64	31.13	9.25	7.3	11.0	33.17	27.14	35.74			
I ₃ = Rice + Daincha (every 15 th row for SP)	23.28	16.84	25.78	7.6	5.12	9.12	28.25	20.79	30.78			
I ₄ = Rice + Daincha (every 20 th row for SP)	20.73	13.76	22.14	6.4	4.2	7.8	23.98	16.74	25.23			
N split dose (%)												
N ₁ = 25:25:25:25	20.2	17.0	25.9	7.60	5.47	9.02	28.1	20.2	30.2			
N ₂ = 25:33:21:21	20.5	17.4	26.3	7.81	5.57	9.30	28.4	21.5	30.6			
N ₃ = 25:42:16.5:16.5	21.0	17.8	26.9	7.85	5.60	9.58	28.8	22.1	30.9			

GM: Green manure; SP: Seed production
Data statistically not analysed.

Among different seasons, *kharif* 2000 recorded higher NPK uptake than rest of the seasons. Least uptake was recorded in *rabi* 1999 season.

4.4. Effect of daincha seed crop on adjacent rice rows under intercropping system

Retaining a few rows of daincha for seed production after *in situ* green manuring of intercropped daincha had a detrimental effect on rice by inhibiting yield components and yield. Details of yield components, grain yield, straw yield and light interception are depicted in Tables 58, 59 and 60.

4.4.1. Effect on yield components

Panicle numbers m^{-2} were severely restrained by the intercropped daincha for seed production, particularly on first adjacent rice row with values of 22.6 to 26.7 per cent in *kharif* 1999, 24.0 to 27.8 per cent in *rabi* 1999 and 26.1 to 30.1 per cent of reduction in *kharif* 2000 respectively relative to pooled net plot values, This was followed by second adjacent rice row from the daincha seed crop. Least reduction on panicle number m^{-2} was noticed in third adjacent row with value of 7.12 to 11.1 per cent in *kharif* 1999, 12.1 to 17.2 per cent in *rabi* 1999 and 12.0 to 16.6 per cent in *kharif* 2000 respectively.

Number of filled grains panicle⁻¹ was greatly differed among the rice rows. Heavy reduction was recorded in the first adjacent row with values of 15.4 to 21.7 per cent in *kharif* 1999, 16.7 to 20.2 in *rabi* 1999 and 17.9 to 25.2 per cent in *kharif* 2000 respectively relative to pooled net plot value, this was followed by second adjacent rice row. Least effect on filled grains was noticed in the third adjacent rice row (1.92 to 6.9 per cent in *kharif* 1999, 4.4 to 7.0 per cent and 5.3 to 10.3 per cent in *kharif* 2000 respectively).

Percentage of illfilled grains was also greatly affected by daincha seed crop, the highest percentage of illfilled grains being noticed in the first adjacent rice row, followed by second row. Least effect was observed in third row.

Table 58. Influence of daincha intercropping for seed production on yield, yield attributes and light interception (%) of rice during *kharif* 1999

Parameters	I ₂ = Every 10 th daincha row for seed production			I ₃ = Every 15 th daincha row for seed production			I ₄ = Every 20 th daincha row for seed production					
	Adjacent rows			Adjacent rows			Adjacent rows					
	I	II	III	I	II	III	I	II	III	Net plot value	Net plot value	Net plot value
No. panicle m ⁻²	326.0	353.0	391.0	421.0	321.0	349.0	388.0	428.0	317.0	345.0	386.0	434.0
No. filled grains panicle ⁻¹	88.0	95.0	102.0	104.0	86.0	94.0	106.0	110.0	90.0	98.0	107.0	115.0
No. illfilled grains panicle ⁻¹	19.0	18.4	15.3	14.2	18.7	17.3	15.5	13.1	19.8	18.1	15.9	11.5
Test weight	16.3	16.3	16.4	16.4	16.5	16.6	16.7	16.9	16.8	17.0	17.2	17.2
Grain yield m ⁻² (g)	337.0	359.0	411.0	536.3	331.0	356.0	409.0	570.3	327.0	353.0	407.0	598.0
Straw yield m ⁻² (g)	518.0	522.0	617.0	674.3	510.0	503.0	593.0	714.4	439.0	503.0	574.0	748.0
Light interception by rice crop												
Panicle initiation stage	54.9	57.4	58.7	59.0	54.3	58.1	58.9	63.0	53.9	57.3	57.8	65.2
Flowering stage	42.8	51.3	59.3	70.2	41.6	49.8	54.3	74.7	39.4	48.5	56.2	78.1
Milky stage	37.2	43.6	52.7	64.7	35.3	41.4	49.8	69.2	34.9	40.1	47.6	73.1

Data statistically not analysed.

Table 59. Influence of daincha intercropping for seed production on yield, yield attributes and light interception (%) of rice during *rabi* 1999

Parameters	I ₂ = Every 10 th daincha row for seed production			I ₃ = Every 15 th daincha row for seed production			I ₄ = Every 20 th daincha row for seed production					
	Adjacent rows			Adjacent rows			Adjacent rows					
	I	II	III	I	II	III	I	II	III			
No. panicle m ⁻²	307.0	319.0	353.0	404.0	304.0	314.0	349.0	409.0	302.0	314.0	346.0	418.0
No. filled grains panicle ⁻¹	75.0	79.0	86.0	90.0	77.0	81.0	88.0	94.0	80.0	85.0	93.0	100.0
No. illfilled grains panicle ⁻¹	19.8	18.2	15.4	14.8	20.4	18.7	16.4	13.2	20.7	19.3	16.5	11.9
Test weight	20.2	20.4	20.5	20.5	20.4	20.5	20.6	20.7	20.8	20.9	23.0	21.0
Grain yield m ⁻² (g)	262.0	304.0	341.0	456.3	259.0	301.0	346.0	484.0	269.0	306.0	343.0	514.5
Straw yield m ⁻² (g)	464.0	537.0	616.0	689.8	457.0	512.0	585.0	729.5	483.0	513.0	593.0	758.6
Light interception by rice crop												
Panicle initiation stage	69.4	72.4	73.0	73.5	74.3	76.3	77.0	77.2	76.3	78.9	79.3	81.0
Flowering stage	46.3	52.1	60.1	68.0	45.8	50.3	59.2	73.1	43.2	49.8	57.3	76.9
Milky stage	41.2	47.8	53.9	64.2	40.3	46.9	51.6	68.7	39.4	44.2	50.9	72.5

Data statistically not analysed.

Table 60. Influence of daincha intercropping for seed production on yield, yield attributes and light interception (%) of rice during *kharif* 2000

Parameters	I ₂ = Every 10 th daincha row for seed production			I ₃ = Every 15 th daincha row for seed production			I ₄ = Every 20 th daincha row for seed production					
	Adjacent rows			Adjacent rows			Adjacent rows					
	I	II	III	I	II	III	I	II	III			
No. panicle m ⁻²	320.0	338.0	381.0	433.0	317.0	341.0	380.0	443.0	316.0	340.0	377.0	452.0
No. filled grains panicle ⁻¹	78.0	82.0	90.0	95.0	81.0	86.0	94.0	101.0	80.0	87.0	96.0	107.0
No. illfilled grains panicle ⁻¹	18.4	16.8	15.3	14.1	19.0	17.3	15.5	13.2	19.1	17.5	15.8	11.7
Test weight	16.3	16.5	16.6	16.8	16.4	16.5	16.6	16.9	16.3	16.5	16.5	17.2
Grain yield m ⁻² (g)	307.0	353.0	402.0	543.0	305.0	374.0	401.0	578.0	304.0	375.0	399.0	625.0
Straw yield m ⁻² (g)	539.0	597.0	673.0	706.0	514.0	568.0	649.0	743.0	504.0	547.0	621.0	771.0
Light interception by rice crop												
Panicle initiation stage	50.4	53.1	54.2	54.4	51.7	54.2	55.9	58.1	51.1	54.9	56.3	60.7
Flowering stage	43.8	50.3	56.8	65.3	41.7	49.4	54.8	70.1	41.2	46.3	54.2	74.8
Milky stage	38.7	44.5	49.2	61.3	36.1	42.8	48.1	65.8	33.8	39.7	45.6	70.4

Data statistically not analysed.

Daincha seed production treatment did not greatly reduce test weight. From the first adjoining row to the second and third rows little differences were evident in respect of test weight compared to net plot test weight.

4.4.2. Grain yield (g/m^2)

Yield reduction in rice by daincha seed crop was more in the first adjacent rice row (37-45 per cent in *kharif* 1999, 42.5 to 47.7 per cent in *rabi* 1999 and 43.5 to 51.4 per cent in *kharif* 2000 respectively) than in net plot yield. Third row registered 25-34 per cent yield reduction over net plot yield irrespective of the seasons. Similar trend was noticed in straw yield also.

4.4.3. Light interception (%)

Intercropping daincha for seed production, greatly hindered light availability to adjacent rice rows. During panicle initiation stage, there was little difference in light interception among the adjacent rice rows and remaining rice rows irrespective of treatment as well as season. At flowering and maturity stages, greater reduction in light interception in first adjacent rice row was recorded followed by second and third rows in that order

Different seed production treatments (I_2 , I_3 and I_4) also exhibited a slight difference in light availability to the adjacent rice rows.

4.4.4. Monetary profit/loss of rice + daincha (seed crop) intercropping (Table 61)

Growing daincha for seed production after *in situ* green manuring had a greater yield reduction of adjacent rice row irrespective of the seasons. More yield reduction was noticed under every 10th daincha row for seed production and remaining rows for green manuring (I_2) (14.81, 15.30 and 16.10 per cent during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). This was followed by every 15th daincha row for seed production and remaining rows for green manuring (I_3). Least yield reduction was recorded in every 20th daincha row for seed production (I_4). Yield reduction of rice was compensated by intercropped daincha through seed production. Among the different rice + daincha (seed crop) intercropping systems, allowing every 20th daincha row for seed

Table 61. Monetary profit / loss of rice + daincha (seed crop) intercropping in wet seeded rice

Treatments	Yield reduction over I ₁ (%)	Yield reduction in rice over I ₁ (kg ha ⁻¹)	Value reduction in rice over I ₁ (Rs.ha ⁻¹)	Income from daincha seed crop (Rs.ha ⁻¹)	Profit (+)/ Loss(-) (Rs.ha ⁻¹)
Kharif 1999					
I ₂ = Rice + Daincha (every 10 th daincha row for SP and other rows for GM)	14.81	932	5359	4250	- 1109
I ₃ = Rice + Daincha (every 15 th daincha row for SP and other rows for GM)	9.40	592	3404	3425	+ 21
I ₄ = Rice + Daincha (every 20 th daincha row for SP and other rows for GM)	5.00	315	1811	2725	+ 914
Rabi 1999					
I ₂ = Rice + Daincha (every 10 th daincha row for SP and other rows for GM)	15.30	824	4738	3300	-1438
I ₃ = Rice + Daincha (every 15 th daincha row for SP and other rows for GM)	10.19	549	3157	2425	- 732
I ₄ = Rice + Daincha*(every 20 th daincha row for SP and other rows for GM)	4.49	242	1392	1850	+ 458
Kharif 2000					
I ₂ = Rice + Daincha (every 10 th daincha row for SP and other rows for GM)	16.10	1041	5986	4575	- 1411
I ₃ = Rice + Daincha (every 15 th daincha row for SP and other rows for GM)	10.61	686	3945	3625	- 320
I ₄ = Rice + Daincha (every 20 th daincha row for SP and other rows for GM)	3.40	220	1265	2925	+1660

I₁ = Daincha intercropping entirely for GM; GM = Green manuring; SP = Seed production; Data statistically not analysed.

production and remaining rows for green manuring gave additional profit of Rs.914, 458 and 1660 ha⁻¹ in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. Growing daincha as seed crop at every 10th row led to a net loss of Rs.1109, 1438 and 1411 ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively relative to rice + daincha entirely for green manuring alone (I₁).

Among the three seasons, *kharif* 2000 gave more profit of Rs.1660 ha⁻¹ through daincha seed production over rice + daincha intercropping for green manuring alone. *Rabi* 1999 resulted in lesser benefit from rice + daincha intercropping for seed production.

DISCUSSION

CHAPTER V

DISCUSSION

Towards realizing the objectives enumerated in Chapter I, field experiments were conducted and the salient results are discussed herein.

5.1. Seasonal influence

The weather parameters that prevailed during *kharif* 1999 and 2000 were more favourable and played a crucial role in augmenting rice yield. The maximum and minimum temperatures were 33.7 and 20.8°C during *kharif* 1999 and 32.8° and 22.1°C during *kharif* 2000 as against 32.7 and 18.1°C in *rabi*. Higher temperature coupled with bright sunshine hours during *kharif* season favoured tiller production, LAI and other growth parameters. The maximum temperature and sunshine hours that prevailed during reproductive phase might have influenced favourably various yield attributes in *kharif* season crop as compared to *rabi* season crop. The weather data clearly indicated the conducive conditions that prevailed during *kharif* season which resulted in higher yield. Krishnakumar (1986) and Deepa Thomas (1996) also reported similar effect of weather on rice yield.

5.2. Studies on green manure crop

In daincha, plant population and plant height were ideal at the time of its incorporation (37 DAS). This might be due to adoption of uniform seed rate irrespective of the daincha intercropping treatments. The daincha incorporation was completed in a day. N split treatments were imposed only after daincha incorporation.

Quantum of biomass addition (Table 5) greatly differed among the intercropping treatments because a few rows of daincha were retained for seed production after *in situ* incorporation. More biomass was added where daincha was grown purely for green manuring purpose (I₁). It was 6.13, 5.59 and 6.65 per cent higher than where every 20th row of daincha was retained for seed production and 15.33, 18.41 and 16.14 per cent higher than where every 10th row was retained for seed production in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively.

N accumulation also varied greatly with quantity of biomass produced. Daincha grown exclusively for green manuring (I_1) put forth more biomass resulting in more accumulation of N. This was followed by 20th row allowed for seed production (I_4). When compared with the treatment allowing every 10th row for seed production (I_2), higher N accumulation (11.9 to 13.1 kg N ha⁻¹) was observed in utilizing daincha entirely for green manuring (I_1). Retaining a few rows (10:1, 15:1 and 20:1) for seed production resulted in reduction of biomass addition as well as N contribution in all the seasons.

5.2. Studies on rice

5.2.1. Growth parameters

Plant height, number of tillers LAI and LAD were higher in sole rice (I_0) than in daincha intercropped treatments at active tillering stage. This might be due to vigorous growth of daincha after 30 DAS and the resultant partial smothering effect on the standing rice crop and competition for resource bases as opined by Sharma and Das (1994) and Abraham Varughese and Sushama Kumari (1993). Sole rice (I_0) exhibited lesser plant height at panicle initiation, flowering and maturity stages and lesser number of tillers at panicle initiation and flowering stages and lower LAI and LAD at flowering stage when compared to daincha intercropped treatments. This clearly shows that the initial suppression by the intercrop was compensated during subsequent growth stages by constant supplementation of N from *in situ* incorporated daincha and also applied fertilizer N, which might have triggered the growth, since N being a growth stimulant. Matiwade and Sheelavantar (1994) reported that green manuring along with 100 per cent N, substantially increased values of growth parameters in rice. The findings of Pathak and Sarkar (1994) and Vaiyapuri *et al.* (1998) are also in agreement with the results of the present investigation. The increased availability of NPK due to incorporation of green manure coupled with fertilizer N at distinct physiological phases might have favourably accelerated the growth characters as opined by them.

Split application of N influenced plant height, tiller number and LAI during *rabi* 1999 at active tillering stage alone and not in *khariif* seasons. This might be due to the time difference between short duration and medium duration rice varieties and stage

difference. There is sufficient time available in medium duration rice (ADT 38 in *rabi* 1999) to coincide with peak period of N release from *in situ* incorporated daincha (2 to 3 weeks) (Dey and Jain, 1997; Sihag and Singh, 1997). The active tillering stage in short duration rice was 44 DAS whereas in medium duration rice it was 53 DAS. Considering that daincha was incorporated 37 DAS the medium duration cultivar had an edge over the short duration cultivar.

At panicle initiation stage, the treatment N_3 (42 per cent N application at daincha incorporation) showed more plant height and tiller numbers. This might be due to higher level of N applied at daincha incorporation stage and this might have hastened N mineralisation (Rana *et al.*, 1998). Higher level of N applied at active tillering stage induced profuse tillering. This besides additional N supply from green manure resulted in maximum tillers in daincha intercropped treatments. Similar findings of higher tiller production with application of higher dose of N at initial crop growth stage was also reported by Siddeswaran (1992).

At flowering and maturity stages, both N_1 (four equal splits) and N_2 (33 per cent N application at daincha incorporation) were equally effective on plant height. This might be ascribed to the constant release of N from both four equal splits (N_1) and 33 per cent N application at daincha incorporation (N_2) than N_3 (42 per cent N application at daincha incorporation). N uptake was higher between panicle initiation and flowering stage and the higher level of N application which coincided with the cited stage might have greater effect on growth components of rice as opined by Babu (1995).

At flowering stage tiller number, LAI and LAD were higher in 42 per cent N applied treatment (N_3). Increased amount of N supply at vegetative stage of the crop would have produced taller plants with profuse tillering and enlarged leaves size as opined by Muralidharan (1996).

5.2.2. Chlorophyll content

SPAD meter readings were closely related to the chlorophyll content and in turn to the N concentration of the leaves which is an essential constituent of chlorophyll (Greenwood *et al.*, 1991).

At active tillering stage, sole rice registered higher SPAD values than rice + daincha intercropping treatments. This might be due to the greater competition for nutrient between rice and daincha at initial stages under dual cropping (Abraham Varughese and Sushama Kumari, 1993). At panicle initiation and flowering stages, the trend was reversed. Intercropped treatments had higher SPAD values due to adequate and continuous supply of N with minimal loss and subsequent increase in leaf N (Jayachandran and Veerabadran, 1996a).

Split application of N exhibited greater effect on SPAD reading. At active tillering stage, split application of 42 per cent N at daincha incorporation stage recorded higher SPAD values. This could be attributed to the application of urea, which on hydrolysis released inorganic N at a much faster rate resulting in higher leaf N (Pathak and Sarkar, 1994). Whereas, at panicle initiation and flowering stages the above N treatment failed to show more leaf N concentration in terms of SPAD values. Dingkuhn *et al.* (1991) reported that early N application led to fast initial growth which resulted in N dilution in the tissues leading to a high demand during panicle initiation. Panicle initiation to flowering stage is the most critical stage for N absorption at higher rate (Babu, 1995).

5.2.3. Dry matter production

At active tillering stage, sole crop of rice recorded higher DMP over daincha intercropped treatments. This might be due to the temporary shading as well as suppression of growth by intercropped daincha on rice. This corroborates the results of Sharma and Das (1994). At subsequent growth stages upto maturity, intercropping of daincha exclusively for green manuring purpose (I_1) recorded 10.4, 14.5 and 11.7 per cent increased DMP over sole rice in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively (Fig.5). As a result of higher LAI and increased CO_2 exchange and due to

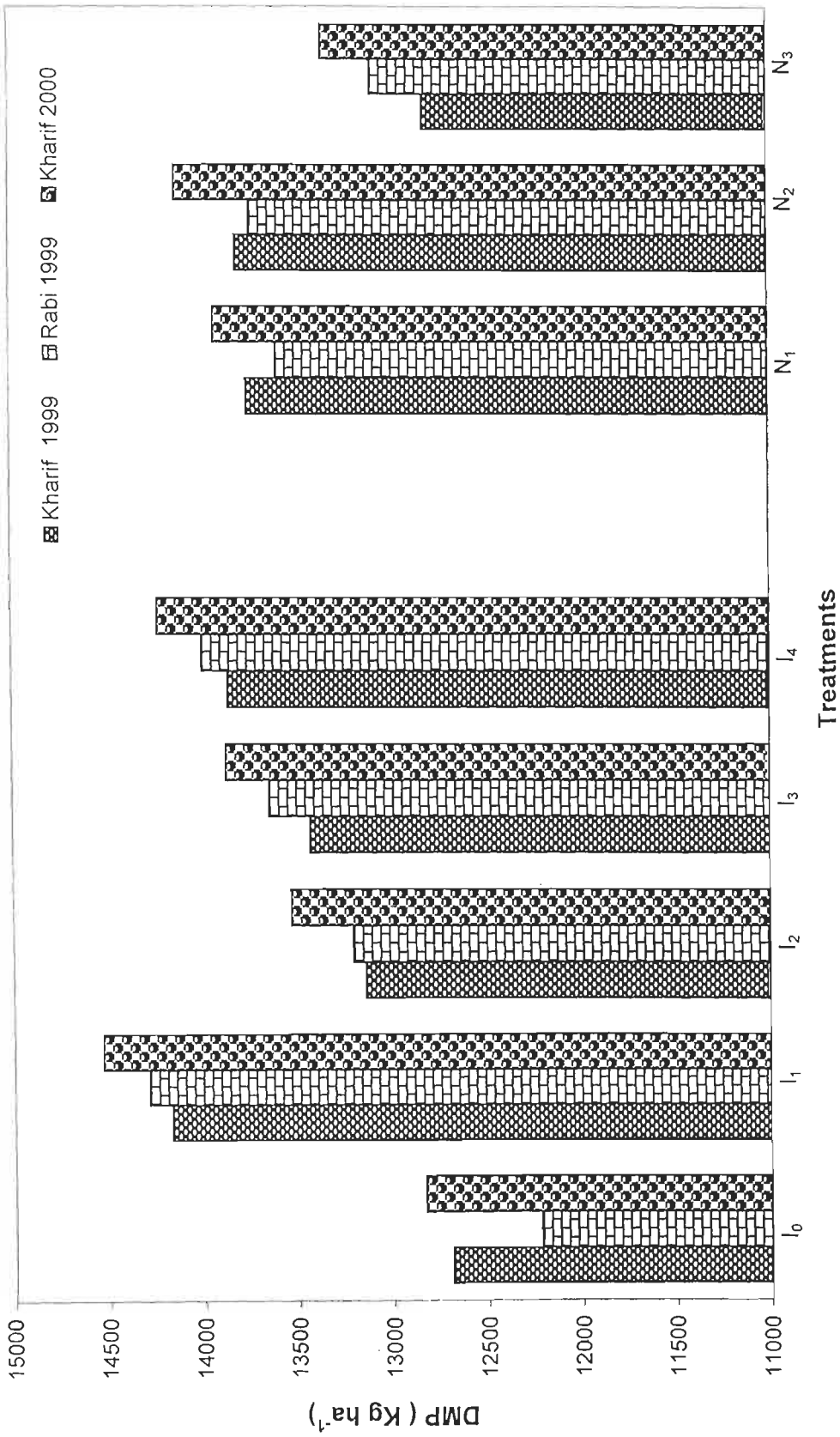


Fig.5. Influence of daincha intercropping/seed production and N split doses on dry matter production of rice at maturity stage

the synergistic influence of integrated use of green manure along with fertilizer N, the plant might have photosynthetically more active and contributed to greater biomass production (Siddeswaran, 1992; Somasundaram, *et al.*, 1996). Incorporation of green manure improves the physical properties of soil and favours vigorous root growth of rice (Aggarwal *et al.*, 1997). The reduction in the DMP in daincha seed production treatments (I₂ to I₄) might be due to competition for light. Tiller mortality as observed might have reduced the DMP during active vegetative growth stage (Lenka and Misra, 1980). Plant growth was indirectly reduced due to early senescence of vegetative organs (especially lower leaves) as a measure of translocation of minerals and carbohydrates to ears due to the uninterrupted carbon distribution inspite of mutual shading (Mitsuru Osaki *et al.*, 1995).

Though split application of N did not significantly influence the DMP of rice at active tillering stage, higher DMP of 6-7 per cent was recorded at maturity in 33 per cent N application at the time of daincha incorporation (N₂) than in 42 per cent N application at similar stage (N₃). The synchronized N release with crop demand might have resulted in greater influence on growth attributes, which ultimately maximized the DMP. Eventhough, 42 per cent N application at daincha incorporation exerted a prolific growth upto flowering stage probably due to faster N release from green manure coupled with higher dose of N added at daincha incorporation. Much reduction in fertilizer N supply during panicle initiation to flowering stages led to dilution of N and this stress of low N availability might have resulted in lower DMP (Dingkuhn *et al.*, 1991).

