NUTRIENT MANAGEMENT FOR BASMATI RICE (*Oryza sativa* L.) IN WETLANDS

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Thesis submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled "**Nutrient management for basmati rice (*Oryza sativa* L.) in wetlands**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Nutrient management for basmati rice (*Oryza sativa* L.) in wetlands**" is a record of research work done independently by Ms. Sindhu. M.S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

@	At the rate of
^0C	Degree Celsius
%	per cent
a.i.	Active ingredient
BCR	Benefit : Cost ratio
CD	Critical difference
cm	Centimetre
DMP	Dry matter production
Ec	Emulsifiable concentrate
et al.	And others
FIB	Farm Information Bureau
Fig.	Figure
FYM	Farmyard manure
g	Gram
ha^{-1}	Per hectare
HI	Harvest index
$Hill^{-1}$	Per hill
i.e.	That is
IRRI	International Rice Research Institute
K	Potassium
kg	Kilogram
kg^{-1}	Per kilogram
kw	Kilo watt
LAI	Leaf area index

LIST OF ABBREVIATIONS continued

m	Metre
m^{-2}	Per square metre
ml	Milli litre
mm	Millimetre
N	Nitrogen
NUE	Nitrogen use efficiency
P	Phosphorus
$Panicle^{-1}$	Per panicle
RBD	Randomised block design
Rs	Rupees
SE	Standard error
t	Tonne
WP	Wettable powder

INTRODUCTION

1. INTRODUCTION

Kerala which is chronically short in food grain production, is confronted with a serious problem of retaining even the small area under cultivation. Despite governmental support for rice production, from mid seventies onwards Kerala witnessed a change in cropping patterns. Now in Kerala, rice occupies an area of about 3.49 lakh ha which forms only 11.75 per cent of the gross cropped area (FIB, 2001) and contributes 7.71 lakh tonnes to our food grain production. With the current rate of grain production, our state can meet only 20 per cent of the demand and the rest met by government distribution through public distribution system and import by private traders.

A large part of Kerala's paddy lands gave way for cultivation of cash crops like coconut, arecanut, banana, tapioca and even plantation crops like rubber. This shift in cultivation is mainly due to the high cost of production of rice with little or no net returns. It is seen that paddy has the lowest gross income among various crops cultivated in Kerala. This is due to the increase in input costs more than proportionately to the price of the produce. Thus low profit of rice cultivation and attractive alternative crops are driving out the farmers from paddy cultivation.

In Kerala, the policymakers are now giving much thrust for retaining the rice areas so as to serve for food security and environmental security. To protect rice farming, first and foremost thing that has to be ensured is a reasonable return to the farming community. In this context, cultivation of basmati rice which is highly remunerative is gaining popularity among the farmers of Kerala.

Basmati rice is an elite group among rice varieties which is distinguished by acceptable grain quality traits like aroma, elongation of grains after cooking, higher volume expansion ratio, non-sticky texture etc. Although the yield of scented rice varieties is comparatively low, the price is three times the price of common rice. It is produced exclusively in specific geographical areas of India and Pakistan. Now reports are available on the successful cultivation of basmati rice in wetlands of Kerala. But systematic study on agro-techniques of basmati rice has not yet been conducted in Kerala.

Nutrient management has got profound influence on basmati rice with regard to yield and quality. Apart from the quantity of nutrients, the source of nutrients also has got correlation with yield, aroma and quality of grains (Dutta *et al.*, 1999). Integration of organic and inorganic sources of nutrients is the best solution for yield improvement. The use of organic manures which supplement the chemical fertilizers is also a solution for the increasing fertilizer prices which often prevent the farmers from using the recommended dose of nutrients. Thus it saves the cost of production and maintain soil fertility and rhizosphere environment by improving the physico-chemical properties of paddy soils without hindering the production of succeeding crop (Tiwari and Tripathi, 1998).

Among the organics, farmyard manure (FYM) is the most commonly used bulky organic manure. Higher efficiency of FYM in producing higher yield and improving chemical properties of soil compared to urea was revealed in a study conducted by Gomes *et al.* (1983). Verma (1990) suggested incorporation of FYM for saving 50 per cent of inorganic fertilizers in paddy crop and Tripathi and Chaubey (1996) opined that incorporation of FYM in combination with inorganic fertilizers economizes the fertilizer need.

Vermicompost is also regarded as a potential source due to the presence of readily available plant nutrients, growth enhancing substances and a number of beneficial micro organisms. Vermicompost can substitute or complement chemical fertilizers. It contains various amino acids and minerals which humidify the organic matter in the surrounding soil and acts as a biofertilizer for plants (Shanbhag, 1999).

Keeping these views under consideration, the present investigation entitled "Nutrient management for basmati rice (*Oryza sativa* L.) in wetlands" was undertaken to derive an optimum package for nutrient management for basmati rice in wetland condition.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Aromatic or scented rices have occupied a prime position in Indian society not only because of their high quality, but also because they had been considered auspicious (Ahuja *et al.*, 1995). The basmati type among them is accepted as the best scented, longest and slenderest rice in the world and the Indian subcontinent continues to be its homeland. Now reports are available on the successful cultivation of basmati rice in wetlands in different parts of Kerala. But the yield of basmati rice varieties is comparatively low, probably due to lack of information on proper agronomic management practices especially on nutrient management.