5.2. Nutrient uptake by crop

Nitrogen uptake is the product of N concentration and dry matter production and hence, it follows the pattern of DMP and N concentration. Sole rice (I₀) recorded higher NPK uptake at active tillering stage over daincha intercropped treatments. This might be attributed to the competition ushered in by the intercropped daincha as opined by Abraham Varughese and Sushama Kumari (1993). At later stages, intercropped daincha after incorporation might have constantly released N in addition to fertiliser N, resulting in better N availability and concomitantly maximized the N uptake (Ramanathan, 1995). Greater uptake of N was associated with the green manured plots as *S. aculeata* contains

appreciable quantity of N (2.5-2.7 per cent) which might have favoured the release of N for growth and uptake. This corroborates with the finding of Padmavathy (1992). Apart from this, biological N supply made by decomposition of incorporated *Sesbania* might have enabled the crop to absorb more amount of available N (Rangasamy *et al.*, 1997; Vaiyapuri *et al.*, 1998).

Split application of N showed that application of 33 per cent N at daincha incorporation (N_2) and equal splits (N_1) recorded more N uptake at maturity. This might be due to steady or continuous supply of N at initial stages that synchronized with peak nutrient requirement of the crop, which might have resulted in higher amount of N uptake. N uptake was greater during 61 days after seedling emergence and again 4 weeks before maturity (panicle initiation to flowering stage). After that, the nutrient uptake decreased steeply as opined by Sims and Place (1968). Influence of treatments on N uptake was depicted in Fig.6.

Daincha intercropping for green manuring coupled with inorganic fertilizer N application in different splits had shown significant differences in P and K uptake at flowering and maturity stages. This might be due to increased DMP (Medhi and De Datta, 1993). The increased P availability might also be due to the organic acids produced during the decomposition of organic matter in flooded soils resulting in mineralization of insoluble iron phosphate into more soluble phosphorus, which in turn might have favoured better P uptake (Sreedevi and Thangamuthu, 1991). The lower P uptake under daincha seed production treatments might be the result of competition for P from the daincha seed crop, as legumes normally deplete more P for pod setting. The increase in K availability and uptake could also be due to the priming effect of K besides the direct contribution by green manures (Deepa Thomas, 1996).

5.3. Yield components and yield

5.3.1. Yield components

The yield potential of rice is determined by yield components and the values of yield components are generally in accordance with that of growth parameters. This was reflected in the present investigation also.

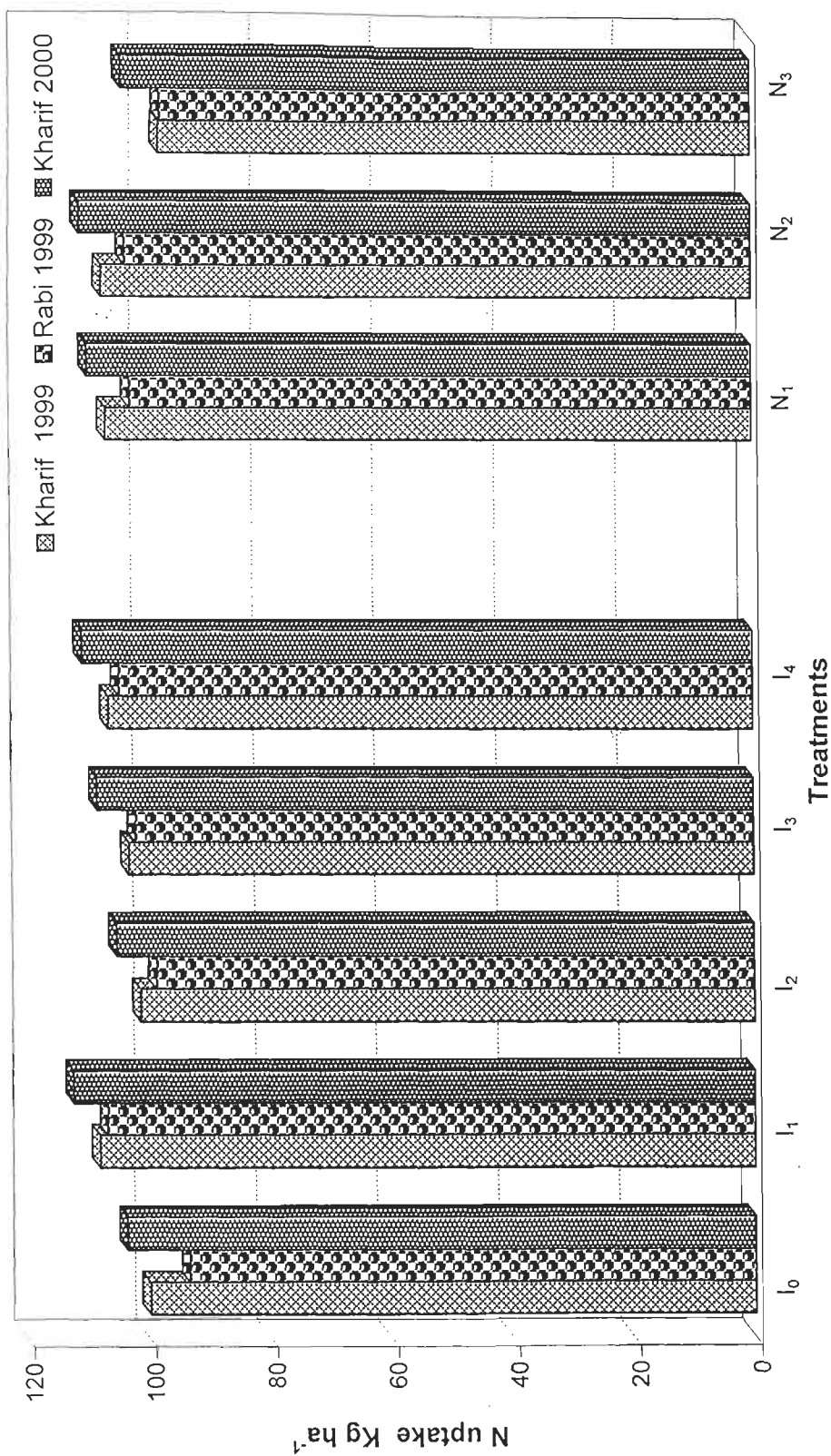


Fig.6. Influence of daincha intercropping/seed production and N split doses on nitrogen uptake by rice at maturity stage

The yield components exhibited superiority in I_1 (daincha entirely for GM) compared to the remaining treatments (Fig.7). This might be due to *in situ* incorporation of daincha as observed by Solaiappan and Veerabadrán (1997) and Joseph (1998). Higher N (both organic source as well as fertiliser N) and the resultant higher nutrient uptake, might have delayed senescence and increased photosynthetic efficiency which ultimately led to increased number of productive tillers (Yoshida, 1981). The greater contribution of carbohydrate from current photosynthesis consequently increased the number of filled grains per panicle (Reddy and Reddy, 1989).

The reduction in panicle number as well as filled grains and increase in illfilled grains (Fig.8) under intercropped daincha (seed crop), might be due to competition for light. Shading during active tillering to panicle initiation stage had effected greater reduction in productive tillers, panicle length and grains per panicle, whereas during panicle initiation to flowering stage there was a decrease in grain fertility and grain weight (Lenka and Misra, 1980; Roy *et al.*, 1998a).

Split application of 33 per cent N at daincha incorporation (N_2) registered superiority in yield components, which was closely followed by four equal split applications (N_1). The uninterrupted supply of N in adequate amount in these treatments might have favoured yield components. Steady supply of N with different split levels synchronizing with peak requirement of N for rice crop, exclusively during panicle initiation to flowering stage, resulted in positive influence on yield components. Nitrogen top dressing at booting and heading stages also would increase yield components compared to higher dose of N application upto vegetative stage (Pandey *et al.*, 1997b). Availability of adequate N promotes the supply of assimilates to sink thus increasing the number of spikelets and filled grains. Application of higher level of N at daincha incorporation failed to evoke positive effects on yield components. This might be due to heavy dilution of N at flowering stage because of higher demand for N during panicle initiation to flowering stage (Dingkuhn *et al.*, 1991). The huge addition of N at incorporation might have led to profuse tillering in the early stage and tiller mortality in the later stage (Pradeep Prasad *et al.*, 1994) which might be the reason for lower values of

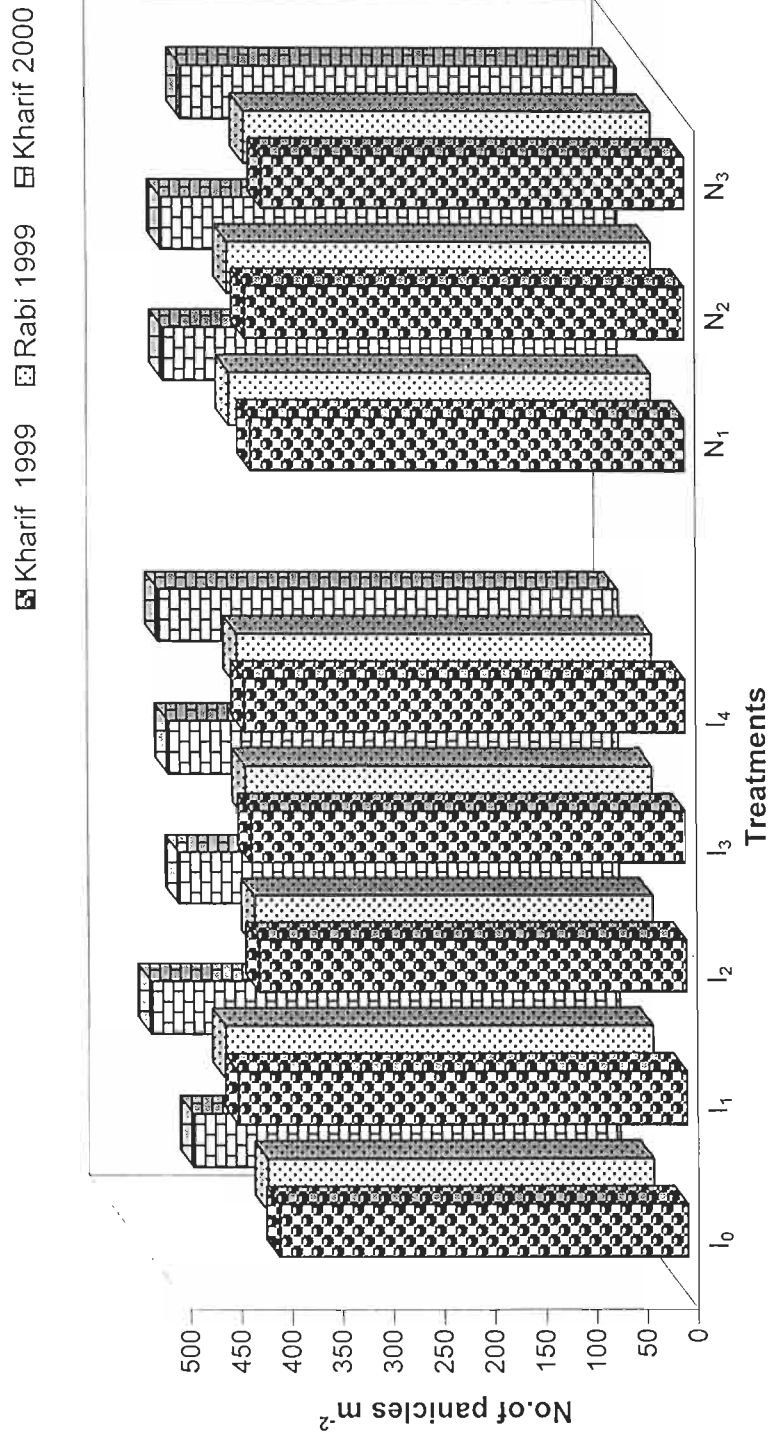


Fig.7. Influence of daincha intercropping/seed production and N split doses on number of panicles m^{-2} of rice

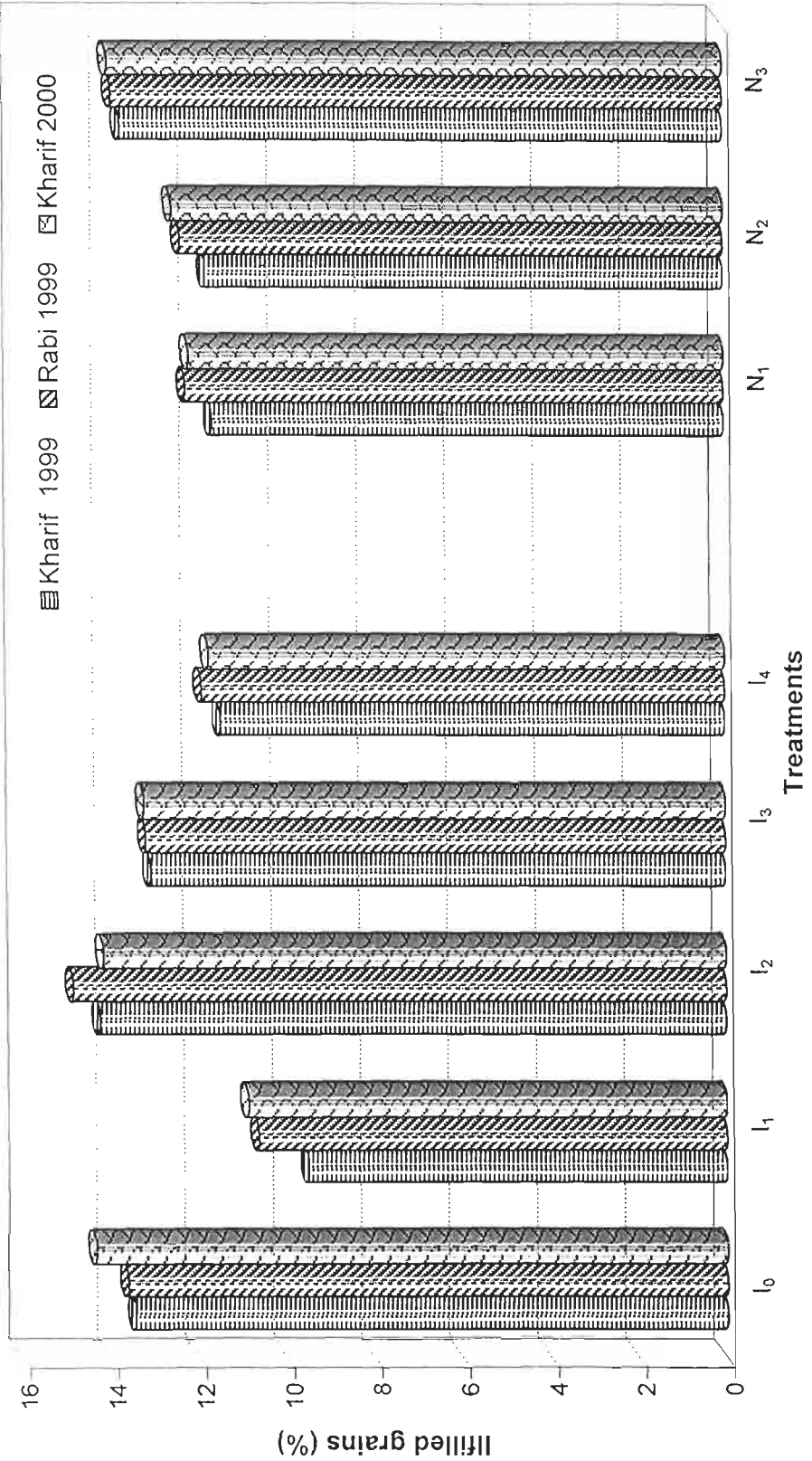


Fig.8. Influence of daincha intercropping/seed production and N split doses on percentage of illfilled grains

yield components in N_3 (42 per cent N application at daincha incorporation) in the present study.

5.3.2. Grain and straw yield

Daincha intercropping in wet seeded rice increased grain and straw yields when compared to sole rice (Fig.9). The treatment I_1 (daincha entirely for green manuring) recorded increased rice yield of 20.1, 20.0 and 17.3 per cent over sole rice and 14.8, 15.3 and 16.1 per cent over I_2 in *kharif* 1999, *rabi* 1999 and *kharif* 2000 seasons respectively closely followed by I_4 (20th row of daincha for seed production). Intercropping *sesbania* in wet seeded rice added a higher biomass, thereby supplementing the N need of rice crop and imparting a synergistic effect between organic source of N and fertilizer N. This phenomenon could have promoted the growth components and helped in the development of a better source-sink relationship that ultimately maximized the yield determinants as well as grain and straw yields in the green manured plots. These results are in agreement with the findings of Gracy Mathew *et al.* (1991), Herrera and Garrity (1993) and Bayan (2000). The constant N release from organic source supplemented with inorganic source would have satisfied the rice crop demand at every phenophase after complete decomposition and mineralization of nutrient sources as opined by Talukdar *et al.* (1996). Green manuring also increased the post-anthesis leaf area duration, by which, the accumulation of photosynthates increased (Peltonen Saino *et al.*, 1997). By increasing LAD, the source activity was extended and the assimilate availability to the sink increased.

Rice yield reduction in plots where daincha was grown for seed production especially at narrow ratio (10:1) to the extent of 14.8, 15.3 and 16.1 per cent over I_1 (daincha grown entirely for green manuring) in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively might be due to disturbance in the normal light availability to the rice crop particularly the adjacent paddy rows. Chauhan (1994) recorded that shading at 40 and 60 per cent levels reduced the yield components namely percentage of filled grains, whereas 1000 grain weight remained unaffected. The findings of Lenka and Misra (1980) and Roy *et al.* (1998b) indicated a greater reduction in effective tillers, grains per panicle, panicle length and grain yield due to shading during active vegetative and that of

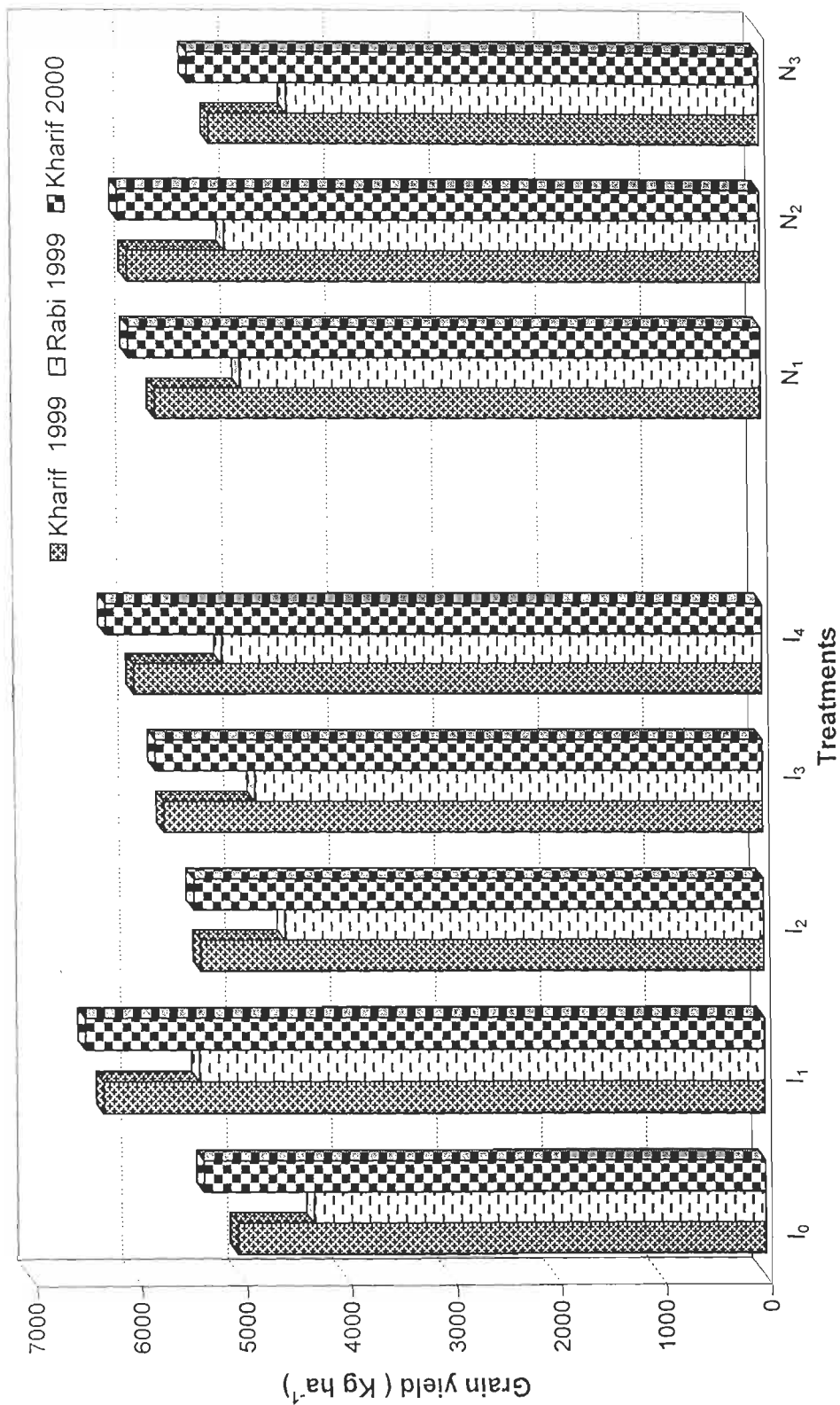


Fig.9. Influence of daincha intercropping/seed production and N split doses on Grain yield of rice

reproductive stage. However, Jha *et al.* (1989) reported that 15:1 and 20:1 rice + daincha seed crop did not affect rice yield. The present investigation is at variance with the findings of Sirajul Islam *et al.* (1999) who reported that daincha seed production in rice did not affect the rice yield.

Nitrogen is known to improve grain production, since it is a prime substrate for synthesis of organic N compounds which constitute protoplasm and chloroplasts (Yoshida and Oritani, 1974; Beringer, 1980). Split application of 33 per cent at daincha incorporation (N_2) and four equal splits (N_1) performed equally in terms of grain and straw yields except during *kharif* 1999. Increased yield was noticed in N_2 (13.0, 11.8 and 10.9 per cent) over N_3 during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. This could be attributed due to the top dressing of N at panicle initiation stage enhanced the assimilates from the flag leaf during ripening stage (Yong-Rui Wang and Ying-Jie-Zhang, 1995). The results of Bhattacharyya and Singh (1992) revealed that four equal splits significantly increased grain yield.

The above results clearly indicated that there was no need to increase the N level at daincha incorporation stage because both the application of four equal splits and 33 per cent N application performed equally in respect of most of growth and yield attributes. The performance of these two treatments clearly indicate that application of N at relatively higher dose during daincha incorporation is prone to losses (Budhar, 1994) and also which could lead to shortage of N requirement during later stages (Dingkuhn *et al.*, 1991).

The combined effect of daincha and urea application as in I_1N_1 resulted in higher grain and straw yields. This might be due to the synergistic effect of organic N from intercropped daincha as well as timely applied inorganic N (Rekhi and Bajwa, 1994; Das *et al.*, 1998). This indicates that decomposition and transformation of organic N in combination with fertilizer N (urea) proceeded in a predictable path.

5.3.3. Rice yield equivalent

In the intercropped situation, the yield of different crops cannot be compared. So, the production potential of different crops (rice and daincha seed crop) was evaluated in terms of rice yield equivalent. Intercropping daincha in wet seeded rice for green manuring cum seed production at 20:1 ratio (I_4) gave higher rice yield equivalent of 2.5, 1.5 and 4.3 per cent over I_1 in *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively. Eventhough I_1 recorded higher grain yield than I_4 , the yield reduction in I_4 was compensated by daincha seed yield as the market value of daincha seed was 3 to 4 times higher than rice grain value. Growing daincha for seed purpose at 20:1 ratio did not affect rice yield equivalent in the present study. Jha *et al.* (1989) also reported that allowing 15:1 and 20:1 row ratio of daincha for seed production in rice did not affect the rice yield.

The different N split applications did not affect daincha seed yield. Accordingly, the magnitude of differences in rice yield equivalent among, the treatments was solely dependent on rice yield only.

The treatment combination of I_4 with N_2 recorded higher rice yield equivalent due to higher grain yield as well as seed yield of daincha with least effect on rice.

5.4. Nitrogen use efficiency

Various parameters namely, agronomic efficiency, apparent recovery and partial factor productivity were applied to determine the nutrient use efficiency (NUE). It was greatly altered by N application through inorganic source, and combined application of both organic and inorganic sources under rice + daincha intercropping.