Chemical fertilizers are costly inputs and their use pose problems on soil health and pollution on a long run. The conjunctive use of organic manures and inorganic fertilizers increases the efficiency of applied nutrients and improves soil health and quality of grains. So the present study was thus based on an integrated nutrient supply which is important to sustain higher levels of soil fertility and crop productivity. Since there are only limited research works on nutrient management of basmati rice, relevant literature on nutrient management of other varieties of rice was also reviewed with emphasis on different levels of nitrogen (N), organic N sources, NPK ratios and combined application of organic and inorganic nutrients as given in this chapter.

2.1 EFFECT OF NITROGEN LEVELS ON GROWTH AND YIELD OF RICE

2.1.1 Effect on Growth Parameters

2.1.1.1 Plant Height

Increase in plant height due to incremental doses of N has been reported by many workers (Balasubramanian, 1980; Datta and Surjith, 1981; Yoshida, 1981; Singh and Sharma, 1987). Reddy and Reddy (1989) observed significantly enhanced plant height in rice with N fertilization. According to Gupta (1996), increasing levels of N from 0 to 80 kg ha^{-1} significantly enhanced plant height in rice. Similar results were also reported by Dwivedi (1997), Behera (1998) and Chopra and Chopra (2000). Lin *et al.* (1997) reported that plant height significantly increased in Basmati-370 with N application. Same result was also reported by Singh and Prasad (1999). Kumari *et al.* (2000) observed taller plants at higher doses of N (120 kg ha^{-1}) application. Jaiswal and Singh (2001) reported that application of 120 kg N ha^{-1} recorded significantly higher plant height in rice than 60 kg N ha^{-1}.

2.1.1.2 Tiller count

Lenka and Behra (1967) and Datta and Surjith (1981) reported that tiller production in rice increased with increase in N level. Singh *et al.* (1983) observed that tiller number in rice was favourably influenced by N upto 80 kg ha^{-1}. Similar findings were reported by Dalai and Dixit (1987). Munda (1989) concluded that higher levels of N significantly improved tiller production in rainfed rice.

2.1.1.3 Leaf Area Index (LAI)

Prasad *et al.* (1992) concluded that LAI increased with increase in nitrogen level upto 80 kg ha^{-1} in rice. A significant increase in the LAI of medium duration rice was reported by Babu (1996) with the highest level of 120 kg ha^{-1} of N over normal rate of 90 kg N ha^{-1}. Increase in LAI of rice with increase in nitrogen rates upto 120 kg ha^{-1} was also reported by Jaiswal and Singh (2001).

2.1.1.4 Drymatter Production (DMP)

Sannigrahi and Mendel (1984) reported that due to the beneficial effect of N on tillering and vegetative growth, there was more accumulation of drymatter at all stages of sampling in rice with increase in N level from 0 to 120 kg ha^{-1}. Similar results were also reported by

Reddy *et al.* (1986) and Sudhakar *et al.* (1986). Subbiah and Palaniappan (1988) concluded that N applied at 80 kg ha^{-1} increased drymatter accumulation in rice. Significant increase in drymatter accumulation of rice with increase in N levels from 0 to 150 kg ha^{-1} has been reported by Hari *et al.* (1997). In rice, DMP increased with increase in the level of N (Kumari *et al.*, 2000; Singh and Singh, 2000a) and maximum drymatter was obtained at 90 kg ha^{-1}.

2.1.2 Effect on Yield Attributes

2.1.2.1 Number of Productive Tillers $Hill^{-1}$

Sing *et al.* (1990) observed that the important yield determinant of rice i.e., panicles m^{-2} increased with increasing rates of nitrogen. Similar result was reported by Rao *et al.* (1993) in scented rice. Incremental doses of N increased the number of panicles $plant^{-1}$ in rice and recorded maximum panicles $plant^{-1}$ at 120 kg N ha^{-1} (Dwivedi, 1997; Behera, 1998; Lakpale *et al.*, 1999; Chopra and Chopra, 2000; Kumari *et al.*, 2000). Singh and Singh (2000b) reported that application of 150 per cent of recommended dose of N (75 kg ha^{-1}) gave significantly higher number of panicle density in rice.

2.1.2.2 Length of Panicle

Sing *et al.* (1990) observed that the length of panicle increased significantly with increasing rates of N in rice. According to Gupta (1996), increasing levels of N from 0 to 80 kg ha^{-1} significantly increased panicle length in rice. In scented rice, N application upto 100 kg ha^{-1} resulted in significant increase in panicle length (Singh *et al.*, 1997). However, Chopra and Chopra (2000) reported that the panicle length in scented rice remained unaffected due to nitrogen.

2.1.2.3 Weight of Panicle

In scented rice, the panicle weight showed an increasing trend with increase in the level of N (Rao *et al.*, 1993). According to Singh *et al.*

(1997), N application upto 100 kg ha^{-1} resulted in significant increase in panicle weight of scented rice. Chopra and Chopra (2000) observed that increasing levels of N from 0 to 80 kg ha^{-1} significantly increased seed weight $panicle^{-1}$ and declined at the highest dose of 120 kg N ha^{-1} in scented rice.

2.1.2.4 Number of Grains Panicle^{-1}

Fertile spikelets $panicle^{-1}$ in rice increased significantly with every increment in N application (Sing *et al.*, 1990). According to Padmajarao (1995), high density of grains was observed in scented rice with 40 kg N ha^{-1}. Gupta (1996) reported that increasing levels of N from 0 to 80 kg ha^{-1} significantly increased grains $panicle^{-1}$ in rice. Singh and Prasad (1999) opined that application of N had significant effect on grain number $spike^{-1}$ in rice. Kumari *et al.* (2000) also reported that the filled grains $panicle^{-1}$ in rice increased with increase in N application.

2.1.2.5 Thousand Grain Weight

According to Sing *et al.* (1990), the thousand grain weight increased significantly with every increment in N application. Singh and Prasad (1999) also reported significant effect of N application on thousand grain weight of rice. Singh and Singh (2000b) observed that application of 75 kg N ha^{-1} produced significantly higher thousand grain weight in rice.

2.1.3 Effect on Yield

2.1.3.1 Grain Yield

Grain yield of rice increased significantly with every increase in the rate of N (Sing *et al.*, 1990). Rao *et al.* (1993) considered the application of 60 kg N ha^{-1} as the optimum for obtaining higher grain yield in basmati type varieties. Gupta (1996) observed that the grain yield of rice increased correspondingly with increasing level of N upto 80 kg ha^{-1}. Singh *et al.* (1997) recorded the highest grain yield of rice (4.05 t ha^{-1}) with 100 kg N ha^{-1}. Lakpale *et al.* (1999) observed that application of 120 kg N ha^{-1}

significantly increased grain yield of rice over 60 kg N ha^{-1}. In basmati rice, each incremental dose of N gave significantly higher grain yield and maximum grain yield was obtained with 100 kg N ha^{-1} (Singh *et al.*, 2000b). According to Singh and Singh (2000b), application of 75 kg N ha^{-1} gave higher grain yield of rice than lower N levels. Kumari *et al.* (2000) opined that increasing N level from 40 to 120 kg ha^{-1} brought about significant increase in grain yield of rice over no nitrogen. According to Chander and Pandey (2001) and Jaiswal and Singh (2001), N application at 120 kg ha^{-1} markedly increased the grain yield of rice compared to 60 kg N ha^{-1}.

In scented rice, N application upto 100 kg ha^{-1} resulted significant increase in grain yield and further increase in dose to 150 kg N ha^{-1} decreased the grain yield (Singh *et al.*, 1997). Singh and Sreedevi (1997), Thakur *et al.* (1997) and Behera (1998) reported a significant linear increase in grain yield of scented rice upto 90 kg N ha^{-1} and thereafter the increase in grain yield was marginal. According to Ranwa and Singh (1999), the increase in yield due to application of 150 kg N ha^{-1} was 75.70, 27.30 and 7.40 per cent over 0, 50 and 100 kg N ha^{-1} respectively. Singh and Prasad (1999) reported a linear increase in grain yield upto 75 kg N ha^{-1} and Chopra and Chopra (2000) reported the same upto 80 kg N ha^{-1} and thereafter a marginal reduction in seed yield was observed at 120 kg N ha^{-1}.

2.1.3.2 Straw Yield

Application of N had significant effect on straw yield of rice (Singh and Prasad, 1999). In scented rice, each incremental dose of N gave significantly higher straw yield (Chopra and Chopra, 2000; Singh *et al.*, 2000b). According to Singh and Singh (2000b) application of 75 kg N ha^{-1} gave higher straw yield than lower N levels. Chander and Pandey (2001) reported a marked increase in straw yield of rice at 120 kg N ha^{-1} compared to 60 kg N ha^{-1}.

2.1.3.3 Harvest Index (HI)

Chavan *et al.* (1989) observed low grain : straw ratio with increased N application rates in rice. Dhyani and Mishra (1994) reported slight reduction in HI of rice with N levels above 60 kg ha^{-1}. Hari *et al.* (1997) observed progressive decrease in HI of rice with increased rate of N application. However according to Patel *et al.* (1997), HI of rice was significantly higher with the application of 80 and 120 kg N ha^{-1} over 40 kg N ha^{-1}.

2.1.4 Effect on Quality of Grains

2.1.4.1 Protein Content of Grains

Singh and Modgal (1978) observed an increase in protein content of rice grains with increase in N levels. Akram *et al.* (1985) reported that in basmati rice, 90 kg N ha^{-1} gave the highest average protein content (9.34 per cent). Reddy *et al.* (1986) reported that highest protein content of 7.13 per cent was obtained at 120 kg N ha^{-1}. Increase in protein content with increasing dose of N was also reported by Chandra (1992). According to Singh *et al.* (1997), N fertilization resulted in significant increase in protein content in rice grains upto 100 kg N ha^{-1}.

2.1.4.2 Cooking Quality of Grains

According to Rao *et al.* (1993), application of 60 kg N ha^{-1} may be considered as the optimum for obtaining higher grain quality of rice in basmati type varieties. They also reported that there was no adverse effect of N on volume expansion and elongation ratio of scented rice due to different levels of nitrogen. Pandey *et al.* (1999) observed an increase in elongation ratio of rice grains with the application of N fertilizers.