Agronomic efficiency, which indicates the quantity of rice grain produced per unit of N applied, is the product of efficiency of N absorption as well as its utilization (Fig.10). Apparent recovery indicates the efficiency of absorption of applied N (Fig.11). Whereas, partial factor productivity is the simplest way to find out the NUE, in which the quantity of grain yield/unit of total N applied (without considering control yield) is determined (Fig.12).

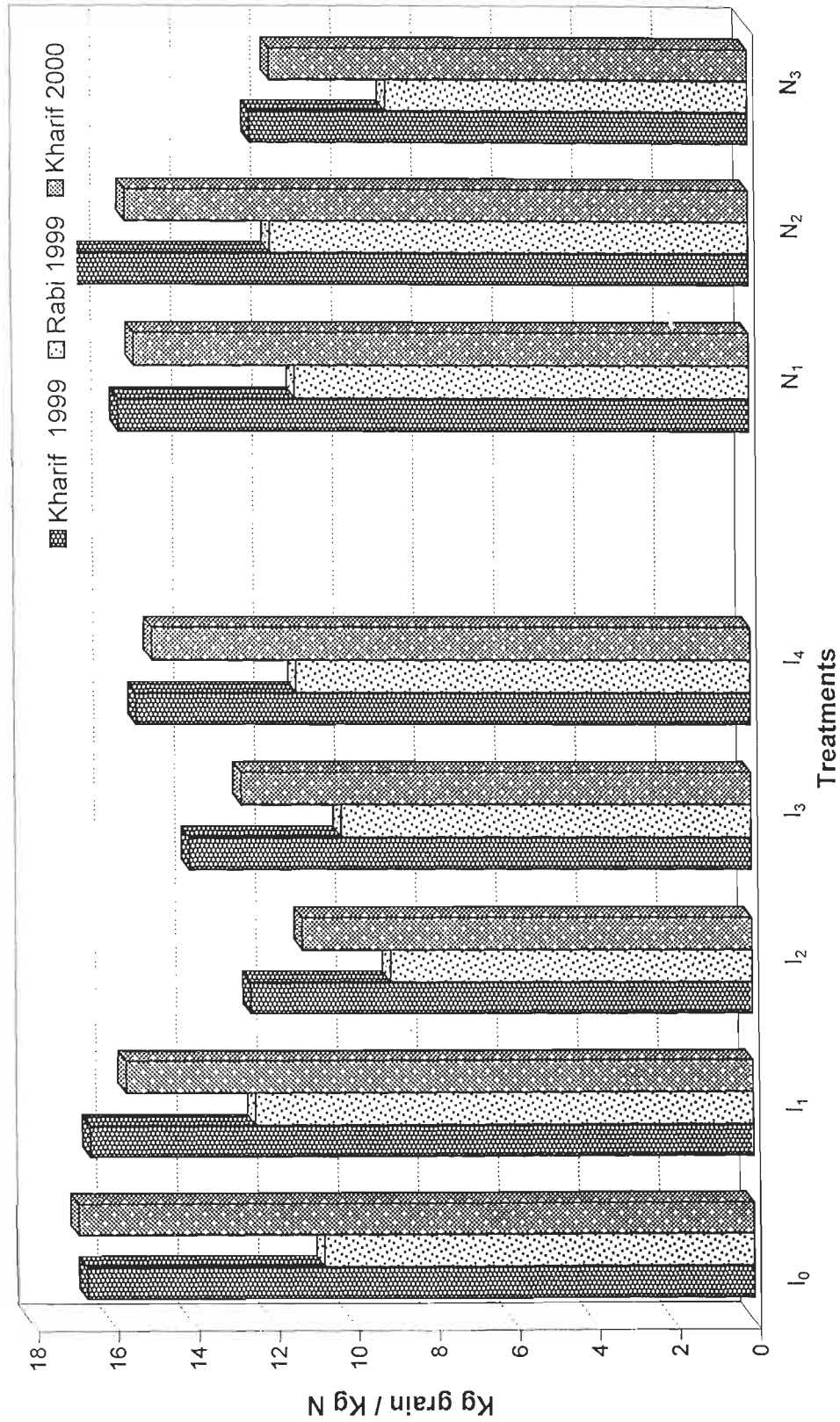


Fig.10. Influence of daincha intercropping/seed production and N split doses on agronomic efficiency

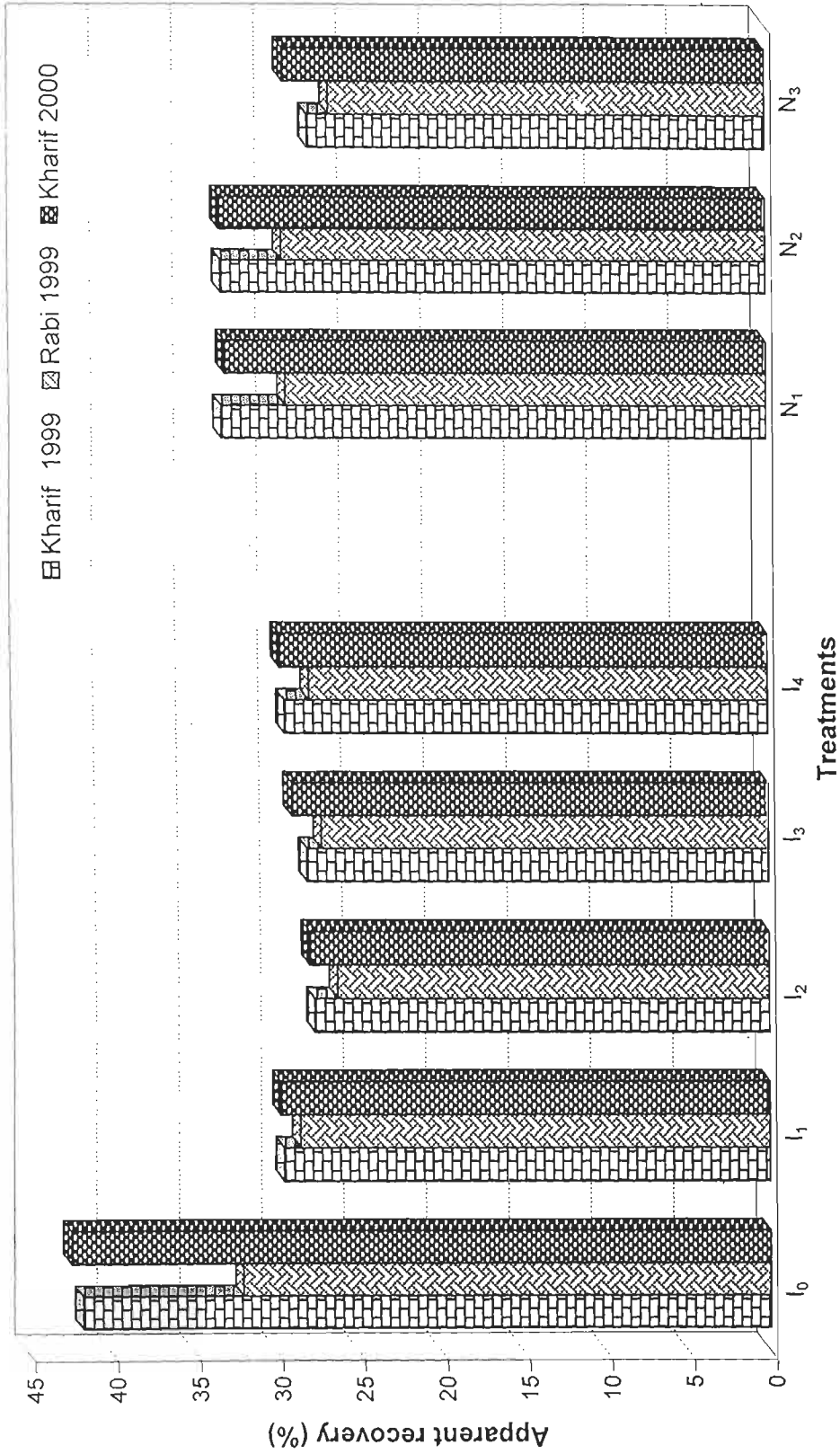


Fig.11. Influence of daincha intercropping/seed production and N split doses on apparent recovery

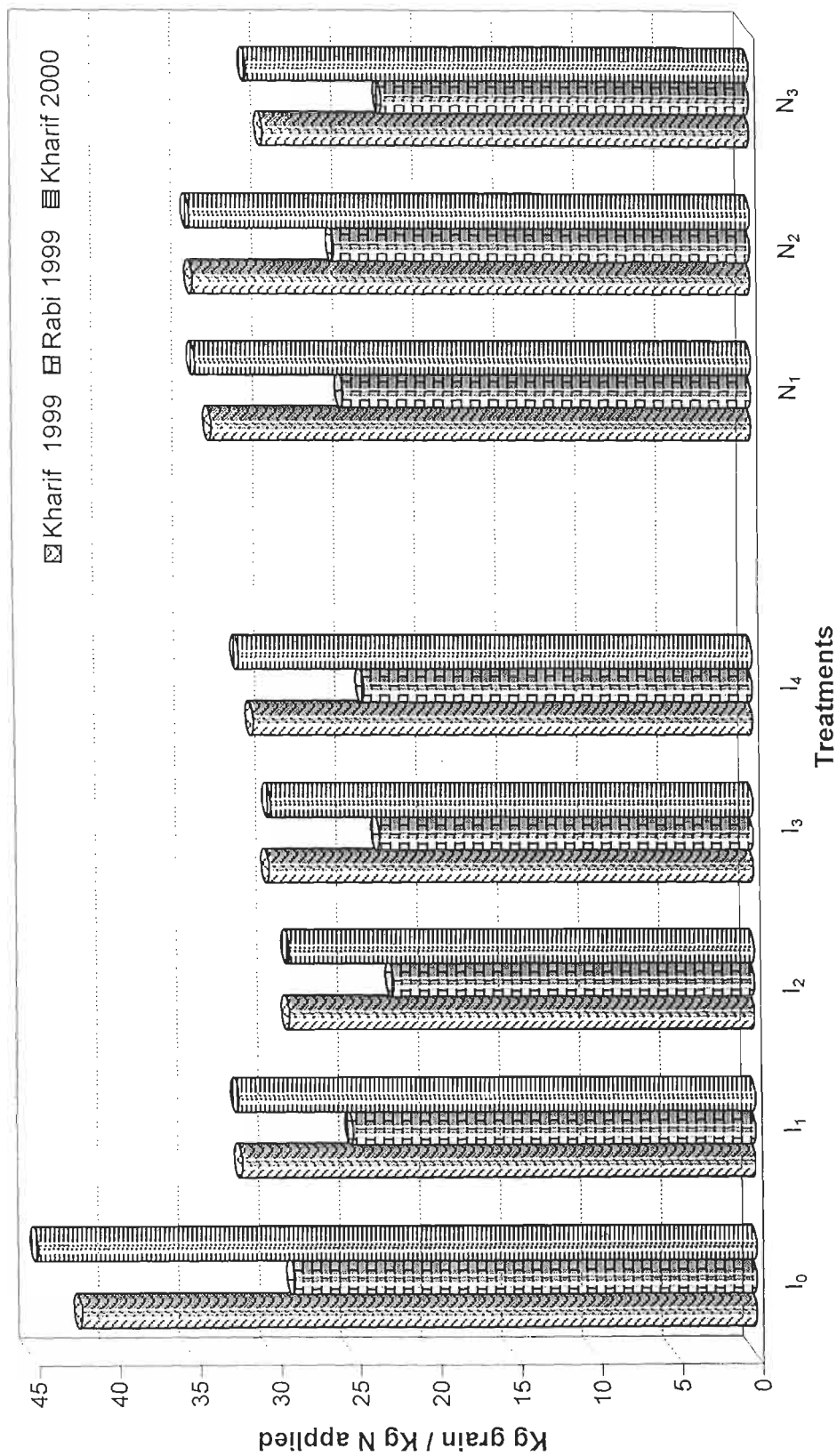


Fig.12. Influence of daincha intercropping/seed production and N split doses on partial factor productivity

Higher NUE was registered in sole rice (I_0) than in rice + daincha intercropping for a given level of inorganic N. Lower values of NUE associated with green manure in the present study, could be explained as follows. While intercropping daincha in wet seeded rice and *in situ* incorporation contributes additional N, besides N applied through inorganic source uniformly to both sole as well as rice + daincha intercropping system, this led to higher level of N added under rice + daincha intercropping treatments (I_1 to I_4). Usually, higher NUE is associated with lower level of N and it tends to decline progressively with additional levels of N (Krishnakumar and Subramanian, 1991). They also opined that rice plant was unable to utilize the major portion of N applied at higher doses as there were chances for appreciable loss of applied N.

In the presence of green manuring, the efficiency was further decreased as N supply was increased by green manuring. This result is in consonance with the findings of Srinivasulu Reddy (1988). The increasing levels of N both recommended N along with green manure addition reduced the efficiency of applied N through wastage (Garrity and Becker, 1994).

Among rice + daincha intercropping treatments, allowing a few rows of daincha for seed production, further reduced the efficiency of applied N. This might be attributed to yield reduction caused by shade effect of daincha seed crop.

With regard to N splits, both 33 per cent N application at daincha incorporation (N_2) stage and four equal splits (N_1) performed more or less similarly and were better than 42 per cent N application at daincha incorporation (N_3). Increased level of N application through fertilizer N would increase the nutrient losses and decrease the N efficiency corresponding to utilization efficiency (De Datta, 1987). N uptake in rice was higher during panicle initiation to flowering stages rather than at vegetative stage (Alagesan, 1997). The ultimate N uptake will be determined by the daily N demand of crop and N supply synchronous with that demand. Application of higher quantity at vegetative stage led to poor recovery of applied N because of loss in soil due to the non-demand period and also unable to utilize the inherent supply from soil (Thomas

George *et al.*, 1998). Higher level of N applied particularly at active tillering stages was subject to various N losses in the present study also.

5.5. Soil fertility

Daincha intercrop, raised in rice for green manuring, failed to improve the organic carbon status as well as available soil N and P at active tillering stage during *kharif* season, whereas in *rabi* crop slight improvement in organic carbon was noticed. This might be due to the lag period taken for humification (2-3 weeks) for the N release from the incorporated green manures (Buresh *et al.*, 1993). Under such situation, coincidence of peak N release with active tillering stage was noticed in the medium duration rice varieties, grown during *rabi* season. During *kharif* season only a short duration variety was grown.

From panicle initiation to maturity stages, higher level of soil organic carbon status was observed irrespective of daincha intercropping treatments. This might be due to the contribution of organic carbon by *Sesbania* sp. Build up of organic carbon in soil due to green manuring has been reported by Deka Medhi and De Datta (1996) and Gurung and Sherchan (1996) in rice soil ecosystem. Green manures contain two fractions of which, one undergoes faster decomposition and release of N for the current crop while the other does so at slower rate. Enhanced carbon status of the soil has been attributed to the latter fraction (Bouldin, 1988).

Increasing the level of N (N_3) application at daincha incorporation stage hastened the mineralization process thereby reducing the organic carbon status in the soil at later stages. But, higher level of organic carbon was noticed in four equal split applications (N_1). This might be due to uniform application of N in a phased manner without incurring any loss as experienced in the N_3 (42 per cent at daincha incorporation) treatment which became prone for leaching and volatilization losses (Dingkuhn *et al.*, 1991).

Low organic carbon and soil N were found in plots that received fertilizer N alone (I_0) showing that fertility build up by fertilizer application is likely to be lower than that with use of organic manures (Sanjay Sharma *et al.*, 2000).

Available soil N was higher in daincha intercropped plots during panicle initiation to maturity stages (Fig.13). This might be due to considerable addition of available N in the intercropped plots (33, 26 and 37 kg N ha⁻¹ during *kharif* 1999, *rabi* 1999 and *kharif* 2000 respectively). Besides release of N from the incorporated green manure, further mineralization also enhanced the soil available N status. The leguminous green manures grown in rice can forage soil mineral N which might otherwise be lost by denitrification (or) leaching (Singh, 1984). Build up of soil available N with green manuring is in consonance with the findings of Salu Reddy *et al.*(1995) and Tiwari *et al.* (1995). Legume crop also demands more amount of N during reproductive stage. Hence, soil application of N had improved the yield in leguminous crops as opined by Thangaraju (2000). In accordance with this, the daincha seed crop also exhibited a decrease in available soil N in the respective plots. This might be due to partial utilization of N from the soil besides self reliance on N requirement of the leguminous crops.

Likewise, higher soil N was noticed in the four equal split (N_1) applications of N, but during early stage, 42 per cent N application (N_3) recorded higher available soil N. This might be due to the higher amount of fertilizer N application which made N availability in plenty but the high N was prone to volatilization and leaching losses. Whereas, the equal split treatment supplied N in coincidence with the N requirements of the wet seeded rice (Alagesan, 1997).

Available soil P was also greatly influenced by the daincha intercropping treatments from panicle initiation to maturity stages (Fig.14). This might be due to P contribution from the added biomass and by acid solubilization of native P during the decomposition (Lekha Sreekantan, 1987; Cosico, 1990). Allowing a few rows of daincha for seed production had shown greater reduction in the availability of soil P. This might be due to the uptake of P by daincha seed crop, particularly during reproductive phase. More over, legumes are prolific P loving crops(Ravi ,1998). Lowest available soil P was

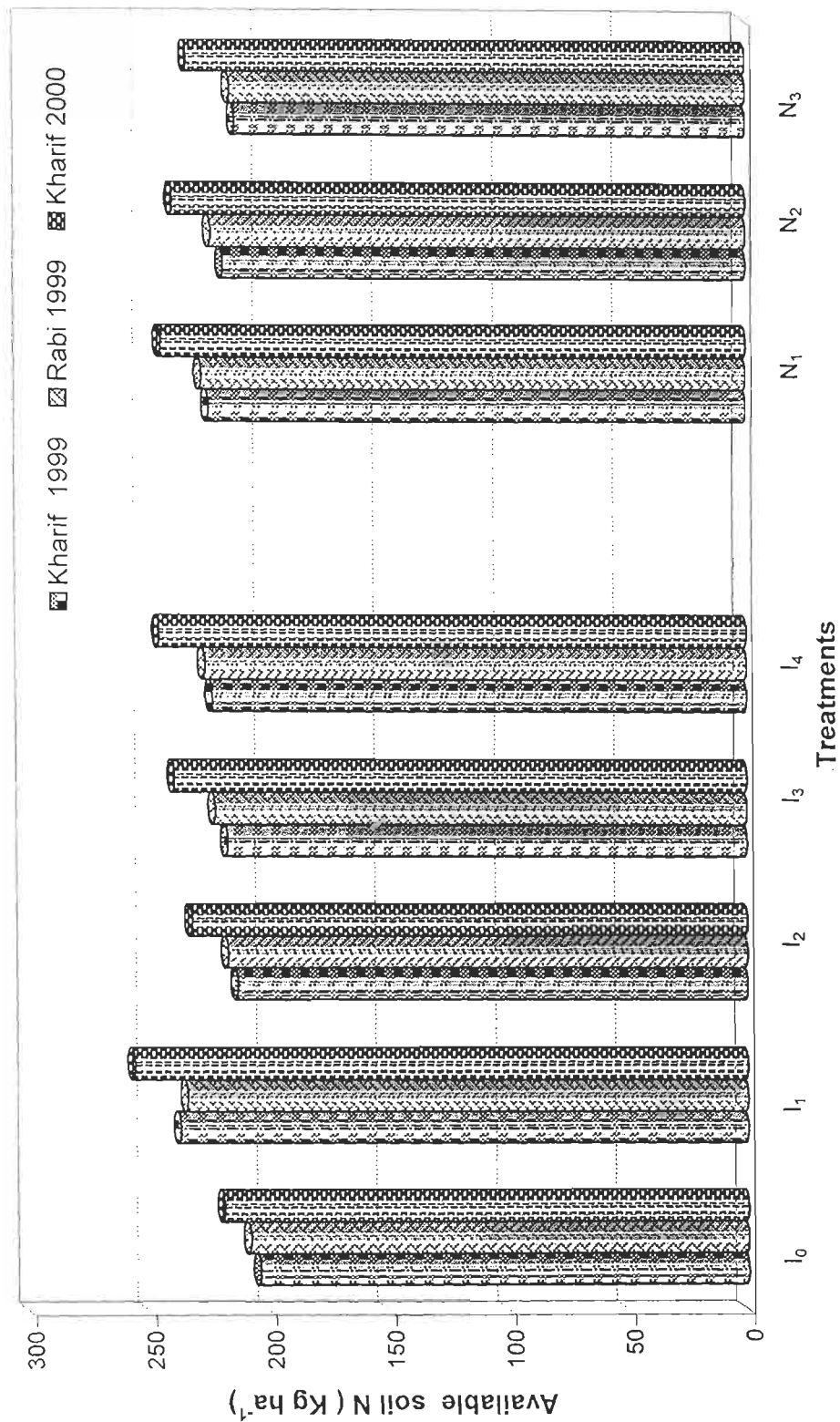


Fig.13. Influence of daincha intercropping/seed production and N split doses on available post harvest soil N

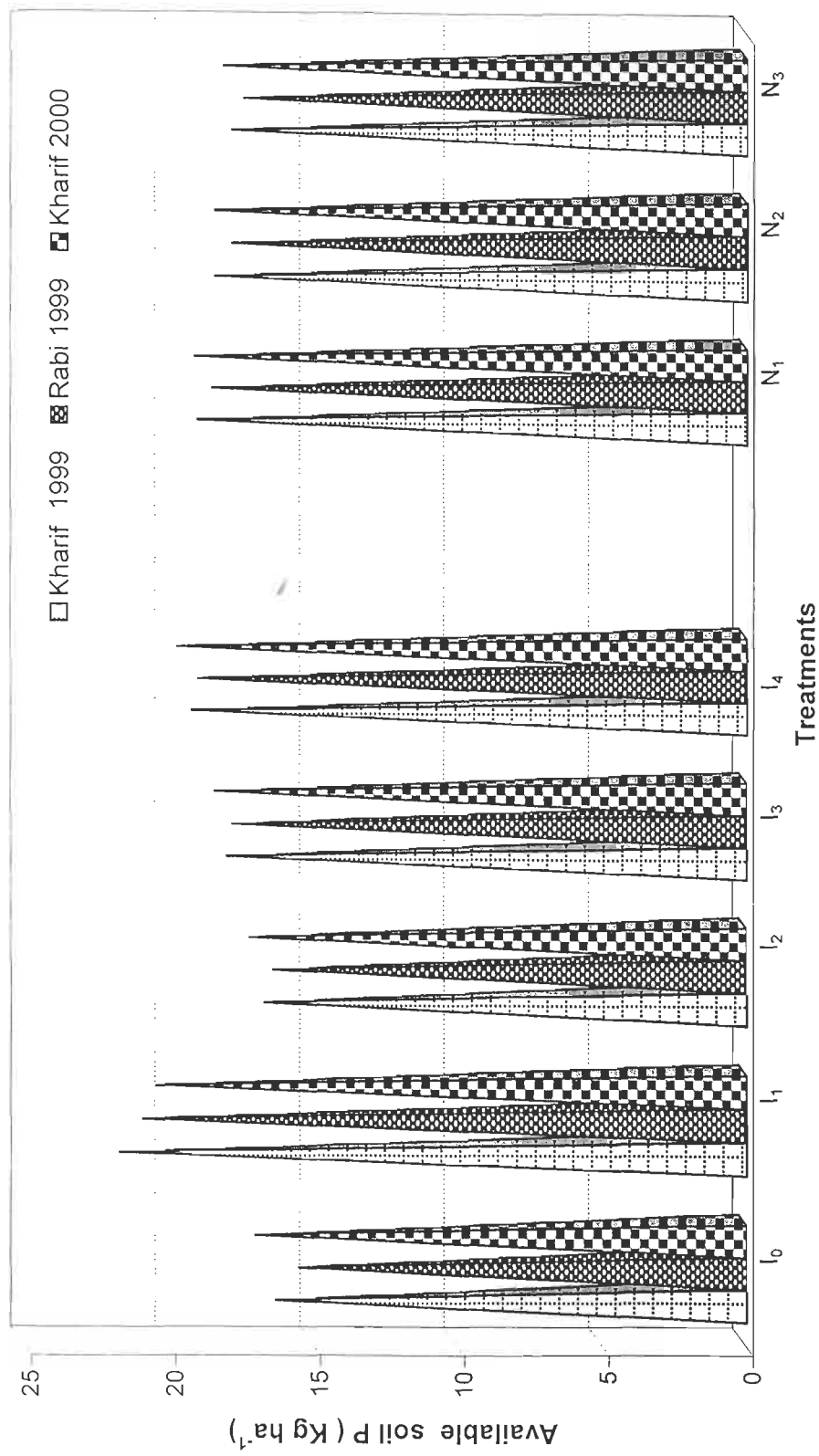


Fig.14. Influence of daincha intercropping/seed production and N split doses on post harvest available soil P

recorded in the triple blooming (extended growth of green gram) crop relative to single crop. This is attributed to the higher uptake of P and efficient utilization of externally applied P for higher productivity of the pulses. *Sesbania*, as sole crop was observed to make use of applied P from soil more efficiently than other green manures. In general, green manure crops have the ability to absorb more P from the soil (Mappaona *et al.*, 1995).