2.1.5 Effect on Nutrient Uptake and Nitrogen Use Efficiency

2.1.5.1 Nutrient Uptake

Uptake of nutrients and dry matter accumulation in rice are influenced by several factors. The uptake of nutrients differs with the stage of crop growth. Reports show that there is progressive increase in uptake of nutrients with every additional dose of N (Mehta *et al.*, 1983). Reddy *et al.* (1986) revealed that, in rice increasing levels of N upto 120 kg ha^{-1} increased the N uptake and recorded maximum uptake of 65.2 kg ha^{-1} at harvest. Sudhakar *et al.* (1987) observed that N application @ 180 kg ha^{-1} increased the grain, straw as well as the total N uptake. Sarmah and Baroova (1994) observed significantly higher N uptake by the highest level of 90 kg N ha^{-1}. According to Patel *et al.* (1997), N uptake by rice grain, straw as well as total uptake increased significantly with the application of higher dose of N (120 kg ha^{-1}) over 40 kg ha^{-1}. At 120 kg N ha^{-1}, N uptake was higher than 60 kg N ha^{-1} (Chander and Pandey, 2001; Jaiswal and Singh, 2001).

Sushamakumari (1981) observed significant increase in P uptake with increasing levels of N from 45 to 90 kg ha^{-1} in rice variety Jaya. Surendran (1985) also reported an increase in P uptake with increase in the levels of N from 20 to 80 kg ha^{-1}. Munda (1989) observed higher N and P uptake by rice with increase in N levels. Significantly higher N, P and K uptake by rice grain and straw with 90 kg N ha^{-1} over 60 and 30 kg N ha^{-1} was reported by Pandey *et al.* (1991). According to Tiwana *et al.* (1999), the N application significantly increased the total uptake of K in rice upto the highest level of 240 kg N ha^{-1}.

2.1.5.2 Nitrogen Use Efficiency (NUE)

According to Rao *et al.* (1993), the response of grain yield to N application in wet season was upto 60 kg ha^{-1} and in the dry season upto 90 kg ha^{-1}. Singh and Sreedevi (1997) observed a decrease in NUE with increase in rate of N application in dwarf scented rice. Behera (1998) reported the maximum N response of 30 kg N ha^{-1} in scented rice. However, Chopra and Chopra (2000) opined that the maximum response to N in scented rice was at 40 kg N ha^{-1} and thereafter it decreases with increase in N level.

2.1.6 Effect on Soil Available Nutrients

Sushamakumari (1981) reported that the available N tended to increase with the increase in the level of applied nitrogen. Anu (2001) also reported that the available soil N was high in plots treated with higher levels of N and maximum availability of soil N and K was observed with 80 kg N ha^{-1}.

2.2 EFFECT OF ORGANIC MANURES ON GROWTH AND YIELD OF RICE

2.2.1 Effect on Growth Parameters

2.2.1.1 Plant Height

Sharma (1994) opined that plants with FYM application were taller than those grown without FYM. Significant increase in plant height of rice variety Pavizham has been reported with FYM @ 10 t ha^{-1} (Babu, 1996). Increased plant height with vermicompost @ 2.5 t ha^{-1} was recorded by Janaki and Hari (1997).

2.2.1.2 Tiller Count

Subbiah *et al.* (1983) opined that incorporation of organic residues @ 10 t ha^{-1} had no influence in increasing tiller number m^{-2}in rice. However, Shuxin *et al.* (1991) reported a 10 per cent increase in effective tillering in rice due to vermicompost application. According to Sharma (1994), FYM application produced more tillers in rice than in conditions without FYM. Janaki and Hari (1997) reported higher production of tillers in rice with 2.5 t ha^{-1} of vermicompost.

2.2.1.3 Leaf Area Index

Babu (1996) reported that LAI of medium duration rice variety Pavizham was significantly increased by organic manure addition as 10 t ha^{-1} of FYM. However, according to Sudha (1999), different levels and sources of organic manure application had no significant effect on LAI at any stage of growth of rice.

2.2.1.4 Dry Matter Production

Incorporation of organic residues @ 10 t ha^{-1} could influence the DMP in rice at maturity stage (Subbiah *et al.*, 1983). Sharma (1994) opined that rice plants produce more dry matter when grown with FYM application. Enhanced dry matter accumulation in rice with organic matter addition has been reported by Babu (1996). According to Sudha (1999), different levels and sources of organic manures showed significant influence on DMP at all growth stages of rice. In general, increased DMP was noticed with higher doses of organic manures and vermicompost (5 t ha^{-1}) as a source of organic manure could increase the DMP comparable to higher dose of FYM (10 t ha^{-1}).

2.2.2 Effect on Yield Attributes

2.2.2.1 Number of Productive Tillers $Hill^{-1}$

According to Deepa (1998), the performance of organic manure applied plots were better than untreated and complete inorganic fertilizer applied plots, in producing higher number of panicles in rice variety Kanchana.

FYM as a source of organic manure was effective in increasing the number of panicles m^{-2} in rice (Zia *et al.*, 1992). Sharma and Sharma (1994) and Rathore *et al.* (1995) also observed an increase in panicle number m^{-2} in rice with FYM application. In a study, Janaki and Hari (1997) noticed that the panicles $plant^{-1}$ increased twice due to vermicompost application @ 2.5 t ha^{-1}.

2.2.2.2 Length of Panicle

Ranwa and Singh (1999) observed that organic manures had no significant effect on panicle length. According to Dwivedi and Thakur (2000), the panicle length of rice was significantly influenced due to green manuring only, but fertility levels and other organic manures could not influence the length of panicle.

2.2.2.3 Weight of Panicle

According to Ranwa and Singh (1999), the grain weight spike^{-1} of wheat was maximum with vermicompost @ 10 t ha^{-1} but statistically at par with vermicompost @ 7.5 t ha^{-1}. Pandey *et al.* (2001) also observed the beneficial effect of organic manures in influencing the panicle weight of rice.

2.2.2.4 Number of Grains Panicle^{-1}

Prakash *et al.* (1990) observed considerable reduction in chaff percentage in rice due to organic manure addition. Sharma and Sharma (1994) and Rathore *et al.* (1995) observed significantly higher grain number panicle^{-1} in rice with FYM addition. A two time increase in the grain number panicle^{-1} in rice was observed with application of vermicompost @ 2.5 t ha^{-1} by Janaki and Hari (1997). Contrary to the above results, Sudha (1999) observed that organic manure application at different levels and through different sources could not produce any significant effect on the total and filled grains panicle^{-1} in rice.

2.2.2.5 Thousand Grain Weight

Rathore *et al.* (1995) observed significant increase in thousand grain weight of rice with FYM application. According to Deepa (1998), organic manuring in rice field could increase the thousand grain weight. But Ranwa and Singh (1999) and Dwivedi and Thakur (2000) reported that there was no significant effect on thousand grain weight due to organic manure application.

2.2.3 Effect on Yield

2.2.3.1 Grain Yield

Zia *et al.* (1992) reported higher grain yields of rice with organic manuring through FYM. Sharma and Sharma (1994) also obtained significantly higher grain yields of rice through FYM incorporation. Brar and Dhillon (1994) observed that grain yield of rice reached upto 6.7 t ha^{-1}

using 40 t ha^{-1} of FYM as against 4.1 t ha^{-1} in control plot. Sharma (1994) observed 26 per cent increase in yield of rice with the application of 10 t ha^{-1} of FYM. Rathore *et al.* (1995) reported significantly higher grain yield of rice with FYM addition.

Janaki and Hari (1997) reported that rice gave almost double yield over control when supplemented with 2.5 t ha^{-1} of vermicompost. Ranwa and Singh (1999) reported that highest grain yield of 3.84 t ha^{-1} was recorded with vermicompost @ 10 t ha^{-1} which was 16.50, 7.20, 3.40 and 1.60 per cent higher than no organic manures, vermicompost @ 5 t ha^{-1}, FYM @ 10 t ha^{-1} and vermicompost @ 7.5 t ha^{-1} respectively. Sudha (1999) opined that vermicompost at lower rates (5 t ha^{-1}) and FYM at higher rates (10 t ha^{-1}) were equally good for grain production in rice. Nehra *et al.* (2001) observed that FYM at 15 t ha^{-1} and vermicompost at 10 t ha^{-1} were statistically on par and resulted in higher grain yield in wheat.

*2.2.3.2 **Straw Yield***

Sharma and Sharma (1994) reported significant increase in the straw yield of rice with FYM incorporation. Babu (1996) could observe significant increase in the straw yield of rice variety Pavizham with FYM addition @ 10 t ha^{-1}. However, Sudha (1999) reported that different levels and sources of organic manures could not significantly influence the straw yield.

*2.2.3.3 **Harvest Index***

Babu (1996) reported that application of organic manures @ 10 t ha^{-1} of FYM could not influence the HI of rice. Sudha (1999) observed that different levels and sources of organic manures had no significant influence in the HI of rice.

2.2.4 Effect on Quality of Grains

Hemaletha *et al.* (2000) observed higher crude protein content in rice grains from plots treated with organic manures like FYM, Dhaincha and Sunhemp than control plots. They also reported that incorporation of organics increased the optimum cooking time of rice over control and the highest value was recorded by the incorporation of Dhaincha @ 12 t ha^{-1}.

2.2.5 Effect on Nutrient Uptake and Nitrogen Use Efficiency

2.2.5.1 Nutrient Uptake

Varma and Dixit (1989) reported that in a rice-wheat system, incorporation of FYM increased the NPK uptake both with and without N fertilization in paddy. Sharma and Mittra (1991) revealed that application of organic manures including FYM could increase NPK uptake in rice. Sudha (1999) observed increased uptake of N, P and K by the application of 10 t ha^{-1} of FYM over 5 t ha^{-1} of FYM and 5 t ha^{-1} of vermicompost.

Contrary to the above results, Babu (1996) reported that uptake of N, P and K by rice was not influenced by the application of organic manures even @ 10 t ha^{-1} FYM.

2.2.5.2 Nitrogen Use Efficiency

Padmaja and Veeraraghavaiah (1998) reported that addition of FYM @ 5 t ha^{-1} improved the fertilizer use efficiency.

2.2.6 Effect on Soil Available Nutrients

Application of organic wastes irrespective of the sources recorded higher available K status of soil over no organics (Chithra and Janaki, 1999). Sudha (1999) reported that organic manure addition at all levels could maintain the available N and P status of soil well above the original status before the experiment and vermicompost application recorded the most superior K status of soil. Also organic manure applied plots maintained a higher level of K in the soil after the experiment.

2.3 EFFECT OF NPK RATIOS ON GROWTH AND YIELD OF RICE

2.3.1 Effect on Growth Parameters

Different NPK ratios (2 : 1 : 1, 2 : 1.5 : 1.5, 2 : 2 : 2, 2 : 2.5 : 2.5) failed to influence the height of plants and tiller count at any of the growth stages of rice (Sushamakumari, 1981). But Deshmukh *et al.* (1988) observed increase in growth characters like plant height and tiller number for early duration rainfed rice when NPK was applied @ 80 : 60 : 40 kg ha^{-1} (2 : 1.5 : 1).