Available K was more under sole rice than in green manure amended plots. A decline in soil available K was recorded with increased inorganic and organic N and this was due to higher amount of K uptake proportionate to N uptake. This might be also due to improvement of soil physical properties following addition of green manures which might have facilitated better root growth with higher N supply (Priming effect on K) that had hastened higher K uptake from the soil, which ultimately resulted in decline in the soil K status (Biswal, 2000). The seed production treatments and N split applications did not show any significant difference in available soil K status at harvest.

5.6. Light interception

During early stage prior to daincha incorporation, light interception was notably high in rice + daincha dual cropping. This finding is in accordance with the observation made by Srinivasan (1996). Total light interception by the crop canopy increased, when the plant density was increased as opined by Begna *et al.*(1997). At panicle initiation stage, higher light interception was noticed under I₁ (Rice + daincha entirely for green manuring) followed by I₄. This might be due to the enhanced values of growth components through synchronized N supply, realized from both organic and inorganic sources as opined by Joseph (1998).

At flowering and milky stages, the daincha rows retained for seed production greatly affected the light availability to the base crop, thereby, reducing the light utilization by rice crop. Narrow row ratio (every 10th daincha row for seed production) had a greater reduction in light utilization by rice crop. This might be due to the shade effect caused by the tall and profusely branched daincha seed crop. The extended duration of daincha seed crop prolonged the duration of shading upto the reproductive

stage of rice crop. Thirumavalavan (1989) reported that 2:1, rice + black gram intercropping at Coimbatore condition caused severe reduction in light availability to rice by 56 per cent compared to sole rice. In the present investigation, the reduction in light availability to rice from narrow row ratio of rice + daincha seed crop (I_2) over I_1 (rice + daincha for green manuring alone) was 24 to 29 per cent at flowering stage and 32 to 34 per cent at milky stage. Influence of treatments on light interception by rice at milky stage was depicted in Fig.15.

5.7. Economic evaluation

Influence of intercropping on net income (Fig.16) and BCR was conspicuous in all the three seasons studied. Rice + daincha intercropping (every 20th daincha row for seed production) (I_4) gave higher net income as well as BCR, which was followed by I_1 (rice + daincha entirely for green manuring alone). The treatment I_4 comprised two crops namely rice and daincha seed crop. The additional income from the seed crop of daincha contributed more towards the net income and BCR in I_4 (every 20th daincha row for seed production and remaining rows for green manuring). Split application of N exhibited differences in net income and BCR. The treatment N_2 proved superior to N_3 . The higher net income and BCR, when 33 per cent N was applied at the time of daincha incorporation, which might be due to the cumulative influence of growth and yield determinants on grain yield of rice.

The treatment combination of growing rice + daincha (every 20th daincha row for seed production and the other rows for green manure biomass production) (I_4) and split application of N (25:33:21:21 per cent at 20, 37, 55 and 70 DAS respectively) (N_2) came into sharp focus among the various treatments from the standpoint of fetching higher monetary advantage. This was due to higher rice yield from N_2 as well as I_4 coupled with additional income from daincha seed production that contributed towards higher net income and BCR.

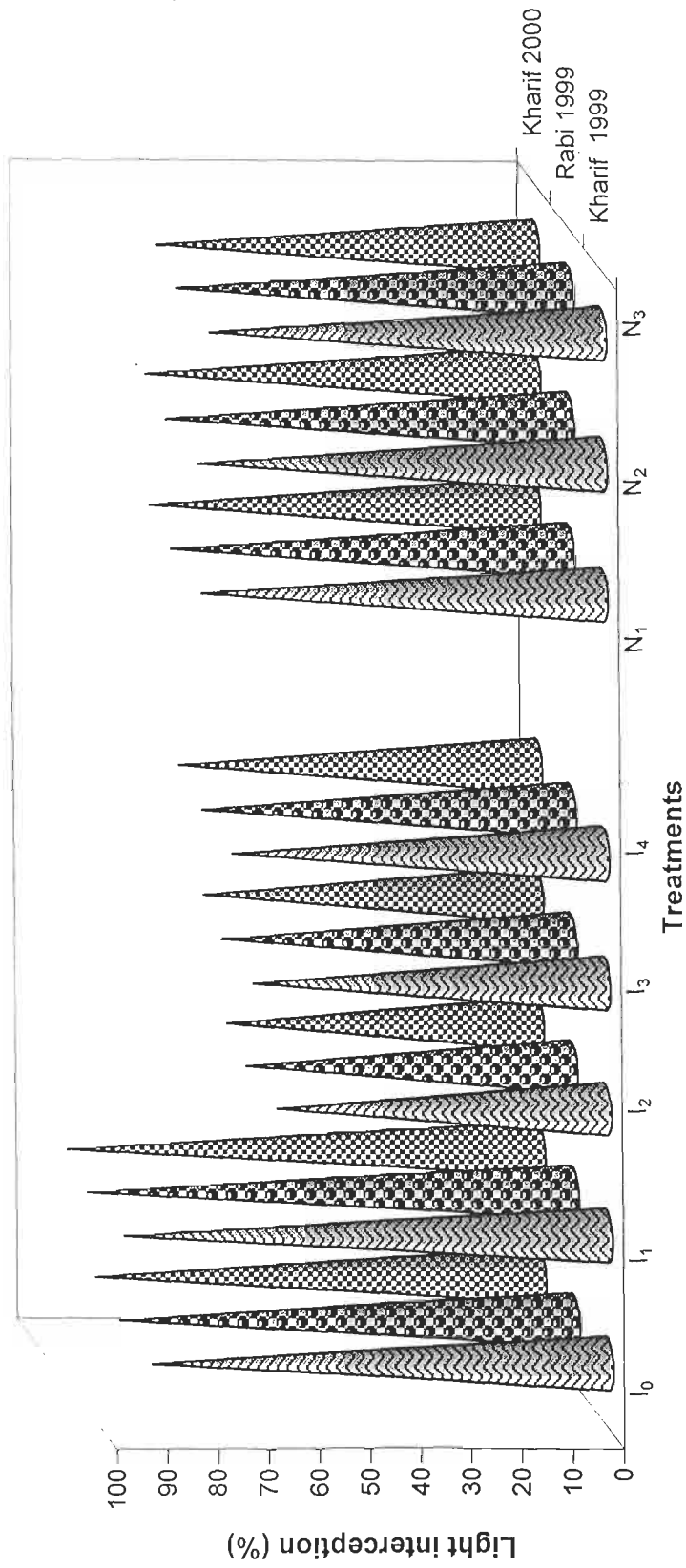


Fig.15. Influence of daincha intercropping/seed production and N split doses on light interception(%) at milky stage of rice

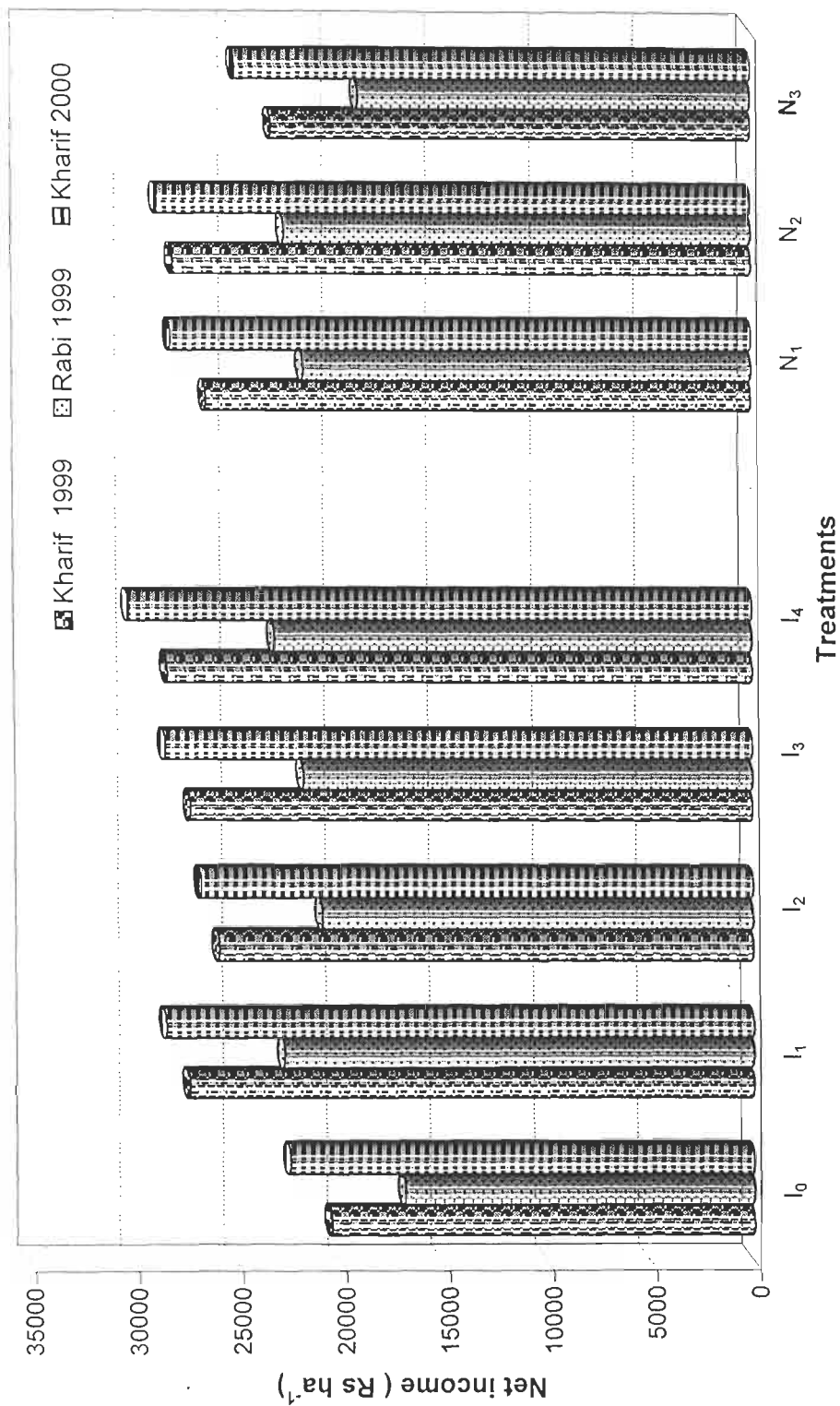


Fig. 16. Influence of daincha intercropping/seed production and N split doses on net income of rice

5.8. Daincha seed crop

5.8.1. Growth components

Intercropping daincha for green manuring cum seed production (retaining every 20th, 15th and 20th daincha rows for seed production) influenced growth components. Every 20th daincha row for seed production treatment had taller plants, more number of branches and canopy coverage than other treatments irrespective of season. However, this effect was feeble and not appreciable. Experimental findings of Sirajul Islam (1999) revealed that wider row spacing (3 x 3 m) produced taller plant and wider crop canopy coverage than narrow row spacing (2 x 2 m). In the present study, the treatment difference between (5 m) wider row spacing (I₄) and narrow row spacing (2.5 m) (I₂) was not marked. Split levels of N failed to influence yield components of daincha irrespective of season.

5.8.2. Yield components

Yield component *viz.*, number of pods plant⁻¹, seeds pod⁻¹, pod length and seed weight were not influenced appreciably by different row spacings of daincha retained for seed production. Negligible difference was observed in yield component between wider row spacing (I₄) and narrow row spacing (I₂). Palaniappan and Budhar (1992) reported that wide row spacing recorded higher values for yield components than close spacing. Nitrogen application failed to improve the yield components irrespective of the seasons.

5.8.3. Seed and haulm yields

Narrow row spacing (I₂) recorded higher seed and haulm yields than wider row spacing (I₄). Under narrow spacing, the number of rows accommodated per unit area were more than that of wider row ratio, thereby producing higher daincha seed yield (Fig.17). This finding is in agreement with that of Jha *et al.* (1989), Aktar *et al.* (1994) and Sirajul Islam *et al.* (1999).

5.8.4. Nutrient uptake

In general, the crop nutrient uptake was proportional to the biomass accumulation by the crop and nutrient concentration in the plant. Higher nutrient uptake was registered in the daincha grown for seed crop with narrow rows spacing (I₂) than in wider rows.

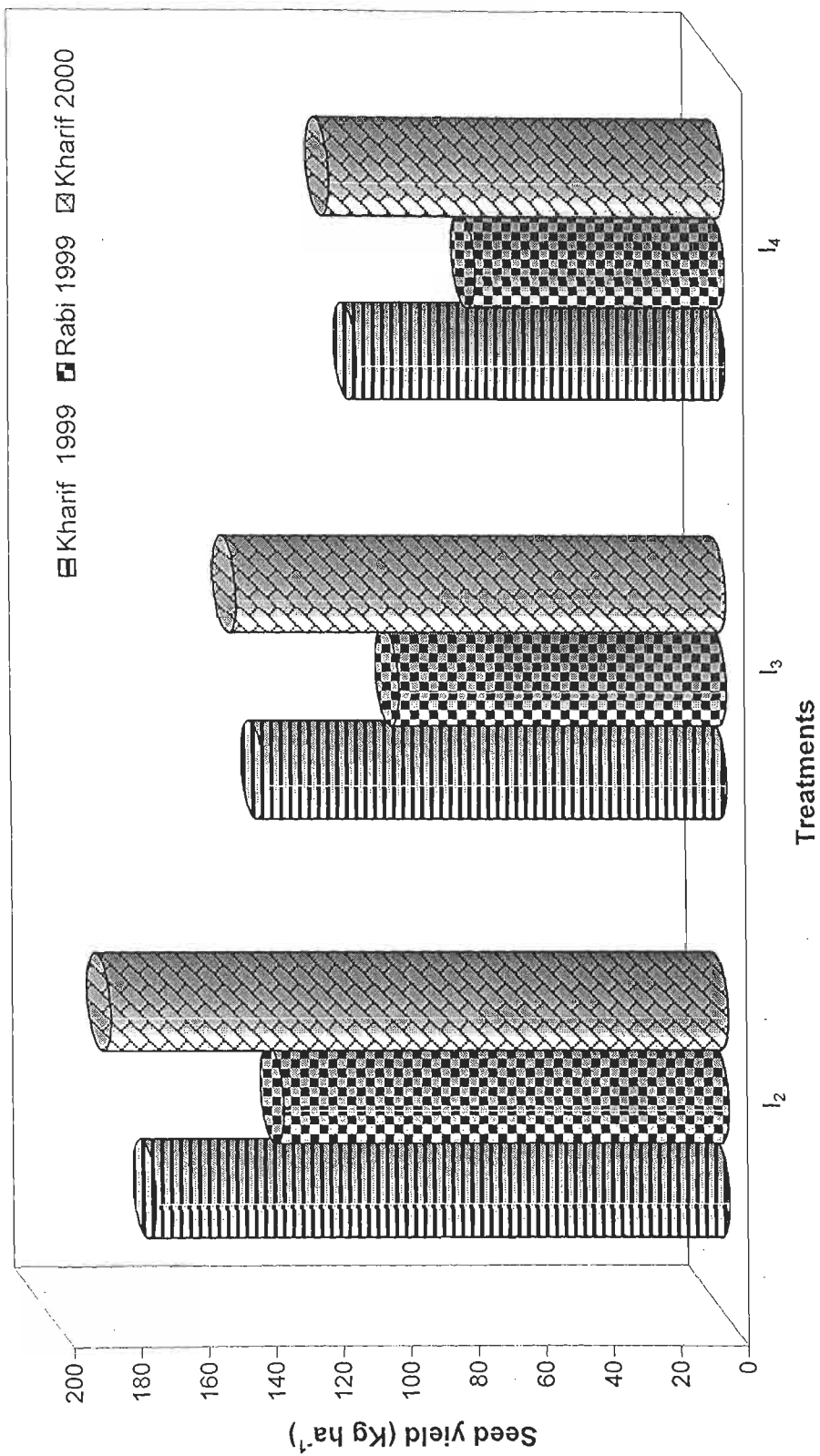


Fig.17. Influence of intercropping treatments on seed yield of daincha

This resulted in higher seed and haulm yields from the narrow rows than from wider rows because of higher DMP and enhanced nutrient uptake.

5.8.5. Seasonal influence

Daincha crop grown for seed production during *kharif* season (June-September) recorded higher values for growth, yield components, seed and haulm yields. Green manure raised during summer season (May) produced better growth and development and ultimately increased the seed yield and quality as opined by Radha (1991). Jacquelin Selvaraj and Ramasamy (1984) opined that number of seeds pod^{-1} was greatly season dependant.

Hundred seed weight was maximum during summer season, which might be due to the influence of photothermal period with the resultant photothermic quantum deciding the net reproductive effort. Similar increase in weight of seeds, during summer, was reported in cowpea (Srimathi, 1982) and lablab (Ushamythili, 1982).

5.9. Effect of daincha intercropping (Seed crop) on adjacent rice rows

Retaining daincha rows for seed production in rice cultivation caused drastic reduction in yield components *viz.*, number of panicles m^{-2} , filled grains panicle^{-1} with higher percentage of illfilled grains and grain yield. Heavy reduction on yield components and yield is ascribed to poor light availability to the adjacent rice rows particularly from flowering to ripening phase, as opined by Janardhan *et al.* (1980) and Khushu and Mavi (1991) since grain yield is influenced mostly from post flowering photosynthesis. It is associated with capability of light interception under rice intercropping system (Jana *et al.*, 1988).

Low light (63% of normal light) induced reduction in economic yield especially during ripening phase. In general C_3 plants require greater amount of light for proper growth and yield (Singh, 1997). Under low light availability, there was greater reduction in photosynthetic rate (Pramod Kumar *et al.*, 2000). Chauhan (1994) reported that in rice grown under shaded treatments (40 to 60% shade), the percentage of filled spikelets

and grain yield per plant was reduced significantly where the test weight of grains remained unaffected.

In the present study also there was a greater reduction in the light availability and interception by rice crop under the treatment meant for daincha seed production resulting in lower value of yield components and grain yield from seed production treatments.

The yield reduction under daincha intercropped (seed crop) situation was adequately compensated by the seed yield from daincha crop. It fetched good market price thereby offsetting the loss incurred by rice.

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

Field experiments were conducted during *kharif* and *rabi*, 1999 and *kharif* 2000 at TNAU, Coimbatore in wet seeded rice by using the newly developed rice + green manure seeder of TNAU. Rice varieties were changed depending upon seasons, while daincha (*S. aculeata*) was raised in all the seasons as intercrop alternating with rice rows.

The experiment had multiple objectives. Sole rice (wet seeded) was raised as check (I_0). The objectives were built up one by one over sole rice and studied. Rice + daincha exclusively for green manuring purpose was studied as an objective to find out the feasibility of green manure intercropping (I_1). Besides, daincha as an intercrop in rice for green manuring cum seed production was studied. For these, every 10, 15 and 20th row of daincha was allowed for seed production and other rows for green manuring in order to arrive at optimal rice-green manure (seed purpose) ratio (I_2 to I_4). This constituted the second objective. Added advantages of the dual cropping of green manure on growth and development of wet seeded rice was the third objective. Averting temporary setback in rice rows due to intercropping and *in situ* incorporation of daincha was considered as fourth objective for which suitable N split dose strategy as briefed below was studied. Influence of *in situ* incorporation of green manure on soil health was framed as fifth objective. The overall influence / beneficial effect in terms of economics was the sixth objective. Thus five different systems (I_0 to I_4) including sole rice were studied.

Four N split timings to rice *viz.*, 20 DAS, at incorporation of green manure (37 DAS) and on 55 to 70 DAS with variation of doses were followed. The total N dose was, however, not altered. The recommended dose of fertilizer N was applied in 4 splits comprising different ratios *viz.*, 25:25:25:25, 25:33:21:21 and 25:42:16.5:16.5 per cent (3 combinations totally) and tested for correcting temporary setback of rice growth immediately after incorporation of green manure. Thus with the combination of five systems and 3 N split doses altogether 15 treatments were studied in split plot design.

The salient findings of the experimental results are reported hereunder.

Raising daincha as an intercrop exclusively for *in situ* green manuring promoted growth factors of rice *viz.*, plant height, number of tillers m^{-2} , LAI, LAD and DMP compared to sole rice. Further 33 per cent N application at the time of green manure incorporation and corresponding reduction in the dose later was found to be more advantageous than other split doses in influencing the growth parameters.

Nutrient uptake of rice was also higher with *in situ* green manuring of intercropped daincha than with sole rice. Applying 33 per cent of fertilizer N at the time of green manure incorporation enhanced the uptake till rice maturity.

Daincha as an intercrop exclusively for green manuring enhanced the values of yield components *viz.*, number of panicles m^{-2} , number of filled grains $panicle^{-1}$ and panicle length with low per cent of illfilled grains compared to sole rice.

Applying a higher dose of N (33% N) at the time of intercropped green manure incorporation had augmentative effects on increasing the values of yield components. Test weight and panicle length were not, however, influenced by N split doses.

Illfilled grains were found to be more when rice-daincha (seed purpose) ratio was narrow (every 10th row for seed purpose) due to more shading.

Promotion of yield components due to exclusive green manuring of daincha resulted in higher rice grain and straw yields. Similarly application of 33 per cent N at the time of green manure incorporation increased grain and straw yields of rice. Combination of these two *viz.*, daincha for green manuring purpose and 33 per cent N to rice at the time of green manure incorporation promoted higher rice grain and straw yield as did 25 per cent equal splits.

Rice culturing along with daincha for green manuring-cum-seed production with seed row at farther interval (20th row for seed production and other rows for green manuring) registered higher rice equivalent than other systems, while the lowest was with sole rice. Applying 33 per cent of fertilizer N at the time of green manure

incorporation increased rice yield equivalents in all the seasons, while a higher dose of 42 per cent N at that time was found unfavourable.

Nitrogen use efficiency depended on the sum total of fertilizer N and contribution from the intercropped daincha. Agronomic efficiency was higher in sole rice during *kharif* seasons. Apparent recovery and partial factor productivity were higher in sole rice irrespective of seasons. Nitrogen use efficiency distinctly increased with 33 per cent fertilizer N application to rice at the time of green manure incorporation proportionately reducing the dose at latter stages.

There was improvement in soil fertility status as a result of raising daincha as an intercrop exclusively for green manuring. This was reflected by enhancement in higher organic carbon, available N and P contents at the end of rice cropping. When daincha was raised for seed purpose there was depletion of soil phosphorus. Sole rice cropping resulted in a decline in soil fertility.

Light interception was higher in rice + daincha intercropping than in sole rice. The interception varied depending upon the purpose of daincha cultivation. Under daincha grown exclusively for green manuring, rice crop intercepted more light. Whereas when daincha was allowed for seed purpose, there was reduction in light interception particularly in the adjoining rice rows of daincha (seed crop) with the magnitude of reduction being more in the first row followed by second and third rows respectively. Consequently, the number of rice rows affected per unit area was more when daincha was raised for seed purpose at narrow interval (every 10th row).

The growth and yield components of daincha were not influenced by row ratio. However, daincha seed yield per unit area was more when every 10th row was allowed for seed purpose. But at this narrow interval, due to more shading and suppressing effect of daincha rice yield was inhibited.

Considering, economics of systems, the dual purpose of raising daincha (both for green manuring and seed production) in rice with daincha seed row at farther interval (every 20th row) proved to be more remunerative with higher net income and benefit cost

ratio. The values of these economic indices were distinctly low in sole rice. Higher dose (33%) at the time of green manure incorporation with a reduction in dose thereafter increased net income and benefit cost ratio.