Sushamakumari (1981) while studying the effect of NPK ratios on maximisation of yield of rice observed that the NPK ratio of 2 : 1.5 : 1.5 with 90 kg N ha^{-1} registered the highest LAI at panicle initiation, flowering and harvest and NPK ratio of 2 : 2 : 2 with 45 kg N ha^{-1} recorded the lowest LAI and the DMP at flowering was progressively and significantly increased in accordance with ratios from 2 : 1 : 1 to 2 : 2.5 : 2.5. Rani *et al.* (1997) reported higher drymatter accumulation in rice with NPK application @ 120 : 80 : 40 kg ha^{-1} (3 : 2 : 1). Channamallikarjuna (2000) obtained significantly superior values for all growth characters of hybrid rice with the application of 100 : 50 : 75 kg NPK ha^{-1}(2 : 1 : 1.5) than 100 : 50 : 50 kg NPK ha^{-1} (2 : 1 : 1).

2.3.2 Effect on Yield Attributes

Sushamakumari (1981) reported that different NPK ratios did not have substantial influence on number of productive tillers $hill^{-1}$, number of spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$ and thousand grain weight, but there was an increasing trend in panicle weight from the NPK ratio of 2 : 2.5 : 2.5 to 2 : 2 : 2 and from the ratio 2 : 2 : 2 to 2 : 1.5 : 1.5. The ratio of 2 : 1 : 1 recorded the lowest weight of panicle. Kanungo and Roul (1994) obtained higher panicle number m^{-2} and thousand grain weight with NPK application of 100 : 50 : 50 kg ha^{-1} (2 : 1 : 1) over 60 : 40 : 40 kg NPK ha^{-1}, but the filled grain number $panicle^{-1}$ showed a reduction with higher NPK application of 100 : 50 : 50 kg ha^{-1} over 60 : 40 : 40 kg NPK ha^{-1} (1.5 : 1 : 1). The yield attributing characters of hybrid rice viz., number of productive tillers $hill^{-1}$, panicle length, number of spikelets $panicle^{-1}$, weight of panicle, number of filled grains $panicle^{-1}$ and thousand grain weight recorded significantly superior values with NPK application of 100 : 50 : 75 kg ha^{-1} (2 : 1 : 1.5) than 100 : 50 : 50 kg NPK ha^{-1} (2 : 1 : 1) (Channamallikarjuna, 2000).

2.3.3 Effect on Yield

Munegowda *et al.* (1972), in a multilocation trial with IR-8 found that 120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} (2 : 1 : 1) was the best level in Sagar and Honnali areas while 120 kg N with 30 kg P_2O_5 ha^{-1} (4 : 1 : 0) was adequate in Bhadravathi and Kumsi areas. Nair and George (1973) obtained the highest yield of 2.29 t ha^{-1} when N and K were applied in the ratio 1 : 1. Khatua *et al.* (1976) found that higher grain yield of rice could be obtained with 120 : 30 : 30 kg ha^{-1} (4 : 1 : 1) of N, P and K during kharif season, whereas, during the rabi season 120 : 60 : 60 kg ha^{-1} (2 : 1 : 1) of N, P and K could be better for high yielding varieties of rice under red laterite soils of Orissa. The NPK ratio of 3 : 2 : 1 was recommended as optimum for paddy by Dixit and Singh (1977). According to Sushamakumari (1981), different NPK ratios did not exert any marked influence in the grain yield of rice. But Balasubramaniyan and Palaniappan (1992) observed highest grain yield of rice variety IR-50 with 150 kg N and 50 kg K_2O ha^{-1} (3 : 0 : 1). Tiwana *et al.* (1999) reported that significantly higher grain yield of rice were obtained with 180 : 30 : 30 kg NPK ha^{-1} (6 : 1 : 1) over the recommended fertilizer level of 120 : 30 : 30 kg NPK ha^{-1} (4 : 1 : 1). While studying the effect of NPK levels on growth and yield of KRH-2 hybrid rice, Channamallikarjuna (2000) observed superior values of grain and straw yield with the application of 100 : 50 : 75 kg NPK ha^{-1} (2 : 1 : 1.5) than with the application of 100 : 50 : 50 kg NPK ha^{-1} (2 : 1 : 1).

The different NPK ratios (2 : 1 : 1, 2 : 1.5 : 1.5, 2 : 2 : 2, 2 : 2.5 : 2.5) did not have any significant influence on the straw yield and harvest index of rice (Sushamakumari, 1981).

2.3.4 Effect on Quality of Grains

According to Sushamakumari (1981), the different NPK ratios had no significant effect on protein content of rice grains. Thomas (2000) reported maximum values for protein content of rice grains with NPK application @ 60 : 30 : 45 kg ha^{-1} (2 : 1 : 1.5).

2.3.5 Effect on Nutrient Uptake

Sushamakumari (1981) observed no significant difference in N uptake with different NPK ratios. But the P uptake at harvest was maximum with NPK ratio of 2 : 1.5 : 1.5 and K uptake with NPK ratio of 2 : 2.5 : 2.5. Tiwana *et al.* (1999) reported significant increase in N, P and K uptake at harvest with NPK application @ 180 : 30 : 30 kg ha^{-1} (6 : 1 : 1) over 120 : 30 : 30 kg ha^{-1} (4 : 1 : 1) in rice. Maximum uptake of N, P and K was observed with the application of NPK @ 60 : 30 : 45 kg ha^{-1} (2 : 1 : 1.5) by Thomas (2000).

2.3.6 Effect on Soil Available Nutrients

Different NPK ratios had no significant influence on soil N, P and K status (Sushamakumari, 1981). According to Mishra and Sharma (1997), there was significant increase in the available N, P and K status of soil with NPK @ 120 : 50 : 40 kg ha^{-1}.

2.4 EFFECT OF COMBINED APPLICATION OF ORGANIC MANURES AND INORGANIC NUTRIENTS

2.4.1 Effect on Growth Parameters

In an experiment conducted on integrated nutrient management at Regional Agricultural Research Station, Pattambi, Mathew *et al.* (1994) reported higher plant height and tiller count of rice with the combined use of 10 t ha^{-1} FYM and chemical fertilizers. In a study, Babu (1996) observed that the integration of FYM @ 10 t ha^{-1} along with chemical fertilizers could increase the plant height, tiller count, LAI and DMP of medium duration rice variety Pavizham. In a pot experiment conducted on rice with different combinations of urea, FYM and vermicompost, it was observed by Jadhav *et al.* (1997) that DMP was highest with 75 kg N ha^{-1} as urea along with 25 kg N ha^{-1} as vermicompost. Rani and Srivastava (1997) reported that supplying one third or one quarter of nitrogen as vermicompost increased plant height in rice.

2.4.2 Effect on Yield Attributes

Mathew *et al.* (1994) observed an increase in panicle number m^{-2}, grain number $panicle^{-1}$ and thousand grain weight in rice with 10 t ha^{-1} FYM along with chemical fertilizers in rice variety Jyothi. Mondal *et al.* (1994) observed an increase in panicle number m^{-2}, grain number $panicle^{-1}$ and thousand grain weight in rice with higher NPK rates along with FYM application. Singh *et al.* (1998) observed increase in grain number $panicle^{-1}$ and thousand grain weight of rice with higher NPK rates along with 7.5 t ha^{-1} FYM.

2.4.3 Effect on Yield

Higher yield with integrated use of organic and inorganic fertilizers was reported by many workers (Kundu and Pillai, 1992; Pandey *et al.*, 1995; Chetrei *et al.*, 1998; Pandey *et al.*, 2001).

2.4.3.1 Grain Yield

Singh and Verma (1990) reported that application of FYM at the same level of fertilizers increased the grain and straw yields significantly as compared to the grain and straw yield recorded without FYM. Anilakumar *et al.* (1993) obtained an yield increase of 7.6 per cent in rice by the combined application of FYM and NPK than application of NPK alone in rice. Mathew *et al.* (1994) observed significantly higher grain yields of rice variety Jyothi with the integrated application of 10 t ha^{-1} FYM along with inorganic nutrients. Babu (1996) reported higher grain yield of medium duration rice upto 5.6 t ha^{-1} with the combined application of organic manures and chemical fertilizers. Roy *et al.* (1997) observed higher grain yield of rice with the combined application of NPK @ 90 : 60 : 90 kg ha^{-1} along with 10 t ha^{-1} of FYM. Saxena *et al.* (1999) reported that NPK @ 100 : 80 : 60 kg ha^{-1} along with 10 t ha^{-1} of FYM produced significantly higher yield of rice. Singh *et al.* (2000a) observed that FYM with recommended dose of NPK (120 : 60 : 40 kg ha^{-1}) gave the highest grain yield (5.16 t ha^{-1}) and application of FYM contributed to yield upto 50 per cent of the recommended NPK.

Singh *et al.* (1996) reported that substitution of 25 per cent N through FYM particularly at higher N rates increased rice yields. Rani and Srivastava (1997) observed higher grain yields of rice with the integration of one third or one quarter of N as vermicompost and the rest as NPK. Dubey and Verma (1999) obtained the highest increase in yield by the combined use of 50 per cent NPK and 50 per cent organic manures. Substitution of organic sources to a tune of 25 per cent of the recommended dose did not resulted in much yield reduction like 50 per cent substitution (Sujathamma *et al.*, 2001).

2.4.3.2 Straw Yield

Babu (1996) observed significant increase in the straw yield of medium duration rice variety Pavizham upto 7.3 t ha^{-1} by the combined use of organic manures and inorganic fertilizers. Maximum straw yield for rice variety Kanchana was obtained during kharif season through an integrated management which provided 50 per cent of recommended N through FYM and the rest as NPK fertilizers (Deepa, 1998). Similar finding was also reported by Pandey *et al.* (2001).

Mathew *et al.* (1994) observed a slightly reduced but statistically comparable straw yield for rice variety Jyothi with the integration of 10 t ha^{-1}

of FYM along with chemical fertilizers in comparison to chemical fertilizers alone. Sudha (1999) also reported that different levels and sources of organic manures could not significantly influence the straw yield. Lower straw yields by FYM treatment than 50 per cent FYM + NP treatment was reported by Sengar *et al.* (2000).

2.4.4 Effect on Quality of Grains

Hemaletha *et al.* (1999) reported that incorporation of organic fertilizers along with the application of inorganic N significantly increased the crude protein content and optimum cooking time of rice grains. However, the elongation ratio of grains was not influenced by the treatments.