The conclusions that could be drawn from the study are:

- ❖ Regardless of season, it is advantageous to go in for wet seeding of rice and daincha in alternate rows using the newly developed rice cum green manure seeder and incorporating the latter at the tender stage (37 DAS).
- ❖ Self production of green manure seed by the farmer is possible by keeping a daincha row in rice + green manure intercropping at farther interval (every 20th row). This new innovative low cost approach will be the panacea against the paucity of green manure seed.
- ❖ Growing of daincha for green manure purpose along with wet seeded rice did not affect the yield components of rice crop. This rice + daincha intercropping system proved to be a better proposition than sole rice cropping in terms of rice growth and yield.
- ❖ When rice + daincha intercropping system is followed, the N dose to rice has to be increased to 33 per cent at the time of green manure incorporation with a reduction in the dose thereafter as ascertained in the study. This effective non monetary input is advocated when rice + green manure intercropping is followed.
- ❖ Improvement in soil fertility in terms of soil organic carbon, available N and P was observed when daincha was intercropped in wet seeded rice.
- ❖ Dual cultivation of daincha in wet seeded rice for *in situ* incorporation of green manure and retaining few rows for seed production at farther interval (every 20th daincha row) fetched higher values from the standpoints of net income and benefit cost ratio under Coimbatore conditions of Tamil Nadu.

FUTURE LINE OF WORK

- (i) For green manuring cum seed production, rice + daincha at 20 : 1 ratio was found ideal. Still at farther interval (for instance 30 : 1 or 40 : 1 ratio), daincha as seed crop might be more optimal and it requires further studies.
- (ii) Exclusive application of elements particularly phosphorus to the daincha seed crop may enhance the seed yield and this also requires separate studies as the expected seed yield was not obtained in the present study.
- (iii) Daincha seed production cum green manuring studies are required in long duration *Samba* rice varieties also.
- (iv) Similar to long term fertilizer experiments, the findings of the present study have to be imposed and studied as soil sustainability may improve with continuous green manuring by raising daincha as an intercrop.

REFERENCES

REFERENCES

- Abraham Varughese and P. Sushama Kumari. 1993. Dual culture of leguminous green manure crops in dry sown rice in sandy soils of Onattukara. **J. Trop. Agric.** **31**: 259-261.
- Aggarwal, P., D.K. Parashar, V. Kumar and R.P. Gupta. 1997. Effect of *kharif* green manuring and *rabi* tillage on physical properties of puddled clay loam under rice-wheat rotation. **J. Indian Soc. Soil sci.** **45**(3): 434-438.
- Ahmed, N.U. and K. Moody. 1981. Effect of time of N application on weed growth and yield of dry-seeded rice. **IRRN** **6**(2): 12-13.
- Akita. S. 1989. Physiological aspects for improving yield potential in tropical rice cultivation. In: Progress in irrigated rice research. IRRI, Phillipines. pp.41-76.
- Aktar, M.S., S.M. Asaduzzaman, N.A. Mondal, R.C. Adhikery, M.A. Hossain and M.F. Haque. 1994. Effect of green manuring and nitrogen fertilizer on the yield of BR11 rice. **Bangladesh J. Science and Industrial Res.** **29b**(2): 95-108.
- Alagesan, A. 1997. Studies on optimizing nitrogen levels and time of application for wet seeded rice. M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimabtoe.
- Ali, M. and J.H. Narsico. 1993. The perception and reality of GM use in rice: An economic evaluation. IRRI Social Science Division Paper Series. IRRI, Los Banos, Philippines.
- Ali, M. and J.H. Narsico. 1995. Comparative evaluation and farmers perception of green manure use in the rice based farming systems. In: Proc. of the International Rice Research Conf., IRRI, Los Banos, Philippines. p.42.
- Alonge, D.M. 1988. Influence of environmental factors on N mineralization. **Microb. Ecol.** **15**: 59.
- Angadi, V.V., Ganajaxi, S. Rajakumara, Yashoda Hegde and H.D. Mohankumar. 2000. Evaluation of direct wet seeding techniques and seeder for crop establishment in lowland rice. CREMNET 2000. IRRI, Los Banos, Phillipines, pp.150-151.
- Anonymous, 1986-87. Proceedings from 16th Annual Report of TNAU Research highlights.
- Anonymous. 1999. Saving water in rice cultivation. The Hindu dated 28.10.1999.
- Anonymous. 2000. Agricultural Statistics at a Glance. Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. p.18.

- Arunin, S., C. Dissataporn, Y. Anulustipan and D. Nana. 1988. Potential of *Sesbania* as a green manure in saline rice in Thailand. **In: Green manuring in Rice Farming. Proc. sympos. on sustainable agriculture, IRRI, Los Banos, Philippines, 25-29 May, 1987, pp.83-95.**
- Ayyangar, R.S., W.H. Freeman and R.B. Musgrave. 1977. Variation in light intensity during certain growth stages of Sona rice on dry matter production. **Cereal Res. Comm. 5(3): 287-302.**
- Babu, R. 1995. Integrated nitrogen management for wet seeded rice: Ph.D. Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Balasubramanian, V. 1989. Studies on intercropping of flood tolerant green manure *Sesbania rostrata* in rice. M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Balasubramanian, P. and SP. Palaniappan. 1993. Green manuring and high dose of inorganic fertilization on growth and yield of lowland rice. **Madras Agric. J. 80(9): 521-523.**
- Balasubramanian, P., SP.Palaniappan and H.T. Francis. 1991. Effect of green manuring and inorganic N-K fertilization on nutrient uptake and yield of lowland rice. **Indian J. Agron. 36(2): 293-295.**
- Bana, O.P.S. and A.K. Pant. 2000. Green manuring for ecologically sound crop production. **Indian Farmer's Digest p.19-20.**
- Basnet, B.M.S. 1999. Integrated use of chemical fertilizers and green manure for sustainable rice production - a success story. International Conference on Environment and Agriculture. Kathmandu (Nepal). 1-3 Nov. 1998. Kathmand (Nepal) pp.163-163.
- Bayan, Harihar Chandra. 2000. Studies on integrated weed management under split application of nitrogen in wet seeded rice. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Becker, M. 1990. Potential use of stem-nodulating legumes. *Sesbania rostrata* and *Aeschynomene afraaspera* as green manure for lowland rice (*Lryza satuea*). Ph.D. Thesis, University of Giessen, Germany. p.113.
- Becker, M., J.K. Ladha and J.C.G. Ottow. 1994. Nitrogen losses and lowland rice yield as affected by residue N release. **Soil Sci. Soc. Am. J. 58: 1660-1665.**
- Becker, M., J.K. Ladha, I. Watanabe and J.C.G. Ottow, 1988. Seeding Vs vegetative propagations of the stem nodulating green manure, *Sesbania rostrata*. **Biol. Fertil. Soils 6: 279-281.**

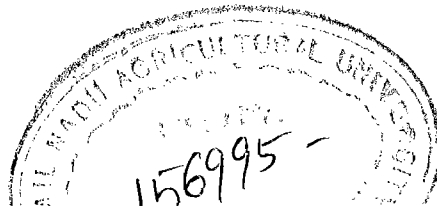
- Becker, M., Ladha, J.K. and M. Ali. 1995. Green manure technology : Potential, usage and limitations. A case study for lowland rice. **Plant and Soil** 174(1-2): 181-194.
- Begna, S.H., R.I. Hamilton, L.M. Dwyer, D.W. Stewart and D.L. Smith. 1997. Effects of population density and planting pattern on the yield and yield components of leafy reduced-stature maize in a short season area. **J. Agron. and Crop Sci.** 179: 9-17.
- Beri, V., O.P. Meelu and C.S. Khind. 1989. Studies on *Sesbania rostrata* as green manure for N accumulation and substitution of fertilizer N in wetland rice. **Trop. Agric.** 66: 2009-212.
- Bering, A.J.B. and M.C. Alba. 1982. The effect of intercropping system on yield of upland rice. Paper presented at the 13th Annual Scientific Meeting of the Crop Science Society of Philippines, Cebu city, Philippines.
- Beringer, H. 1980. Nutritional and environmental effects on yield formation. In: Physiological aspects of crop productivity. Publ. International Potash Institute, Berne, Switzerland, pp.155-174.
- Bharathi, T. 1996. Management options for seeding and weeding in wet-seeded rice. M.Sc.(Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Bhardwaj, K.K.R. 1982. Effect of the age and decomposition period of daincha on the yield of rice. **Indian J. Agron.** 27: 284-285.
- Bhardwaj, K.K.R. and M. Datt. 1995. Effect of legume green manuring on nitrogen mineralization and some microbiological properties in an arid rice soil. **Biol. and Fertil. of Soils** 19(1): 19-21.
- Bhardwaj, K.K.R. and S.P. Dev. 1985. Production and decomposition of *Sesbania cannabina* (Retz.) pers. in relation to its effect on the yield of wetland rice. **Trop. Agric.** 62(3): 233.
- Bhattacharyya, K. and S.R. Mandal. 1996. Effect of green manuring on changes of micronutrients in soil and plant systems of rainfed rice. **Indian Agric.** 40(3): 199-208.
- Bhattacharyya, K. and S.R. Mandal. 1997. Contribution of green manure in controlling the loss of applied fertilizer nitrogen from rainfed rice soil. **IRRN** 22: 41
- Bhattacharyya, H.C. and K.N. Singh. 1992. Response of direct seeded rice to level and time of nitrogen application. **Indian J. Agron.** 37(2): 681-684 ✓

- Bhuiyan. 1993. Wet seeding of rice saves money, labour and water for farmers. IRRI Reporter, June: p.4.
- Bhuiyan, N.I. and S.K. Zaman. 1996. Use of green manuring crops in rice fields for sustainable production in Bangladesh agriculture. **In:** Biological nitrogen fixation associated with rice production, (Ed.) M. Rahman *et al.*, Dordrecht, Netherland : Kluwer Academic Publishers.
- Bhuiyan, S.I., M.A. Sattar and M.A.K. Khan. 1995. Improving water use efficiency in rice irrigation through wet seeding. **Irrig. Sci.** **16:** 1-8.
- Bhuvanewari, P. 1998. Effect of establishment methods and weed control on productivity, energetics and economics of low land rice. M.Sc.(Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Bindra, A.D. and R.C. Thakur. 1995. Effect of green manuring in combination with fertilizer N, P and K on yield and nutrient uptake by paddy and disease incidence (plast) in paddy-wheat crop sequence. **Crop Res.** **9(2):** 224-248.
- Biswal, Ganesh Chandra. 2000. Studies on the effect of integrated use of different levels of inorganic N and green manure on transplanted rice. M.Sc.(Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Biswas, A.K. and N.N. Goswami. 1995. Kinetics of exchangeable and water soluble ammonium N in soil growing rice amended with urea and *Sesbani aculeata*. **J. Indian Soc. Soil Sci.** **43(1):** 20-24.
- Boparai, B.S., Yadvinder Singh and B.D. Sharma. 1992. Effect of green manure (*Sesbania aculeata*) on physical properties of soil in rice-wheat and maize-wheat cropping system. **Int. Agrophysic.** **6(1-2):** 95-101.
- Bouldin, D.R. 1988a. Effect of green manure on soil organic matter content and nitrogen availability. **In:** Sustainable Agriculture : Green Manure in Rice Farming. IRRI, Los Banos, Philippines. pp.151-164.
- Bouldin, D.R. 1988b . The effect of green manure on soil organic matter content and nitrogen availability to crops. **In:** Green manuring in Rice farming. Proc. Symp. on Sustainable Agriculture. IRRI, Los Banos, Philippines, 25-29 May 1987, pp.151-163.
- Brar, D.S. and A.S. Sidhu. 1995. Effect of soil water on pattern of nitrogen release during decomposition of added green manure residue. **J. Indian Soc. Soil Sci.** **43(1):** 14-17.

- Brewbacker. 1987. Nitrogen fixing trees for fodder and browse in Africa. An Alley farming for humid and sub humid regions of tropical Africa.(Ed.) B.T.Kang, International Institute of Tropical Agriculture, Ibadan, Nigeria.pp. 43-61.
- Budhar, M.N. 1994. Effect of conjunctive and individual application of fertilizer and green manure nitrogen on lowland rice (*Oryza sativa* L.) Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Budhar, M.N. and SP. Palaniappan. 1996. Effect of conjunctive and individual application of fertilizer and green manure nitrogen on N uptake and yield of lowland rice. **Fert. News** 41(8): 51-54.
- Buresh, R.J. and S.K. De Datta. 1991. Nitrogen dynamics and Management in rice-legume cropping systems. **Adv. Agron.** 45: 1-59.
- Buresh, R.J.,D.P.Garrity, E.G. Castillo and T.T. Chua. 1993. Fallow and *Sesbania* effects on response of transplanted lowland rice to urea. **Agron. J.** 84(4): 801-808.
- Cassman, K.G., G.C. Gines, M.A. Dizon, M.I. Samson and J.M. Alcantara. 1996. Nitrogen use efficiency in rice. **Field Crops Res.** 47: 1-12.
- Chaphale, S.D., B.S. Chaphale, A.Z. Yerpe and A.D. Lanjewar. 2000. Effect of green manuring on soil properties and yield performance of rice. **J. Soils and Crops.** 10(1): 136-140.
- Chauhan, J.S. 1994. Effect of different temperature regimes and low light stress during ripening on yield of rice. **Madras Agric. J.** 81(5): 243-245.
- Chavan, L.S., B.P. Patil and T.S. Ingole. 1996. Integrated N management with *Gliricidia maculata* and *Sesbania aculeata* for transplanted rice. **IRRN** 21(2-3): 70.
- Choubey, S.D., R.S. Sharma and G.S. Rathi. 1985. A study in increasing nitrogen efficiency in lowland rice. **Indian J. Agron.** 30(1): 107-109.
- Choudhary, T.N., T. Woodhead, K.T. Ingram, J.K. Ladha, K. Moody and G.R. Quick. 1991. Intercropped green manuring in lowland rice. Paper presented in Rice Research Seminar, 29th Aug.1991, IRRI, Los Banos, Philippines.
- Clement, A., J.K. Ladha and F.P. Chalifour. 1998. Nitrogen dynamics of various green manure species and the relationships to lowland rice production. **Agron. J.** 90(2): 149-154.

- Cosico, W.C. 1990. Studies on green manuring in the Philippines. Food and Fertilizer Technology Centre for the Asia and Pacific Region, Extension Bulletin No. 314, Taiwan, Republic of China, p.14.
- *Coxhead, I.A. 1984. The economics of wet seeding. Inducements and consequences of some recent changes in Philippine rice cultivation. M.Sc. Thesis. Australian National University, Australia.
- CPG. 1999. Crop Production Guide, Directorate of Agriculture and Tamil Nadu Agricultural University, Madras. p.1-32.
- Dalel Singh, D. Pal H. Om and D. Singh. 1991. Studies in the availability of phosphorus to rice crop applied with daincha. **Haryana J. Agron.** 7: 174-175.
- Das, R., D.K. Das and B. Das. 1998. Transformation of N in submerged soils in relation to yield and nutrition of rice as affected by sources and method of N application. **Oryza** 35(4): 338-342.
- Das, R.N., K.S. Rao and S.K. Nayak. 1994. Growth, yield and uptake of nitrogen by irrigated rice as affected by timing of fertilizer applications. **In: SARP Research Proceedings - Nitrogen economy in irrigated rice field and simulation studies.** (Ed.) H.F.M. ten Berge, K.C.J. Woperies and J.C. Shin AB-DLO and TPE, Wageningen and IRRI, Los Banos. pp.1-13.
- Dascalsota, J.P., J.C. Calabio and R.C. Evangelista. 1986. Integration of inorganic and organic nitrogen sources for lowland rice. **Philipp. J. Crop Sci.** 11: 97-106.
- De Datta, S.K. 1981. Principles and Practices of Rice Production. John Wiley and Sons Inc., New York, USA. pp.618.
- De Datta, S.K. 1986. Technology development and spread of direct seeded flooded rice in south east Asia. **Fert. Res.** 9: 171-186.
- De Datta, S.K. 1987. Advances in soil fertility research and nitrogen fertilizer management for lowland rice. **In: Efficiency of nitrogen fertilizer for rice.** IRRI, Los Banos, Philippines. pp.27-41
- De Datta, S.K. and K. Ampong-Nyarko. 1988. **In: Proc. Plenary Session of the 19th Annu. Convention of Pest Control of the Philippines.** Cebucity, Philippines.
- De Datta, S.K. and R.J. Buresh. 1989. Integrated nitrogen management in irrigated rice. **Adv. Soil Sci.** 10: 143-169.

- De Datta, S.K. and J.C. Flinn. 1986. Technology and economics of weed control in Broadcast - seeded flooded Tropical rice. **In: Weeds and the Environment in the Tropics, Proceeding of the 10th Conference of Asian - Pacific Weed Science Society.** (Ed.) Nota, K and BL. Mercado Chiang Mai, Thailand, pp.51-74.
- De Datta, S.K., R.J. Buresh and C.P. Mamaril. 1990. Increasing nutrient use efficiency in rice with changing needs. **Fert. Res. 26:** 157-167.
- De Datta, S.K., R.J. Buresh, N.N. Obcemea, M.I. Samson and J.G. Real. 1989. Comparison of ammonia volatilization and denitrification losses in broadcast seeded flooded and transplanted rice. **In: ASA abstract, 1989 annual meeting.** American Society of Agronomy, Las Vegas, Nevada. p.236.
- Deepa Thomas. 1996. Integrated nitrogen management for wet seeded rice. M.Sc.(Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Deka Medhi, B. and S.K. De Datta. 1996. Nitrogen use efficiency and ¹⁵N balance following incorporation of green manure and urea in flooded, transplanted and broadcast seeded rice. **J. Indian Soc. Soil Sci. 44(3):** 422-427.
- Dey, P. and J.M. Jain. 1996. Nitrogen mineralization from urea enriched green manures as influenced by water management practices. **J. Indian Soc. Soil Sci. 44(4):** 633-638.
- Dey, P. and J.M. Jain. 1997. Mineralization and nitrification in soil amended with urea and enriched green manures in submerged soil systems. **J. Indian Soc. Soil Sci. 45:** 249-255.
- Dharmalingam, C. and R. N. Basu. 1989. Seed development and maturation studies in mungbean. **Seed Res. 17(2):** 103-108.
- *Diekmann, K.H. 1990. Nitrogen transformation processes involving N labelled *Sesbania rostrata* and *Aeschynomene afraspera* green manure in lowland rice (*Oryza sativa* L.) (English version), Ph.D. Thesis. **Justus-Lubig University, Giessen, Germany.**
- Diekmann, K.H., J.C.G. Ottow, S.K. Datta and S.K. De. 1996. Yield and nitrogen response of lowland rice to *Sesbania rostrata* and *Aeschynomene afraspera* green manure in different marginally productive soils in the Phillipines. **Biol. Fertil. of Soils 21(1-2):** 103-108.
- Dina Qianta and Wangzhuan. 1980. The cultivation of *Sesbania* stimulates the nodules N fixing activity of *Sesbania*. **In: Annual Report of Shanghai Academy of Agril. Sci., China, pp.123-134.**



- Dingkuhn, M., H.F. Schnier, S.K. De Datta, K. Doerffling, C. Javellana and R. Pamplona. 1990a. Nitrogen fertilization of direct-seeded flooded vs. transplanted rice. II Interactions among canopy properties. **Crops Sci.** **30**: 1284-1292.
- Dingkuhn, M., H.F. Schnier, SK. DeDatta, E. Wijangco and K. Dorffling 1990b. Diurnal and developmental changes in canopy gas exchange in relation to growth in transplanted and direct seeded flooded rice. **Aust. J. Plant Physiol.** **17**: 119-134.
- Dingkuhn, M., H.F. Schnier, S.K. DeDatta, K. Dorffling and C. Javellana. 1991. Relationship between ripening phase productivity and crop duration, canopy photosynthesis and senescence in transplanted and direct seeded lowland rice. **Field Crops Res.** **26**: 327-345.
- Dingkuhn, M., S.K. De Datta, C. Javellana, R. Pamplona and H.F. Schnier. 1992a. Effect of late season N fertilization on photosynthesis and yield of transplanted and direct seeded tropical flooded rice. I. Growth dynamics. **Field Crops Res.** **28**: 223-234.
- Dingkuhn, M., S.K. De Datta, R. Pamplona, C. Javellananad and H.F. Schnier. 1992b. Effect of late-season N fertilization on photosynthesis and yield of transplanted and direct-seeded tropical flooded rice. IIA canopy stratification study. **Field Crops Res.** **28**: 235-249.
- Dommergues, Y.R. 1982. Scarcely explored means of increasing the soil N pool through biological N fixation. **In: Wither Soil Research? 12th Int. Cong. Soil Sci., Indian Soc. Soil Sci. IRRI., Delhi.** pp.138-149.
- Donald, C.M. and J. Humblin. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. **Adv. Agron.** **28(3&4)**: 174-176.
- DRR. 1998. Directorate of Rice Research **Annual Report.** p.47.
- DRR. 1999. Directorate of Rice Research **Annual Report.** pp.47- 49.
- Duhan, B.S. and Mahedra Singh. 1994. Integrated nutrient management in rice with green manuring. **Haryana J. Agron.** **10(2)**: 249-254.
- Erguiza, A., B. Duff, C. Khan. 1990. Choice of rice crop establishment technique transplanting Vs wet seeding IRRI research paper series No.139. p.10.
- FAO. 1977. Recycling of organic waste in agriculture. Report on FAO/UNDP tour to the Republic China, 28 April - 24 May, 1977. FAO soils bulletin. Food and Agricultural Organisation of United Nations, Rome.

- FAO. 1997. Trends of yield and productivity of modern rice in irrigated rice systems in Asia. **Int. Rice Comm. Newsl.** 46: 19-25.
- Furoc, R.E., H.S. Centeno and R.K. Pandey. 1988. A system approach to green manure integration and nitrogen management in rice-corn crop sequence. **Philipp. J. Crop Sci.** 13: 89-102.
- Furoc, R.E., M.A. Dizon, O.P. Meelu, R.A. Morris and E.P. Marqueses. 1986. Agronomic response of transplanted rice to pre-rice and inter sown *Sesbania* green manure. **Philipp. J. Crop Sci.** 7: 2-11.
- *Fu Qinglin, Yu Jinyan, Wang JianHong. 1999. Effect of nitrogen application on N absorption, remobilization and utilization in hybrid rice 518. **Acta Agricultural Zhejiangensis** 11(4): 174-177.
- Garrity, D.P. and M. Becker. 1994. Where do green manure in Asian rice farming systems? **In:** Green manure production systems for Asian rice lands. (Ed.) J.K.Ladha and D.P. Garrity. Selected papers from International Rice Research Conference. IRRI, Los Banos, Philippines, pp.1-10.
- Garrity, D.P. and M. Becker. 1995. Where do green manures fit in Asian rice farming systems. **In:** Green manure production systems for Asian rice lands. Selected Papers from the International Rice Research Conference, (Ed.) J.K. Ladha and D.P Garrity, pp.1-10.
- Garrity, D.P. and J.C. Flinn. 1988. Farm level management systems for green manure crops in Asian rice environments. **In:** Sustainable Agriculture : Green manure in Rice Farming. IRRI, Los Banos, Phillipines. pp.111-129..
- Ghai, S.K., D.L.N. Rao and L. Batra. 1985. Nitrogen contribution to wetland rice by green manuring with *Sesbania* spp. in an alkaline soil. **Biol. Fertil. Soils** 6: 22-23.
- Ghai, S.K., D.L.N. Rao and L. Batra. 1988. Nitrogen contribution to wetland rice by green manuring with *Sesbania* spp. in an alkaline soil. **Biol. Fertil. Soils** 6: 22-23.
- Gines, H.C., R.E. Furoc, O.P. Meelu, M.A. Dizon and R.A. Morris. 1986. Studies on green manuring of rice in farmers fields. Abstract of FCSSP papers. **The Philipp. J. Crop Sci.** 11 (Suppl.1): 1-5 pp.
- Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. 2nd (Ed.) John Wiley and Sons, New York.

- Govindarasu, R., Rammohan, J., Ramamoorthi, N. and Mohamed Hanifa, A. 1998. Direct seeding-a best substitute for transplanted rice cultivation in future. **Kisan World** **25**(11): 20-21.
- Grace, T.M., V. Ganesaraja, V. Venkatachalapathy and M.S. Chandramala. 1999. Intercropping of *Sesbania rostrata* in rice. **J. Maharashtra Agric. Univ.**, **23**(3): 261-264.
- Gracy Mathew and D. Alexandar. 1995. Influence of intercropped green manure crops on weed pressure and grain yield of semi dry rice. **Madras Agric. J.** **82**(7): 66-67.
- Gracy Mathew, D. Alexandar and T.K. Bridigit. 1991. Intercropped cowpea is an ideal green manure for semi dry rice. **Indian Fmg.** **41**(2): 21-22.
- Greenwood, D.J. 1982. Nitrogen supply and crop yield: The global scene. **Plant and Soil** **67**: 45-59.
- Greenwood, E.A.N. 1976. Nitrogen stress in plants. **Adv. Agron.** **28 (3&4)**: 1-36.
- Greenwood, D.J., F. Gastal, G. Lemaire, A. Draycott, P. Millard and J.J. Neeteson. 1991. Growth rate and N per cent of field grown crops: Theory and experiments. **Ann. Bot.** **67**: 181-190.
- Gurung, G.B. and D.P. Sherchan. 1996. Study on biomass production of daincha when relayed under maize and its green manuring effect on rice. PAC-Technical-Paper-Pakhribas. Agricultural Centre. p.170.
- Halepyati, A.S. and M.N. Sheelavantar. 1990. Nitrogen substitution with *Sesbania rostrata* in rice production. **IRRN** **15**(6): 17.
- Hati, N. 1987. Effect of combining chemical N and *Sesbania aculeata* in upland rice. **IRRN** **12**(2): 44-45.
- Hegde, D.M. 1996. Integrated nutrient supply on crop productivity and soil fertility in rice-rice system. **Indian J. Agron.** **41**(1): 1-8.
- Herrera, W.T. and D.P. Garrity. 1993. Top pruning of *Sesbania rostrata* to increase rice grain yield. **IRRN** **18**(1): 42.
- Hiremath, S.M. and Z.G. Patel. 1998. Effect of winter green manuring and nitrogen application on summer rice. **Indian J. of Agron.** **43**(1): 71-76.
- Humphries, E.C. 1956. Mineral component and ash analysis. **In: Modern methods of plant analysis Springer Verlag, Berlin.** pp.468-502.

- IRRI. 1980. Proc. Symp. on Agrometeorology of Rice Crop, World Meteorological Organization and IRRI, Los Banos, Philippines. p.133.
- IRRI 1988. Symposium recommendations. Proc. of the Symp.on sustainable Agriculture: The role of green manure crops in rice farming systems. May 25-29, 1987. IRRI, Los Banos, Philippines. pp.1-4.
- Ito, O. 1998. Strategy for rice production technologies at IRRI. **In:** The 4th JIRCAS Int. Symp. On Sustainable Agricultural Development Compatible with Environmental Conservation in Asia (Ed.) Horiuchi, H; Tsbota, K. JIRCAS Int. Symposium series, No.6: 191-202.
- Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.
- Jacqueline Selvaraj and K.R. Ramasamy. 1984. Studies on pod and seed mutation in Daincha. **Seed Res.** 12(1): 19-23.
- Jana, T.K., B.K. Mandal and Sanjoy Saha. 1988. Growth attributes and solar radation interception in different rice-groundnut intercropping sytem. **Oryza** 35(2): 148-153.
- Janaki, P. and T.M. Thiyagarajan, 1999. SPAD - N management for transplanted rice with different planting densities. Paper presented at the second National CREMNET Workshop cum Group Meeting, Soil and Water Management Research Institute (SWMRI), Thanjavur, India, 24-28 August 1999 IRRI, Los Banos, Philippines.
- Janardhan, K.V., K.S. Murty and N.D. Dash. 1980. Effect of low light during ripening period on grain yield and translocation of assimilates in rice varieties. **Indian J. Pl. Physiol.** 23(2): 163-168.
- Janzan, H.H. and G.D. Radder. 1989. Nitrogen mineralization in a green manure amended soil as influenced by cropping history and subsequent crop. **Plant and Soil** 120: 125-131.
- Javellana, C.B., M. Dingkuhn, H.F. Schniev, E. Marqueses, J.E. Faronilo and J.E. Wijangco. 1988. Effect of transplanting and direct seeding on tillering, crop growth and yield of low land rice. **Phillip J. Crop Sci.** 13: 52.
- Jayachandran, M. and V. Veerabadran. 1996a. Nitrogen economy through intercropping green manures in semi dry rice. **Madras Agric. J.** 83(7): 466-468.
- Jayachandran, M. and V. Veerabadran. 1996b. Suitable green manure crop for intercropping in semi dry rice. **Madras Agric. J.** 83(9): 591-592.

- Jayadeva, H.M., Nanjappa, H.V. and Ramachandrappa, B.K. 1998. Effect of time of herbicide application on crop damage in direct-seeded puddled rice. **Crop Res.** 16(1): 24-27.
- Jayapaul, P., B. Uthayakumar and S. Purushothaman. 1995. Influence of intercropping green manure in wet seeded rice. **IRRN** 20(4): 17.
- Jha, K.P., G.B. Mannaand, A.P. Mishra. 1989. Feasibility of augmenting green manure seed production by rice (*Oryza sativa*)-daincha (*Sesbania cannabina*) intercropping during rainy season. **Indian J. Agric. Sci.** 59: 207-210.
- Jin, H.X. 1984. A preliminary discussion on the role of the green manure crop in rice-rice system. **In:** Annual report of Shanghai Agriculture Science and Technology. 1: 28-29.
- Johnkutty, I. 1996. Nitrogen utilization growth and yield of rice as affected by green manuring and timing of isotope and non-isotope N. Ph.D. Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Johnkutty, I. And SP. Palaniappan. 1996. Use of chlorophyll meter for nitrogen management in lowland rice. **Fert. Res.** 45: 21-24.
- Joseph, M. 1998. Studies on intercropping daincha (*Sesbania aculeata*) as green manure in wet seeded rice. M.Sc. (Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Joshi, R.C., D.D. Haokip and K.N. Singh. 1994. Effect of green manuring on the physical properties of soil under a rice-wheat cropping system. **J. Agric. Science, Cambridge.** 122: 107-113.
- Kailash Kumar and K.V.P. Rao. 1992. N and P requirement of upland rice in Manipur. **Oryza.** 29: 306-309.
- Kalidurai, M. 1998. Nitrogen fixation and mineralization of *Sesbania rostrata* in rice soil ecosystem. **Ann. Agric. Res.** 19(4): 365-369.
- Kalidurai, M. and S. Kannaiyan. 1991. *Sesbania* as a biofertilizer for rice. **Biores. Technol.** 36: 141-145.
- Kalidurai, M. and S. Kannaiyan. 1992. Effect of water logging on biomass production, nodulation and nitrogen fixation by *Sesbania rostrata* and root-nodulating species of *Sesbania*. **Madras Agric. J.** 79(3): 146-153.
- Kandasamy, O.S. 1987. Water, weed and nitrogen management for direct seeded, irrigated lowland rice. Ph.D. Thesis. Tamil Nadu Agric. Univ., Coimbatore.

- Kannaiyan, S. 1993a. Nitrogen fixing green manures. INSURF Progress Report. Tamil Nadu Agric. Univ., Tamil Nadu. pp.1-56.
- Kannaiyan, S. 1993b. Biofertilizers for rice.(Ed.) Kannaiyan, Tamil Nadu Agric. Univ., Coimbatore, Tamil Nadu, India. p.60.
- Kannaiyan, S. 2000. Integrated nutrient management strategy in wetland rice ecosystem. **In: Integrated Nutrient Mangement.** (Ed.) Kannaiyan *et al.* Tamil Nadu Agric. Univ. and Tamil Nadu Dept. of Agric., p.1-32.
- Kannaiyan, S. and M. Kalidurai. 1989. Nitrogen fixing potential of stem nodulating, *Sesbania rostrata*. **In: In vitro** approaches to plant breeding. Proc. Natl. Seminar on Molecular Biol. and Biotechnol. (Ed.) Joseph Varghese, Kottayam, Kerala, India. p.75-84.
- *Khan, M.A.K. 1990. Comparative study on water management and yield performance of direct seeded and transplanted rice. M.Sc. Thesis. Central Luzon State University, Philippines.
- Khind, C.S., O.P. Meelu and Vijay Beri. 1983. Age of daincha, green matter and nitrogen economy in rice. **IRRN** 8(2): 17.
- Khuntia, B., M. Mishra, L. Dixit and A. Mishra. 1989. Comparative efficiency of different cultural practices in rice. **The Orissa J. Agric. Res.** 2: 129-130.
- Khushu, M.K. and H.S. Mavi. 1991. Performance of rice (*Oryza sativa*) varieties under different solar radiation regimes. **Indian J. Agron.** 36(4): 246-247.
- Kleinhenz, V., Schnitzler, W.H. and Midmore, D.J. 1997. Effect of legume live mulch on crop performance, soil available nitrogen and crop N status in intensive tropical vegetable production. **Biological Agric. and Hort.** 14(4): 261-278.
- Kolar, J.S., H.S. Grewal and B. Singh. 1993. Nitrogen substitution and higher productivity of a rice-wheat cropping system through green manuring. **Trop. Agric.** 70: 301-304.
- Krishnakumar, V. 1986. Agrometeorological parameters and hydro nutritional management practices on rice cultivars. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Krishnakumar, V. and S. Subramanian. 1991. Influence of meteorological parameters on growth and yield of lowland rice. **Oryza** 28: 49-54.
- Krishnasamy, V., V. Palanisamy and P. Srimathi. 2000. Green manure seed production. **In: Theme Paper on Integrated Nutrient Management** (Ed.) Kannaiyan *et al.* Tamil Nadu Agric. Univ., Coimbatore. p.245-250.

- Kumar, A. and D.S. Yadav. 1995. Use of organic manure and fertilizer in rice (*Oryza sativa*) - wheat (*Triticum acstivum*) cropping system for sustainability. **Indian J. Agric. Sci.** 65(10): 703-707.
- Kumar, V., B.C. Ghosh and R. Bhat. 1999. Recycling of crop wastes and green manure and their impact on yield and nutrient uptake of wetland rice. **J. Agric. Sci.** 132(2): 149-154.
- Kumar, A., A.K. Sarkar, R.P. Singh and V.N. Sharma. 1998. Yield and trace metal levels in rice (*Oryza sativa*) as influenced by fly ash fertilizer and farm yard manure application. **Indian J. Agric. Sci.** 68(9): 509-512.
- Kundu, D.K., K.V. Rao and K.G. Pillai. 1993. Comparative efficiency of *Sesbania*, *Gliricidia* and urea as N resources in wetland rice. **IRRN** 18(3): 27.
- Ladd, J.N., J.M. Oder and M. Amato. 1985. Nitrogen fixation by leguminous green manures and their availability to tropical lowland rice. **Aust. J. Soil Res.** 23: 603.
- Ladha, J.K., S. Miyan and M. Garcia. 1989. *Sesbania rostrata* as green manure for lowland rice: Growth N₂ - fixation, *Azorhizobium* sp. inoculation and effects on succeeding crop yields and nitrogen balance. **Biol. Fertil. Soils** 7: 191-197.
- Ladha, J.K., R.P. Pareek and M. Becker. 1992. Stem nodulating legume rhizobium symbiosis and its agronomic use in lowland rice. **Adv. Soil Sci.** 20: 147-192.
- Ladha, J.K., I. Watnabe and S. Saono. 1988. Nitrogen fixation by leguminous green manure and practices for its enhancement in tropical lowland rice. Proc. of symp. on sustainable agriculture: Green manure in rice farming, 25-29, May 1987. Int. Rice Res. Inst., Philippines. 165-183pp.
- Lauren, J.G., J.M. Dubry, V. Beri, M.A. Razzaque II, M.A. Sattar, S.P. Pandey, S. Bhattarai, R.A. Mann. And J.K. Ladha. 1996. Direct and residual effects from forage and green manure legumes in rice-based cropping systems. Proc. Workshop, Patancheru, Hyderabad, ICRISAT. pp.55-81.
- Lee, H.C., Rodrigues, M.S. and J.M. Lopez - Real. 1992. Composted manure as a surface mulch for enhanced arable crop production. Proc. of 2nd English Society of Agronomy (ESA) Congress. pp.414-415.
- Lekha Sreekantan. 1987. Integrated phosphorus management in a rice-based cropping system. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Lenka, D. and D. Misra. 1980. Effect of shading on growth and development of rice during dry season. **Indian J. Agron.** 25(3): 551-552.

- *Liangttuan, Wu and Tao, Qin Nan. 1999. Nitrogen fertilizer application based on the diagnosis of N nutrition of rice plants using chlorophyll meter. **J. Zhejiang Agril. Univ.**, **52(2)**: 135-138.
- Lizhi, C. 1988. Green manure cultivation and use for rice in China. **In**: Symposium on Sustainable Agriculture. The role of green manure in rice farming. IRRI, Los Banos, Philippines, pp.97-109.
- Luman, Z. 1988. Low tillage broadcast rice productivity. **IRRN** **13(4)**: 30.
- Madhu, M. and H.V. Nanjappa. 1995. Crop-weed competition in puddled seeded rice. **Indian J. Weed Sci.** **27(3)**: 191-193.
- Mahapatra, I.C., K.N. Singh, K.G. Pillai and S.R. Bapt. 1985. Rice soils and their management - A review. **Indian J. Agron.** **30(1)**: 1-41.
- Majid, A., A.S. Khan, S.I. Ahmed and M.A. Zaidi. 1996. Water consumption of different rice production techniques. AMA, Agricultural mechanization in Asia, Africa and Latin America. **27(1)**: 37-40.
- Malla Reddy, M. and B. Bhaskar Reddy. 1999. **The Andhra Agric. J.** **46(1&2)**: 106-107. ✓
- Mappaona, Shigekata Yoshida, and Makoto Kitou. 1995. Difference in phosphorus response among tropical green manure legumes grown under limed and unlimed soil conditions. **Soil Sci. Plant Nutr.** **41(1)**: 9-19.
- Mathias Becker. 1996. Leguminous green manures in rice based cropping systems. **In**: Biological nitrogen fixation associated with rice production, (Ed.). Rahman *et al.* Dordrecht, Netherland : Kluwer Academic Publishers. The Netherlands.
- Matiwade, P.S. and M.N. Sheelavantar. 1994. Growth analysis of rice as influenced by green manuring with *Sesbania rostrata*. **Oryza** **31**: 196-198.
- Medhi, B.D. and S.K. De Datta. 1993. Influence of green manure and prilled urea incorporation on the nutrient concentration of transplanted and broadcast seeded rice. **JASS**, **6**: 89-92.
- Medhi, D.N., S.K. De Datta and S.K. De Datta. 1997. Phosphorus availability to irrigated lowland rice as affected by source, application level and green manure. **Nut. cycling in Agro ecosys.** **16**: 195-203.
- Meelu, O.P., R.P. Torres and R.A. Morris. 1985. Effect of integrated N management on crop yields and soil fertility in five rice based cropping sequences. **Philip. J. Crop Sci.** **10**: 33.

- Miki, T. and T. More. 1968. Influence of water regimes on mineralization of green manures in tropical soils. **Bull. Takai, Kenkinat. Agric. Exp. Stn.** 17: 59.
- Mikkelson, D.S. 1987. Nitrogen budgets in flooded soil used for rice production. **Plant and Soil** 100: 71-97.
- Minolta, 1989. SPAD 502 Owner's manual industrial meter division. Minolta Corp, Ramsey, N.J., Japan.
- Mitsuru Osaki, Makoto Iyoda, Satoshi Yamada and Toshiaki Tadano. 1995. Effect of mutual shading on carbon distribution in rice plant. **Soil Sci. Plant Nutr.** 41(2): 235-244.
- Mohamed Sherif, M., S. Thangavel and C. Surendran. 1974. Influence of time of sowing on the yield of sorghum. CSH 1 and Swarna. **Madras Agric. J.** 61(10-12): 936-939.
- Mohandoss, S., P. Muthukrishnan, C. Suseela, M. Subramanian and V. Balasubramanian. 2000. Determination of optimum SPAD threshold values for different varieties and seasons in the old Cauvery delta area of Tamil Nadu, India. CREMNET Report, IRRI, Los Banos, Philippines. pp.4-16.
- Moody, K. 1982. Weed control in dry seeded rice. In: Report on Workshop on Cropping Systems Research in Asia. IRRI, Manila, Philippines.
- Moody, K. 1993. Weed control in wet seeded rice. **Expl. Agric.** 29: 393-403.
- Moorthy, B.T.S. and B.N. Mitra. 1992. Influence of time of application of nitrogen and weed management practices on the performance of upland rice. **Oryza** 29: 234-239.
- Morris, R.A., D.P. Meelu and R.E. Furoc. 1985. Green manuring for rice. Paper presented at the UNDP sponsored Biological Nitrogen Fixation Project Advisory Group, 18-21 November 1985. IRRI, Los Banos, Philippines.
- Morris, R.A., A. Villegas, A.N. Pothanee and H.S. Centano. 1990. Water use by monocropped and intercropped cowpea and sorghum grown after rice. **Agron. J.** 82(4): 664-668.
- Mulongoy, K. 1986. Potential of *Sesbania rostrata* as nitrogen source in alley cropping systems. **Biol. Agric. and Hort.** 3: 341-346.
- Muneshwar Singh, Thakur, P.N. and M. Singh. 1997. Influence of neem oil coated urea and mexican lilac (*Gliricidia sepium*) as green manure of transformation of soil nitrogen in rice-wheat system in typical hapluequent. **Indian J. of Agric. Sci.** 67(9): 388-391.

- Murali, B. and T.M.M. Reddy. 1995. Response of rice cultivars to level and times of nitrogen application. **J. Res. APAU** 23: 43-44.
- Muralidharan, K. 1996. Studies on the assessment of leaf nitrogen status through chlorophyll meter (SPAD 502) for top dressing nitrogen in lowland rice (*Oryza sativa* L.). M.Sc.(Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Nabheerong, N. 1995. Root growth comparison between wet seeded and transplanted rice. In: Constraints, opportunities and innovations for wet seeded rice: Proceedings (Ed.) K. Moody. IRRI, Los Banos, Laguna, pp.107-117
- Nagarajak, S. 1987. Transformation of green manure nitrogen in lowland rice soils. Paper presented at the Symposium on Sustainable Agriculture: The role of green manure crops in rice farming systems. 25-29 May, 1987. IRRI, Los Banos, Philippines. pp.193-208.
- Narasimman, R., P. Rollin Baskar and R. Sathiyaseelan. 2000. Evaluation of direct wet seeding of rice under puddled condition in Pondicherry. CREMNET Report. IRRI, Los Banos, Philippines. p. 148.
- Natchimuthu. 1985. Studies on the nitrogen use efficiency of prilled urea and urea super granules with Azolla and neem cake in lowland rice. M.Sc.(Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Nayak, S.K. and K.S. Murthy. 1980. Effect of varying light intensity on yield and growth parameters in rice. **Indian J. Plant Physiol.** 23: 309-316.
- Ndoye, I. And B. Dreyfus. 1988. N₂ fixation by *Sesbania rostrata* and *Sesbania sesban* estimated using ¹⁵N and total N difference methods. **Soil Biol. Biochem.** 20: 209-213.
- Obcemea, W.N., J.G. Real and S.K. De Datta. 1990. Reducing nitrogen loss by switching from transplanted to broadcast flooded rice. **Philipp. J. Crop Sci.** 15: 99-105.
- Okazaki, K., K. Matsuo, K. Kawaski, Y. Uemura, N. Ikokawa and M. Miyazaki. 1990. Development of wet seeded rice cultivation technique for furrow seeding. **Bull. Shikoku Nat. Agric. Exp. Station** 53: 79-86.
- Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soil by extraction with sodium carbonate U.S.D.A. Cire. 939.
- Padmavathy, V.K. 1992. Effect of green manures and green gram on the economy of nitrogen management in rice based cropping system. M.Sc. (Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.

- Pajankar, D.S., B.M. Jibhakate, P.N. Sorte and H.B. Goramnagar. 1997. Production cost of broadcasting paddy in comparison with normal and late transplanting in the puddled field. **J. Soils and Crops** 7(2): 196-199.
- Pal, S.K., K.M. Singh, R. Thakur, U.N. Verma and M.K. Singh. 1999. Growth and yield of rice (*Oryza sativa*). Cultivars under different methods of planting in Bihar plateau. **J. Res. (BAU)**. 11(1): 19-22.
- Palaniappan, SP. and K. Annadurai. 1999. Green manuring. A basic component of organic farming. In: Organic Farming. Theory and Practice. p.23-52. Scientific Publishers (India), Jodhpur, India. pp.23-52
- Palaniappan, SP. and M.N. Budhar. 1989. Study on increasing nitrogen use efficiency in transplanted rice. **Indian J. Agron.** 34: 154-155.
- Palaniappan, SP. and M.N. Budhar. 1992. Seed production, crop establishment and incorporation practices as agronomic constraints in green manure production systems. Int. Rice Res. Conf. 21-25 April, Manila, Philippines. pp 27-33.
- Palaniappan, SP and K. Siddeswaran. 1999. Green manuring for crop production. In: Bioresources Technology for Sustainable Agriculture (Ed.) Kannaiyan, Associated Publishing Company, New Delhi. pp.41-55.
- Palaniappan, SP., K. Siddeswaran, and N. Srinivasalu Reddy. 1990. In: Intern. Symp. on Natural Resource Management for a sustainable Agriculture. New Delhi.p 120.
- Palaniappan, SP., K. Siddeswaran, C. Ramaswami, N.S. Radha and M. Premsekar. 1991. Evaluation management and utilization of green manure for rice-based cropping systems. Paper presented at INSURF Planning cum Workshop Meeting, Bali. Indonesia, March 7-10, 1991.
- Panda, M.M., M.D.Reddy, S.K.Mohanty, A..Bhadrachalam and S.P.Chakravorti. 1994. Integrated nitrogen management with *in situ* green manuring and urea application in wetland rice. **Indian J. of Agric. Sci.** 64(1): 19-23.
- Pandey, S. 1995. Socio-economic research issues on wet seeding. In: Constraints, opportunities and innovations for wet seeded rice : Proc. (Ed.) K. Moody, IRRI, Los Banos, Laguna, IRRI. pp.73-84.
- Pandey, R.V. 1996. Substitution of dhaincha in usar soil. **Indian Farmer's Digest** p.26 & 44.
- Pandey, S. and L. Velasco. 1999. Economics of direct seeding in Asia : Patterns of adoption and research priorities. **IRRN** 24(2): 6-11.

- Pandey, P.C., P.S. Bisht and P. Lal. 1995. Green manure : a substitute for inorganic fertilizer N in rice. **IRRN** 20(1): 22.
- Pandey, P.C., P.S. Bisht and P. Lal. 1997a. Increased yield of low land rice with late N application in the reproductive phase and at high N rates. **IRRN** 22(3): 38-39. ✓
- Pandey, G.K., M.L. Nema, S.P. Kurchania and J.P. Tiwari. 1997b. Nitrogen use efficiency under split application of nitrogen and weed control treatments in drilled rice. **World Weeds** 4(3&4): 131-136.
- Pathak, L. and M.C. Sarkar. 1994. Nitrogen supplying capacity of an Ustrochrept amended with manures, urea and their combinations. **J. Indian Soc. Soil Sci.** 42(2): 261-267.
- Pathak, P.S., P. Rai and R. Deb Roy. 1985. Effect of sowing season on seedling growth of three species of *Sesbania*. **Indian J. Ecol.** 12(1): 29-34.
- Patrick, W.H. Jr., D.S. Mikkelsen and B.R. Weels. 1985. Fertilizer Technology and Use, Soil Sci. Soc. Am., Madison, Wisconsin, USA. p.197
- Paturde, J.T. and M.M. Patnakar. 1998. Effect of green manuring with *Sesbania rostrata* and *S. aculeata* as well as levels of nitrogen on yield of transplanted paddy variety SKL-7. **Agri. Sci. Digest** 18(3): 213-216.
- Peltonen Saino, P., K. Forsman and T. Poutala. 1997. Crop management effects on pre- and post-anthesis changes in leaf area index and leaf area duration and their contribution to grain yield and yield components in spring cereals. **J. Agron. and Crop Sci.** 179: 47-61.
- Peng, S. and Cassman, K.G. 1995. Chlorophyll meter-based nitrogen management. International Rice Research Institute Programme Report, IRRI, Philippines.
- Peng, S., S.F.V. Garcia, R.C. Laza and K.G. Cassman. 1993. Adjustment for specific leaf weight improves chlorophyll meter estimates of rice leaf nitrogen concentration. **Agron. J.** 85: 987-990.
- Peng, S., F.V. Garcia, H.C. Laza, M.I. Samson, A.L. Sanico, R.M. Visperas and K.G. Cassman. 1996. Nitrogen use efficiency of irrigated tropical rice established by broadcast wet seeding and transplanting. **Fert. Res.** 45: 123-134.
- Pillai, K.G. and R. De. 1980. Growth and yield of rice variety Jaya at different levels and timings of nitrogen application under two systems of water management. **Proc. Indian Acad. Sci. (Plant Sci.)** 89: 257-267.
- Pillai, P.S. and V.M. Nair. 1995. *Sesbania rostrata*, a partial substitute for chemical nitrogen. **J. of Trop. Agric.** 33(1): 87-88.

- Pillai, K.G. and V.K. Vamadevan. 1978. Studies on integrated nutrient supply system for rice. **Fert. News** 23: 11-14.
- Pingali, P.L. 1991. Agricultural growth and the environment. Conditions for their compatibility in Asia's humid tropic. IRRI Social Sciences Div. Paper No. 19-12. IRRI, Manila, p.25.
- Pingali, P.L., P.F. Moya and L.E. Velasco. 1990. The post-green revolution blues in Asian rice production. IRRI Social Science Division Paper Series No.90-91. The International Rice Research Institute, Los Banos, Philippines.
- Poovaradom, S., R.L. Tate and R.A. Bloom. 1987. Seasonal influence of nutrient availability from green manures. **Soil Sci.** 145: 257.
- Power, S.L. 1997. Influence of integrated nitrogen management to rice in coastal lateritic soil. **Curr. Agric.** 21(1-2): 65-68.
- Prabhakar, S.V.R.K. and S. Narsa Reddy. 1997. Rice productivity as affected by dates of seeding and methods of planting. **The Andhra Agric. J.** 44(122): 30-32.
- Pradeep Prasad, Ashok Kumar and U.K. Prasad. 1994. Effect of irrigation and nitrogen on yield of medium duration direct seeded rice. **Indian J. Agron.** 39: 294-296.
- Pradhan, S.N. 1969. Mechanization of rice cultivation. **Oryza** 6: 67-71.
- Pramanik, S.C. and B.S. Mahapatra. 1997. Effect of integrated use of inorganic and organic nitrogen sources of mineralization, uptake and grain yield of rice. **Oryza** 34: 181-184.
- Pramodkumar, N. Jothi Lakshmi, K.K.S. Bisht and V.P. Mani. 2000. Effect of photon flux densities on photosynthetic behaviour of rice, ragi, barnyard millet and soybean genotypes in relation to photosynthetic pigments. **Indian J. Plant Physiol.** 5(1): 19-25.
- Prasad, R. and S.K. De Datta. 1999. Increasing fertilizer nitrogen efficiency in wet land rice. In: Nitrogen and rice. IRRI, Manila, Philippines. pp.465-483
- Purohit, K.K., B.L. Chandrakar and S.S. Kolbe. 1990. Effect of different methods of sowing and weed control in direct seeded rice. Extended Summary, Proc. Int. Symp. on Rice Research. **News Front.** 319-328.
- Purushothaman, S. and V.K. Padmayathy. 1994. Performance of intercropped green manure and their effect on the rice. Nat. Symp. on Integrated Nutrient Management in Rice, TNAU, Coimbatore. p.115.

- Rachel Sophia Alexander. 1994. Methods of planting rice and their effect on succeeding pulses. M.Sc. (Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Rachel Sophia Alexander and G. James Martin. 1995. Comparative study on the methods of establishment of rice-ADT 36. **Madras Agric. J.** 82(1): 71-72.
- Radha, N.S. 1991. Studies on seed production, harvest date processing and storage in *Sesbania rostrata*, *Sesbania aculeata* (Jacq.) and *Tephrosia purpursa* (Pers.) M.Sc.(Ag.)Thesis.Tamil Nadu Agric. Univ., Coimbatore.
- *Rajbhandari, N.K. 1984. The effect of age of two leguminous green manure crops on transplanted rice yields. M.Sc. Thesis, University of Philippines at Los Banos, Laguna, Philippines.
- Rajendran, P., A. Tajuddin and C. Ramaswami. 1999. Rice cum green manure culture with modified drum seeder under lowland condition. **IRRN** 23(3): 31.
- Rajeswari, C. 1990 Studies on the effect of seed rate and method of sowing of two green manures on succeeding rice. M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Ramalingam, T., M. Velusamy, N. Farooque Ahmed, V. Shanmugasundaram, V.Sabanayagam and R. Natesan. 2000. Plant nutrient status of Tamil Nadu Soils. **In: Integrated Nutrient Mangement.** (Ed.) Kannaiyan *et al.* Tamil Nadu Agric. Univ. and Tamil Nadu Dept. of Agric. p.79-86
- Ramamoorthy, K. and Subbaiah, S.V. 1999. Effect of butachlor + safener on drum seeded rice at DRR Farm, Andhra Pradesh, India. Paper presented at the 2nd CREMNET Workshop cum Group Meeting, Soil and Water Management Research Institute, Thanjavur, Tamil Nadu, India, 24-27 August, 1999. IRRI, Los Banos, Philippines.
- Ramamoorthy, K., V.V. Krishnamurthi and A. Balasubramanian. 1998. Effect of time of nitrogen application on growth, yield and economics of irrigated rice. **Madras Agric. J.** 84(11/12): 647-649.
- Ramanathan, S.P. 1995. Studies on intercropping and border cropping system. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Ramasamy, S., M. Premsekar and S. Prushothaman. 1994. Evaluation of rice varieties under different systems of crop establishments. **Madras Agric. J.** 81(3): 154.
- Rana, D.S., Hargopal Singh, K.N. Sharma, A.L. Bhandari and H. Singh. 1998. Economy of fertilizer nitrogen through green manuring in rice. **Indian J. Agric. Sci.** 58(11): 848-849.

- Rangasamy, P., T.B. Ranganathan, K. Mohansundaram, S. Kannaiyan, G.A.Palanichamy, P. Shanmugasundaram, K. Natarajamoorthy, P.Vaidyanathan, M. Rangasamy and T.V. Karivaratharaju. 1997. A new *Sesbania rostrata* for irrigated rice farming. **Madras Agric. J.** 84(7): 352-354.
- Rao, D.L. and Batra, L. 1983. Ammonia volatilization from applied nitrogen in alkali soils. **Plant and Soil** 70: 219-228.
- Rao, D.L.N. and S.K. Ghai. 1987. Slow release urea fertilizer in sodic soils. **IRRN** 12(1): 32-33.
- Rao, K.S., R.N. Dash and M.V.R. Murty. 1994. The effect of time of nitrogen application on growth performance of rice-a progressive study. p.14-30. **In: SARP Research Proceedings - Nitrogen economy of irrigated rice**(Ed.): ten Berge *et al.* AB-DLO and TPE-Wageningen and IRRI, Los Banos.
- Rasheed, M., M.A. Ali, N. Saleem, M. Asif. And M. Aslam. 1999. Effect of nitrogen application technique on different parameters of yield in rice (*Oryza sativa*). **Pak. J. of Biol. Sci.** 2(3): 978-979.
- Rathi, G.S. and R.S. Sharma. 1996. Effect of rate and time of nitrogen application on direct sown rice. **Oryza** 33: 140-142.
- Ravi, V. 1998. Effect of multibloom practices to harness the yield potential in blackgram. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Reddy, G.R.S. and K.A. Reddy. 1989. Effect of levels and sources of nitrogen on rice. **Indian J. Agron.** 34: 364-366.
- Regmi, A.P. 1998. Long-term soil fertility experiment in the rice-wheat system, Nepal. CIMMYT Project Report, Mexico. p.63-65.
- Rekhi, R.S. and M.S. Bajwa. 1994. Effect of green manure on the yield, N uptake and floodwater properties of a flooded rice, wheat rotation receiving ¹⁵N urea on a highly permeable soil. **Fert. Res.** 34(1): 15-22.
- Roger, P.A. and I. Watanabe. 1986. Technologies for utilizing biological nitrogen fixation in wetland rice : Potentialities, current usage and limiting factors. **Fert. Res.** 9: 39-77.
- Rovira, A.D. 1993. Sustainable farming systems in the cereal live stock areas of the Mediterranean region of Australia. p.12-20. **In: . Soil Management in sustainable agriculture** , (Ed.) H.F. Cook and H.C. LeeWye College Press, Ashford, UK.

- Roy, N.K., J.K. Handoo and S.S. Mandal. 1998a. Effect of reduced light at different growth stages on the performance of two rice varieties. **J. Applied Biol.** 8(1): 29-32.
- Roy, N.K., J.K. Handoo and R.B. Sharma. 1998b. Performance of two rice varieties under two solar radiation regimes. **J. Applied Biol.** 8(1): 24-28.
- Salu Reddy, N., G. Prabhakara Reddy and Yellamanda Reddy. 1995. Nutrient uptake and yield of semi-dry rice as influenced by preceding crops. **J. Res. APAU.** 23: 97-99.
- Samantaray, R.N., D. Panda and S. Patnaik. 1990. Contribution of seed nitrogen towards the growth and yield of rice varieties of different durations. **J. Indian Soc. Soil Sci.** 38(4): 674-679.
- Sanbagavalli, S. and O.S. Kandasamy. 1998. Studies on the optimisation of seedling age, nitrogen dose and split application of lowland rice established by the seedling throwing method. **Acta Agronomica Hungarica** 46(3): 265-271.
- Sandh, J., M. Sinha and R.S. Ambasht. 1990. Nitrogen release from decomposing litter of *Leucaena leucocephala* in the dry tropics. **Soil Biol. Biochem.** 22: 859-863.
- Sanjay Sharma, S., P. Dev and Rameshwar. 2000. Effect of green manuring of Sunhemp (*Crotalaria juncea* L.) on rice yield, nitrogen turnover and soil properties. **Crop Res.** 19(3): 418-423.
- Sankaran, N., K. Siddeswaran and T.M. Thiyagarajan. 2000. Green manuring perspectives and constraints. In: Integrated nutrient management, Kannaiyan *et al.* (Ed.), Tamil Nadu Agric. Univ., Coimbatore. pp.111-121.
- Sankaranarayana, A.M. 1985. Studies on the influence of nursery manuring and main field nitrogen management on growth and yield of rice. M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Santhi, P., K. Ponnuswamy and N.K. Chetty. 1998. Effect of seeding methods and efficient nitrogen management practices on the growth of lowland rice. **J. Ecobiol.** 10(2): 123-132.
- Saradha Ramani, D.C. Joshna and M.S. Shaikh. 1989. Response of three *Sesbania* species to salinity when grown hydroponically. **J. Plant Nutri.** 2(12): 1447-1455.
- Sarkar, A.K., A.K. Mohapatra, D.C. Pradhan and B. Behera. 1988. Weed control in direct sown rice under puddled condition. **Indian J. Weed Sci.** 20(3): 94-95.

- Sarmah, A.C. 1997. Effect of green manures in phosphorus nutrition of rice. **J. Agric. Sci. Soc. North East India** **10**: 173-175.
- *Sattar, M.A. 1992. Water management and technology adoption for direct seeded rice in an irrigation system. Ph.D. Thesis. Central Luzon State Univ. Philippines.
- Sattar, S.A. and J.C. Biswas. 1991. Intercropping a green manure with direct seeded rice. **IRRN** **16**(1): 23.
- Savant, N.K. and S.K. De Datta. 1982. Nitrogen transformation in wet land rice soils. **Adv. Agron.** **35**: 241-302.
- Schnier, H.F., M. Dingkuhn, S.K. De Datta, K. Mengel and J.E. Faronilo. 1990a. Nitrogen fertilization of direct seeded flooded vs. transplanted rice: I. Nitrogen uptake, photosynthesis, growth and yield. **Crop Sci.** **30**: 1276-1284.
- Schnier, H.F., M. Dingkuhn, S.K. De Datta, K. Mengel, E. Wijangco and C. Javellana. 1990b. Nitrogen economy and canopy carbon dioxide assimilation of tropical lowland rice. **Agron. J.** **82**: 451-459.
- Selvam, K. 1994. Response of *Sesbania rostrata*, *Sesbania aculeata* and *Sesbania speciosa* to season, spacing and phosphorus in maximizing seed yield and quality, M.Sc. (Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Sengupta, U.K. and B.B. Jadhav. 1988. Effect of low light intensity on photosynthesis and translocation of photosynthates in groundnut. **Indian J. Plant Physiol.** **34**: 288-290.
- Setty, R.A. and A.S. Channabasavanna. 1991. Optimum combination of nitrogen and *Sesbania* in rice production. **Curr. Res.** **20**(10): 207-209.
- Shad, R.A. and S.K. De Datta. 1986. Evaluation of method of establishment in wetland rice. **Pak. J. Agric. Res.** **7**: 186-192.
- Shanmugam, A. 1983. Studies on *Azolla* as a partial substitute for N in lowland rice. M.Sc.(Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Sharma, A.R. 1995. Fertilizer use in rice and rice-based cropping system. **Fert. News** **40**(5): 29-41.
- Sharma, A.R. and K.C. Das. 1994. Effect of green manuring with dhaincha (*Sesbania aculeata*) on growth and yield of direct-sown and transplanted rice under intermediate deep water conditions (0-50 cm). **J. Agric. Sci. Camb.** **122**: 359-364.

- Sharma, A.R. and B.N. Mitra. 1988. Effect of green manuring and mineral fertilizer on growth and yield of crops in rice based cropping on arid laterite soil. **J. Agric. Sci. Camb.** **110**: 605-608.
- Sharma, S.K. and K.K. Moorthy. 1988. Green manure crop performance in semi-arid regions of India. **IRRN** **13**(3): 23-24.
- Sharma, G.D. and H.L. Sharma. 1994. Utilization of weed plants as organic manure under different methods of rice establishment. **Indian J. Agric. Sci.** **64**(3): 184-186.
- Sharma, S.K., S.V. Subiah and K. Krishnamurthy. 1989. Nitrogen sources and application methods for direct sown rice under rainfed lowland condition. **Int. Rice Comm. Newsletter** **38**: 71-73.
- Shekar, J. and C.M. Singh. 1991. Influence of methods and dates of stand establishment on growth and yield of rice. **Oryza** **28**: 45-48.
- Siddeswaran, K. 1992. Integrated nitrogen management with green manure and grain legumes in rice-based cropping systems. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Sihag, D. and J.P. Singh. 1997. Effect of organic materials on ammonia volatilization losses from urea under submerged condition. **J. of Indian Soc. Soil Sci.** **45**(4): 822-825.
- Sims, J.L. and G.A. Place. 1968. Growth and Nutrient uptake of rice at different growth stages and nitrogen levels. **Agron. J.** **60**: 692-696.
- Singh, N.T. 1984. Green manures as sources of nutrients in rice production. **In: Organic matter and Rice.** IRRN, Los Banos, Philippines. pp. 217-228.
- Singh, S. 1994. Physiological response of different crop species to low light stress. **Indian J. Plant Physiol.** **37**: 147-151.
- Singh, S. 1997. Growth and yield response of different crop species to low light and high temperature humidity stress. **Indian J. Plant Physiol.** **40**: 151-155.
- Singh, K.N. and H.C. Bhattacharyya. 1989. Direct seeded rice. Principles and Practices, Oxford and IBH Publishing Co. New Delhi, India. p.166.
- Singh, G.B. and B.S. Dwivedi. 1996. Integrated nutrient management for sustainability. **Indian Fmg.** **46**: 9-15.
- Singh, C.P. and I.K. Garg. 1983. Effect of different methods of planting on the yield of paddy. **J. Res. Punjab Agrl. Univ.** **20**(3): 503-509.

- Singh, G. and O.P. Singh. 1993. Effect of method of establishment and nitrogen application on yield and yield attributes of rice. **Oryza** 29: 210-213.
- Singh, Y., C.S. Khind and Bijaj Singh. 1991. Efficient management of leguminous green manures in wetland rice. **Adv. Agron.** 45: 135-189.
- Singh, G., O.P. Singh and R.A. Yadav. 1990. Effect of methods of establishment and nitrogen application on yield and yield attributes of rice. **Oryza** 29: 210-213.
- Singh, R.K., V.P. Singh and C.V. Singh. 1994. Agronomic assessment of beushening in rainfed lowland rice cultivation, Bihar, India. **Agric. Ecosyst. Environ.** 51: 271-280.
- Singh, S.P., B. Sreedevi, R.M. Kumar and S.V. Subbaiah. 1999. Effect of N and weed control scheduling on grain yield of wet seeded rice varieties. Abstr. In: 8th Biennial Conf. **Indian Soc. Weed Sci.** 5-7 Feb.'99. Varanasi, p.6.
- Singh, Y., B. Singh, C.S. Khind and O.P. Meelu. 1988. Response of flooded rice to green manure. **IRRN** 13: 23-24.
- Sirajul Islam, MD., M. Shahjahan and MD. Yusuf Ali. 1999. Intercropping *Sesbania rostrata* with wetland rice (*Oryza sativa*) for seed and fuel. **Indian J. Agron.** 44(1): 77-79.
- Sivabal, M.K. 1989. Integrated nitrogen management practices with green manures (*S. rostrata* and *S. aculeata*) for lowland rice. M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Sivaperumal, V. 1995. Studies on crop establishment technique under different nitrogen levels and weed control methods in low land rice. M.Sc.(Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore, Tamil Nadu.
- Solaiappan, U. and V. Veerabadran. 1997. Effect of green manure intercropping on rice. **Madras Agric. J.** 84(7): 369-370.
- Somasundaram, E., G. Srinivasan and M.L. Manoharan. 1996. Effect of green manuring *sesbania rostrata* and fertilizer application on chemical properties of soil and grain yield in rice-rice crop sequences. **Madras Agric. J.** 83(12): 758-760.
- Songmuang, P., N. Rangsichon and W. Seetanum. 1983. Influence of seed rate and timing of fertilizer application on wet seeded rice yield. **IRRN** 8(3): 6.
- Sprent, J.I., M. Becana and J.M. Suthenland. 1988. Optimising N fixation in legume crops and trees. In: Nitrogen fixation : 100 years after (Ed.)Bothe, H; De Braijn, F. and Newton, W.E. Proc. of the 7th Intern. Congress on Nitrogen Fixation, 13-20 March 1988, Koln, West Germany, New York, pp.725-733.

- Sreedevi, B. and G.S. Thangamuthu. 1991. Studies on NPK uptake by rice under integrated nitrogen management. **Oryza** 28: 255-256.
- Srimathi, P. 1982. A study on seed production, processing and storage in cowpea. M.Sc.(Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Srinivasan, J. 1996. Investigations on the effect of varieties, intercropping daincha (*Sesbania aculeata*) and herbicide use on semi-dry rice. M.Sc.(Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Srinivasulu Reddy, D. 1988. Integrated nitrogen management in a rice leased cropping system. Ph.D. Thesis. Tamil Nadu Agric. Univ., Coimbatore.
- Sriramachandrasekharan, M.V., G. Ramanathan and M. Ravichandran. 1996. Effect of organic manures on the availability of nutrients in rice rhizosphere soil. **Oryza** 33: 126-131.
- Stanford, S. and L. English. 1949. Use of flame photometer in rapid soil tests for K and Ca. **Agron. J.** 41: 446-447.
- Subbaiah, K.K. and C.L. Asija. 1956. A rapid procedure for the estimation of available nitrogen in soil. **Curr. Sci.** 25: 259-260.
- Subbaiah, S.V. and V. Balasubramanian. 2000. Rice situation in India : Present status future prospects and challenges. In: Wet seeding of rice in India. (Ed.) Subbaiah and Balasubramanian, Directorate of Rice Research, Hyderabad and IRRI, Los Banos, Philippines, p.1-9.
- Subbaiah, S.V., S.P. Singh, R.M. Kumar and K. Padmaja. 2000. Drum seeding technology is a substitute for transplanting in India. CREMNET 2000. IRRI, Los Banos, Phillipines.pp. 139-141.
- Subramanian, S. and G.S. Thangamuthu. 1981. Nitrogen management for lowland rice. Technical Bulletin No.82, Tamil Nadu Agric. Univ., Coimbatore.
- Sudhakar, K., R. Prasad and T.V.R. Nair. 1987. Effect of level and time of nitrogen application on nitrate reductase activity on yield and nitrogen uptake by direct seeded rice. **Fert. News** 32:7.
- Sudhakara, K., R. Chauhan and M. Pillaimuthu. 1983. Effects of N level and time of application on nitrate reductase activity, yield and nitrogen uptake by direct seeded rice. **Fert. News** 28:17.

- Sur, H.S., A.S. Sidhu, Rachipal, G.C. Aggarwal and K.S. Sandhu. 1993. Long term effect of green manuring on soil physical properties and production potential in green manure-maize-wheat sequence. **Ann. Agric. Res.** **14**(2): 125-131.
- Susan John, K. and Alice Abraham. 1995. Microbial Immobilization and Mineralization of nutrient during different seasons of the year. **J. Indian Soc. Soil Sci.** **43**(1): 47-52.
- Swarup, A. 1987. Effect of pre-submergence and green manuring (*S. aculeata*) on nutrition and yield of wetland rice on a sodic soil. **Biol. and Fertil. Soils** **5**: 203-208.
- Takebe, M., T. Yoneyama, K. Inada and T. Murakami. 1990. Spectral reflectance ratio of rice canopy for estimating crop nitrogen status. **Plant and Soil** **122**: 295-297
- Talukdar, M.C., P.K. Barkakati and A.K. Pathak. 1996. Effect of sources of nitrogen on soil N status and yield of lowland rice. **Oryza** **33**: 42-45.
- Thakur, R.B. 1993. Effect of sowing methods and seed rate on the performance of high yielding varieties of rice. **Indian J. Agron.** **38**(4): 547-550.
- Thakur, D.S. and S.R. Patel. 1999. Growth and sink potential of rice as influenced by split application of nitrogen with and without FYM in Inceptisols of eastern parts of central peninsular India. **Oryza** **36**(3): 280-282.
- Thamizhvendan, R. and C. Rajeswari. 1999. Studies on the seed rate and method of sowing of two popular *Sesbania* species. **Crop Res.** **18**(2): 307-310.
- Thangaraju, M. 2000. Recent trends in foliar nutrition on pulse crops. **In: Recent trends in pulse crop production technology.** (Ed.) Jaganathan *et al.*, Tamil Nadu Agric. Univ., Coimbatore. pp.105-112.
- Thirumavalavan, P. 1989. Effect of intercropping and moisture regimes on semi dry rice. M.Sc.(Ag) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Thiyagarajan, T.M., R. Sivasamy and Hein. F.M. ten Berge. 1993. Nitrogen and Rice: Influence of N application levels and strategy on growth, leaf N and N use efficiency. Paper presented at the SARP Workshop on crop and soil management, Nov.'93 Suweon, Korea.
- Thiyagarajan, T.M., R. Sivasamy and H.F.M. ten Berge. 1994. Nitrogen and rice: Influence of nitrogen application levels and strategy on growth, leaf nitrogen content and nitrogen use efficiency. pp.56-69. **In: SARP Research Proceedings- Nitrogen economy of irrigated rice: (Ed.) ten Berge et al.,** BA-DLO and TPE-Wageningen and IRRI, Los Banos.

- Thomas, L. and SP. Palaniappan. 1998. Seed production of Velvet beans, Sunhemp and Pillipesara as influenced by plant density and phosphorus application. **Madras Agric. J.** 85(1): 35-38.
- Thomas George, Roland J. Buresh, Jagdish K. Ladha and Gloria Punzalan. 1998. Recycling *in situ* of legume fixed and soil nitrogen in tropical lowland rice. **Agron. J.** 90: 429-437.
- Tiwari, C., Singh, Y., Dheer Singh and D. Singh. 1995. Effect of *Sesbania* green manure and nitrogen fertilizer in rice-wheat cropping system. **Indian J. Agric. Sci.** 65(10): 708-711.
- Torres, R.O., R.P. Pareek, J.K. Ladha and D.P. Garrity. 1995. Stem nodulating legumes as relay-cropped or intercropped green manure for lowland rice. **Field Crop Res.** 42: 39-47.
- Urkurkar, J.S., I.K. Jaggi and S.S. Bagel. 1994. Nitrogen management through green manuring in direct sown rice. Paper presented at the Nat. Symp. on Integrated Input Management for Efficient Crop Production. 22-25 Feb. 1994, TNAU, Coimbatore. p.72.
- Ushamythili, M. 1982. A study on production, processing and storage in lablab. M.Sc.(Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Vaiyapuri, V., M. Ravichandran and M.V. Sriramachandrasekharan. 1998. Effect of graded levels of *Sesbania speciosa* with time of N application on growth and yield in rice-rice sequence. **Ann. Agric. Res.** 19(1): 1-3.
- Venkitasamy, R. 1986. Effect of new form of urea on nitrogen use efficiency and its interaction with weed growth and management in lowland rice. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Veno, M., K. Kunagar, K. Satoa, M. Inove and N. Tanakat. 1990. Soil nitrogen and its release from fertilizer and the application techniques using all fertilizer as basal fertilizer (2). Forecasting soil nitrogen with a system of single blanket application of basal fertilizer **Agriculture and Horticulture** 65(11): 1266-1270.
- Ventura, W. and I. Watanabe. 1993. Green manure preductin of *Azolla microphylla* and *Sesbania rostrata* their long term effects on rice yields and soil fertility. **Biol. Fert. Soils** 15: 241-248.
- Ventura, W., G.B. Mascarina, R.E. Furoc and I. Watanabe. 1987. *Azolla* and *Sesbania* as biofertilizers for lowland rice. **Philipp. J. Crop Sci.** 12: 61-69.

- Vijayalakshmi, C., R. Radhakrishnan, N. Nagarajan and K. Natārajamoorthy. 1992. Effective management of nitrogen for increased productivity in Rice. **Madras Agric. J.** 79: 158-162.
- Vinod Kumar, B.C. Ghosh, R. Bhat, V. Kumar and R. Bhat. 1999. Recycling of crop wastes and green manure and their impact on yield and nutrient uptake of wetland rice. **J. Agric. Sci.** 132: 149-154.
- Walkley, A. and C.A. Black. 1934. An examination of Destifaroff method for determining soil organic matter and proposed modification of the chromic acid titration. **Soil Sci.** 37: 29-34.
- Wan, C.C. and A.H. Daud, 1990. A concept of direct-seeding in rice cultivation under puddled soil. **In: Proc. of the Inter. Agricultural Engineering Conference and Exhibition, Bangkok.** pp.230-248.
- *Wang, H.Y. and T.S. Sun. 1990. The characteristics of machine direct sown rice following wheat and the corresponding techniques. **Acta Agricultural Universities Jiangxiensis** 12: 34-39.
- Watson, D.J. 1958. The dependance of net assimilation rate on leaf area index. **Ann. Bot.** 22: 37-54.
- Williams, R.W. 1946. The physiology of plant growth with special reference to the concept of NAR. **Ann. Bot.** 10: 41-47.
- Yadvinder Singh, C.S. Khind and B. Singh. 1991. Efficient management of leguminous green manures in wetland rice. **Adv. Agron.** 45: 135-189.
- Yashwant Singh, 1999. Effect of seeding method on rice production under puddled condition. **Ann. Agric. Res.** 20(4): 533-534.
- Yong-R. Wang and Ying-Jie Zhang. 1995. Effects of nitrogen and potassium nutrition during late growth stage of rice on translocation of ¹⁴C and grain yield. **IRRN** 20(6): 16.
- Yoshida, R. and T. Oritani. 1974. Studies on N metabolism in crop plants. **In: Effects of N top dressing on cytokinin content in the root exudate in rice plants.** **Proc. Crop Sci. Soc. (Japan)** 43: 47-51.
- Yoshida, S. 1981. Fundamentals of Rice Crop Science. IRRI, Los Banos, Philippines. p.269.
- Yoshida, S. and F.T. Parao. 1976. Climate influence on yield and yield components of lowland rice in the tropics. **In: Int. Rice Res. Inst. Climate and rice, Los Banos, Philippines.** p.471-494.

- Yoshida, S., D.A. Frene, J.H. Cock and K.A. Gomez. 1976. Laboratory manual for physiological studies of rice. IRRI, Los Banos, Phillipines, 6-18.
- Zaman, S.K., A.T.M.A. Choudhury and N.I. Bhuiyan. 1996. Prospects of dhaincha (*Sesbania rostrata*) intercropping with T. Aus. - T. Aman. Cropping pattern. **In:** Biological nitrogen fixation associated with rice production, (Ed.) M. Rahman *et al.* Dordrecht, The Netherlands Kluwer Academic Publishers.
- Zaman, S.K., G.M. Panaullah, M.A. Saleque and N.I. Bhuiyan. 1991. The use of dhaincha manuring as a substitute to urea for wetland rice. **Progress. Agric.** 2(2): 15-19.
- Zeikus, J.G. 1981. Fate of lignin and related aromatic substrates in anaerobic environments. **In:** Lignin biodegradation : (Ed.) Kirk, *et al.*, Microbiology, Chemistry and potential applications. CRC Press Inc. Madison, Wisconsin, USA, pp.101-109.

*Originals not seen.

PLATES



Plate : 1 Field view - Sowing by Drum seeder (Rice + Daincha)



Plate : 2 Field view of Rice + Daincha on 37 DAS



Plate : 3 Trampling with IRRI Cono Weeder on 37 DAS



Plate : 4 Field view - Seed Production row (early stage)



Plate : 5 Initial setback of rice after daincha incorporation



STUDIES ON INTERCROPPING DAINCHA (Sesbania indica) IN
WETSEED RICE FOR IN-CORPORATING OF NITROGEN
PRODUCTION WITH NITROGEN SPLIT AND STRATEGIES

Plot No.	Treatment	Area (m ²)	Planting Date
1	Wetseed Rice	100	15/11/11
2	Wetseed Rice + Daincha	100	15/11/11
3	Wetseed Rice + Daincha	100	15/11/11
4	Wetseed Rice + Daincha	100	15/11/11
5	Wetseed Rice + Daincha	100	15/11/11
6	Wetseed Rice + Daincha	100	15/11/11
7	Wetseed Rice + Daincha	100	15/11/11
8	Wetseed Rice + Daincha	100	15/11/11
9	Wetseed Rice + Daincha	100	15/11/11
10	Wetseed Rice + Daincha	100	15/11/11

Prepared by: Dr. S. S. Choudhary, Dr. S. S. Choudhary, Dr. S. S. Choudhary
Date: 15/11/11

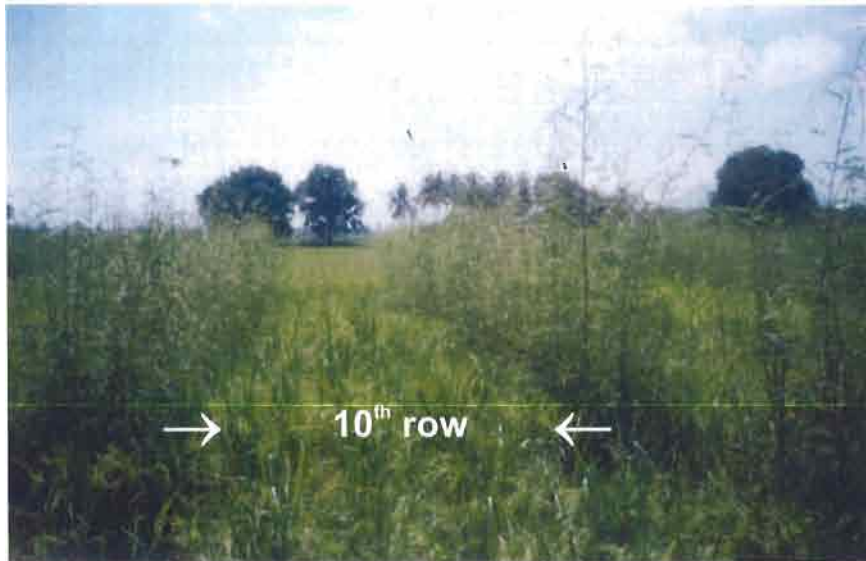


Plate : 7 Daincha - every 10th row for Seed Production

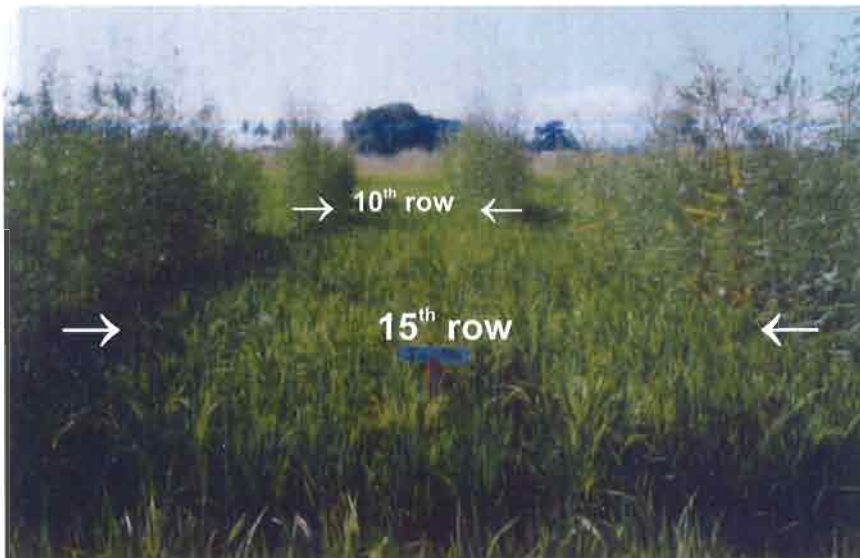


Plate : 8 Daincha - every 15th row for Seed Production

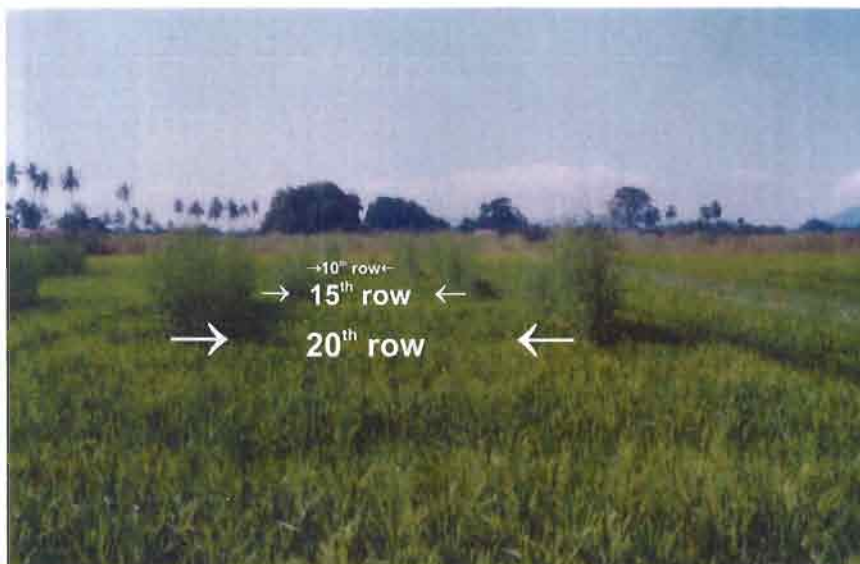


Plate : 9 Daincha - every 20th row for Seed Production



Plate :10 Recording - light availability (Canopy Top)



Plate :11 Recording - light availability (Canopy Bottom)



Plate :12 Recording - Chlorophyll (SPAD 502)

APPENDICES

APPENDIX I

Effect of shading at different growth stages on yield components and yield of paddy variety IR747-82-6 (Reproduced from Yoshida and Parao, 1976)

Sunlight (%)	Yield components		Grain yield (t ha ⁻¹)
	Spikelets No. x 10 ³ m ⁻²	Filled spikelets (%)	
1. Vegetative stage			
100	41.6	88.9	7.11
75	40.6	88.9	6.94
50	38.3	89.5	6.36
25	38.1	84.3	6.33
2. Reproductive stage			
100	41.6	88.9	7.11
75	30.3	87.8	5.71
50	24.4	89.4	4.45
25	16.5	89.4	3.21
3. Ripening stage			
100	41.6	88.9	7.11
75	41.1	81.1	6.53
50	40.6	64.5	5.16
25	41.7	54.9	3.93

APPENDIX II

WEATHER DATA DURING THE CROPPING PERIODS (KHARIF AND RABI)

Period	Standard week	Rainfall (mm)	No. of rainy days	Mean temperature		RH (per cent)		Solar radiation cal/cm/day	Mean sunshine hours day ⁻¹
				Max.	Min.	07.22 hrs	14.22 hrs		
1	2	3	4	5	6	7	8	9	10
KHARIF 1999									
June 18-24	25	10	1	30.1	22.6	77	51	358.5	5.3
June 25 - July 1	26	-	-	32.9	20.8	87	41	446.6	9.6
July 2-8	27	-	-	32.6	22.2	86	49	400.6	7.2
July 9-15	28	1.0	-	31.9	22.4	83	49	348.5	4.6
July 16-22	29	21.0	4	28.3	22.4	79	69	251.6	1.2
July 23-29	30	3.8	-	29.5	23.3	74	56	324.5	4.1
July 30-Aug.5	31	-	-	30.9	23.2	71	49	264.5	5.4
Aug.6-12	32	3.0	1	31.2	23.1	81	55	324.6	4.8
Aug.13-19	33	0.2	-	32.7	22.3	87	50	266.2	8.2
Aug.20-26	34	18.7	1	32.0	21.8	88	52	336.9	5.6
Aug.27-Sept.2	35	-	-	32.2	21.9	85	46	388.1	7.2
Sept.3-9	36	-	-	32.3	22.3	78	43	421.7	7.9
Sept.10-16	37	-	-	33.0	21.4	83	43	440.0	9.3
Sept.17-23	38	-	-	33.7	22.4	89	50	394.3	8.0
Sept.24-30	39	28.0	3	33.5	22.9	91	46	351.4	6.1
Oct.1-7	40	72.3	4	29.9	22.5	94	68	282.7	3.9

...Contd.

	1	2	3	4	5	6	7	8	9	10
RABI 1999										
Oct.29-Nov.4	44	44	2.0	-	30.2	20.2	94	64	304.0	5.7
Nov.5-11	45	45	64.2	-	29.9	19.8	91	51	327.0	4.8
Nov.12-18	46	46	-	-	29.7	18.4	88	47	463.2	9.9
Nov.19-25	47	47	35.0	3	27.4	21.0	93	71	292.3	3.5
Nov.26-Dec.2	48	48	6.4	1	28.4	21.0	91	63	373.8	6.3
Dec.3-9	49	49	-	-	28.3	19.1	91	59	388.3	5.6
Dec.10-16	50	50	3	1	26.2	19.3	91	62	308.1	6.1
Dec.17-23	51	51	10	1	27.9	18.3	88	57	322.0	5.2
Dec.24-31	52	52	8.8	1	26.8	19.3	90	54	416.3	7.6
Jan.1-7	1	1	-	-	28.3	19.9	87	52	281.5	2.9
Jan.8-14	2	2	2.0	-	28.1	20.5	87	62	281.5	2.9
Jan.15-21	3	3	-	-	30.5	18.1	91	39	405.9	9.2
Jan.22-28	4	4	-	-	31.6	16.9	90	35	500.7	9.5
Jan.29-Feb.4	5	5	-	-	31.0	18.3	89	40	420.6	6.7
Feb.5-11	6	6	-	-	32.0	21.9	89	48	406.6	7.4
Feb.12-18	7	7	-	-	32.2	19.9	88	37	425.7	9.2
Feb.19-25	8	8	18	1	32.7	20.9	91	52	366.2	5.7
Feb.26-March 3	9	9	18.9	3	30.5	19.6	90	45	383.7	8.0

...Contd.

1	2	3	4	5	6	7	8	9	10
KHARIF 2000									
June 24-June 31	26	2.3	-	31.5	22.4	76	50	337.9	4.5
July 1-7	27	2.5	1	30.5	22.2	78	51	307.3	2.1
July 8-14	28	12.0	1	30.8	24.2	64	51	380.0	6.1
July 15-21	29	-	-	32.2	22.5	77	47	417.7	7.5
July 22-28	30	-	-	32.8	21.9	88	50	394.1	7.7
July 29-Aug.4	31	41.4	2	32.8	22.6	92	53	380.4	7.8
Aug.5-11	32	6.2	1	30.2	22.8	75	55	339.5	4.5
Aug.12-18	33	89.0	1	31.6	22.1	88	56	374.4	5.9
Aug.19-25	34	22.9	3	28.9	22.8	75	70	255.9	0.8
Aug.26-Sept.1	35	4.1	1	29.8	21.8	86	54	402.5	6.3
Sept.2-8	36	-	-	32.2	22.1	85	54	431.3	8.7
Sept.9-15	37	3.6	1	32.3	22.1	88	59	382.1	6.4
Sept.16-22	38	39.6	3	31.9	22.5	89	60	288.2	5.2
Sept.23-29	39	117.2	5	29.6	22.3	92	70	303.0	3.5
Sept.30-Oct.6	40	10.3	2	29.3	21.4	91	65	339.0	5.7
Oct.7-13	41	11.3	3	30.9	21.6	90	60	338.9	4.7
Oct.14-20	42	10.0	1	31.1	21.7	93	63	378.4	7.3

APPENDIX III

DETAILS OF COST OF RICE PRODUCTION

A. Sole rice

Sl. No.	Particulars	Inputs	Rate	Total cost (Rs. ha ⁻¹)
1	2	3	4	5
1.	Preparatory cultivation			
a.	Tractor ploughing twice and levelling	1 tractor for 5 hours/one time	Rs.135/hour	1350.00
b.	Trimming, plastering and levelling	20 men days	Rs.39.60 day ⁻¹	792.00
2.	Seeds and sowing			
i.	Cost of seeds			
	Paddy seeds	80 kg ha ⁻¹	Rs.14.00 kg ⁻¹	1120.00
ii.	Seed treatment			
	Bavistin	150 gm	Rs.610 kg ⁻¹	91.50
iii.	Rent for drum seeder			
		1 day	Rs.75 day ⁻¹	75.00
iv.	Sowing			
		5 men day ⁻¹ ha ⁻¹	Rs.39.60 day ⁻¹	198.00
3.	Fertilizers and application charges			
i.	Cost of fertilizers			
a.	Urea	260.4 kg ha ⁻¹ (kharif)	Rs.4.60 kg ⁻¹	1198.00
		325.5 kg ha ⁻¹ (rabi)		1497.00
b.	SSP	237.5 kg ha ⁻¹	Rs.3.05 kg ⁻¹	724.00
		312.5 kg ha ⁻¹		953.00
c.	MOP	63.5 kg ha ⁻¹	Rs.4.30 kg ⁻¹	273.00
		83.5 kg ha ⁻¹		359.00
iii.	Application charges			
		2 men days	Rs.39.60 day ⁻¹	79.20
4.	Weed management and application charges			
a.	Herbicide (Butachlor)	2.2 Lit ha ⁻¹	Rs.270 Lit ⁻¹	594.00
b.	Application charges			
		½ men days	Rs.39.6 day ⁻¹	20.00
c.	Hand weeding twice			
		15 women day ⁻¹	Rs.35.2 day ⁻¹	528.00
		15 women day ⁻¹	Rs.35.2 day ⁻¹	528.00

...Contd.

1	2	3	4	5
5.	Plant protection			
	a. Cost of chemicals			
	Dimecron	500 ml	Rs.392.5 Lit ⁻¹	196.00
	Nuvacron	1000 ml	Rs.364 Lit ⁻¹	364.00
	Hinoson	200 ml	Rs.628 Lit ⁻¹	126.00
	Bavistin	250 gm	Rs.619 kg ⁻¹	153.00
	b. Application charges	2 men day ⁻¹	Rs.39.60 day ⁻¹	7920.00
		2 women day ⁻¹	Rs.35.20 day ⁻¹	70.40
6.	Irrigation			
	Guiding water	12 men day ⁻¹ (<i>kharif</i>)	Rs.39.60 day ⁻¹	475.20
		10 men day ⁻¹ (<i>rabi</i>)	Rs.39.60 day ⁻¹	396.00
7.	Harvesting			
	Harvesting, threshing, cleaning and cleaning	15 men days	Rs.39.60 day ⁻¹	594.00
		30 women days	Rs.35.20 day ⁻¹	1056.00
8.	Land Rent	1 season	Rs.500 ha ⁻¹	500.00
	Total cost of production		Rabi	10650.00
			Kharif	11185.00
B. Rice + daincha intercropping				
	i. Daincha seed	20 kg ha ⁻¹	Rs.25 kg ⁻¹	500.00
	ii. Trampling daincha by using IRRI 'Cono' weeder	8 men day ⁻¹	Rs.39.60 day ⁻¹	317.00
	iii. Rent for IRRI 'Cono' weeder	1 day	Rs.10 day ⁻¹	10.00
	Total cost of production		Rabi	11477.00
			Kharif	12012.00
C. Daincha seed crop				
	Harvesting, drying, beating and cleaning	I ₂ =10 women days	Rs.35.00 day ⁻¹	352.00
		I ₃ = 7 women days	"	246.40
		I ₄ = 4 women days	"	140.80

APPENDIX IV

Economics of daincha intercropping/seed production and N split dose in wet seeded rice during *kharif* 1999

Treat- ments	Rice yield (kg ha ⁻¹)		Daincha yield (kg ha ⁻¹)		Total cost of production (Rs.ha ⁻¹)	Gross income (Rs.ha ⁻¹)	Net income (Rs.ha ⁻¹)	BCR
	Grain	Straw	Grain	Straw				
I ₀ N ₁	5438	7086	-	-	11185	34103	22918	3.05
I ₀ N ₂	5036	6719	-	-	11185	31645	20460	2.83
I ₀ N ₃	4616	6088	-	-	11185	28977	17792	2.59
I ₁ N ₁	6306	7634	-	-	12012	39314	27302	3.27
I ₁ N ₂	6761	7881	-	-	12012	42028	30016	3.50
I ₁ N ₃	5817	7352	-	-	12012	36389	24377	3.03
I ₂ N ₁	5373	6704	173	1812	12364	38264	25900	3.09
I ₂ N ₂	5760	7068	171	1827	12364	40587	28223	3.28
I ₂ N ₃	4956	6456	166	1836	12364	35596	23232	2.88
I ₃ N ₁	5713	7116	134	1556	12258	39357	27099	3.21
I ₃ N ₂	6125	7448	138	1576	12258	41963	29705	3.42
I ₃ N ₃	5270	6869	139	1584	12258	36883	24625	3.01
I ₄ N ₁	5992	7452	105	1285	12153	40317	28164	3.32
I ₄ N ₂	6423	7789	110	1310	12153	43060	30907	3.54
I ₄ N ₃	5526	7198	112	1344	12153	37723	25570	3.10

Rice grain = Rs.5.75/kg
Straw = Rs.0.40/kg

Daincha seed = Rs.25.00/kg
Haulm = Rs. 0.20/kg

APPENDIX V

Economics of daincha intercropping/seed production and N split dose in wet seeded rice during *rabi* 1999

Treat- ments	Rice yield (kg ha ⁻¹)		Daincha yield (kg ha ⁻¹)		Total cost of production (Rs.ha ⁻¹)	Gross income (Rs.ha ⁻¹)	Net income (Rs.ha ⁻¹)	BCR
	Grain	Straw	Grain	Straw				
I ₀ N ₁	4647	7238	-	-	10650	29615	18965	2.78
I ₀ N ₂	4312	6919	-	-	10650	27562	16912	2.59
I ₀ N ₃	3949	6487	-	-	10650	25302	14652	2.38
I ₁ N ₁	5438	7942	-	-	11477	34446	22969	3.00
I ₁ N ₂	5718	8104	-	-	11477	36121	24644	3.15
I ₁ N ₃	5006	7678	-	-	11477	31856	20379	2.78
I ₂ N ₁	4606	6926	127	1577	11829	32745	20916	2.77
I ₂ N ₂	4843	7164	132	1583	11829	34330	22501	2.90
I ₂ N ₃	4240	6603	137	1592	11829	30764	18935	2.60
I ₃ N ₁	4883	7313	94	1170	11723	33586	21863	2.86
I ₃ N ₂	5135	7577	96	1178	11723	35193	23470	3.00
I ₃ N ₃	4495	6994	101	1186	11723	31406	19683	2.68
I ₄ N ₁	5193	7487	73	919	11618	34864	23246	3.00
I ₄ N ₂	5461	7939	75	926	11618	36637	25019	3.15
I ₄ N ₃	4781	7332	74	933	11618	32461	20843	2.79

Rice grain = Rs.5.75/kg
Straw = Rs.0.40/kg

Daincha seed = Rs.25.00/kg
Haulm = Rs. 0.20/kg