2.4.5 Effect on Nutrient Uptake and Nitrogen Use Efficiency

2.4.5.1 Nutrient Uptake

Lal and Mathur (1989) reported that application of chemical fertilizers in combination with FYM could regulate the nutrient uptake from soil. Singhania and Singh (1991) reported enhanced uptake of N, P and K in rice with the integrated application of nutrients. Babu (1996) observed higher N and P uptake by medium duration rice with the integration of higher fertilizer dose along with 10 t ha^{-1} of FYM. Mondal and Chettri (1998) observed significantly higher NPK uptake in rice with the combined application of 50 per cent of the recommended N along with 10 t ha^{-1} of FYM. According to Deepa (1998), maximum K uptake in rice variety Kanchana was with the integration of 45 : 22.5 : 22.5 kg NPK ha^{-1} as chemical fertilizers and the same quantity through FYM. Sengar *et al.* (2000) reported the highest values of NPK uptake in NPK + FYM treatment.

Combined use of organic manures and inorganic fertilizers was found significantly better than inorganic fertilizers alone for N uptake (Pandey *et al.*, 2001). In a study, Singh *et al.* (2001) found that substituting 50 per cent of the recommended N through various sources like FYM and green manure did not show any significant variation in total uptake of N, P and K by rice. Sujathamma *et al.* (2001) recorded the highest P uptake with 25 per cent substitution with organic source.

2.4.5.2 Nitrogen Use Efficiency

Sengar *et al.* (2000) obtained a higher value of agronomic efficiency by the application of ½ FYM + NP treatments. Pandey *et al.* (2001) and Sujathamma *et al.* (2001) also reported higher efficiency of applied N by conjunctive use of organics and fertilizer nitrogen.

2.4.6 Effect on Soil Available Nutrients

FYM used either alone or in combination with chemical fertilizers improved the available N and P status of soil than its initial status (Beillaki *et al.*, 1998; Mondal and Chettri, 1998; Sengar *et al.* 2000). Singh *et al.* (2001) observed a slight increase in the available N status of soil by incorporating either total or part of N through organic sources as compared to N solely applied through prilled urea. Sujathamma *et al.* (2001) recorded the highest total N content in the soil with 50 per cent N through vermicompost and 50 per cent N as fertilizer, the highest available K status was recorded with 25 per cent N through vermicompost and 75 per cent N through fertilizers and the lowest N and K status with no nitrogen treatment.

2.5 EFFECT OF NUTRIENT MANAGEMENT ON DISEASE INCIDENCE

Nutritional treatments especially that of fertilizer N are known to increase the yield, but they also increase the vulnerability of the plant to the incidence of pests and diseases. Vulnerability of plants is known to be due to accumulation of soluble N (Ito and Sakamoto, 1942). Paracer and Chahal (1963) reported that heavy application of nitrogenous fertilizers have been reported to increase the incidence of fungal diseases of rice. Muneera (1973) reported that the intensity of sheath blight disease was less with a reduced level of nitrogen. Nair and Gokulapalan (1990) observed a reduction in intensity of sheath blight infection with the increase in level of potash. According to Musthafa and Potty (2001), increasing levels of N significantly increased the incidence of sheath blight and the highest disease index was recorded at the highest level of nitrogen.

2.6 EFFECT OF NUTRIENT MANAGEMENT ON ECONOMICS OF CULTIVATION

Verma (1990) suggested incorporation of FYM for saving 50 per cent of inorganic fertilizers in paddy crop. Hussain *et al.* (1991) reported the highest input cost for the application of 10 t ha^{-1} of FYM alone than an integrated approach in rice cultivation. Tripathi and Chaubey (1996) opined that incorporation of FYM in combination with inorganic fertilizers economizes the fertilizer need. Sudha (1999) reported that different levels and sources of organic manures (FYM @ 5 t ha^{-1}, FYM @ 10 t ha^{-1} and vermicompost @ 5 t ha^{-1}) had no significant influence on the benefit : cost ratio and the highest benefit : cost ratio of 1.59 was recorded by 5 t ha^{-1} of FYM.

Chopra and Chopra (2000) worked out the optimum economic dose of N for scented rice as 98.5 kg ha^{-1} and it gave an additional profit of Rs. 8075 ha^{-1}. According to Singh *et al.* (2000b), in basmati rice fertilizing with 100 kg N ha^{-1} gave maximum net returns and benefit cost ratio.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was carried out in the wetlands of the Instructional Farm, College of Agriculture, Vellayani from September 2001 to January 2002 to derive an optimum package for nutrient management for basmati rice in wetlands.

The details of materials used and methods adopted are presented in this chapter.

3.1 EXPERIMENTAL SITE

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

3.1.1 Soil

The soil of the experimental site is sandy clay loam which belongs to the taxonomical order oxisol. The physicochemical properties of the soil of the experimental site are given in Table 3.1.

Table 3.1 Soil characteristics of the experimental site

A. Mechanical composition

Sl. No.	Parameters	Content, per cent	Methods used
1.	Coarse sand	47.76	Bouyoucos Hydrometer method (Bouyoucos, 1962)
2.	Fine sand	10.64	
3.	Silt	8.60	
4.	Clay	33.00	

B. Chemical composition

Sl. No.	Parameters	Content	Rating	Methods used
1.	Available N	326.11 kg ha^{-1}	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5	32.64 kg ha^{-1}	Medium	Bray colorimeter method (Jackson, 1973)
3.	Available K_2O	174.72 kg ha^{-1}	Medium	Ammonium acetate method (Jackson, 1973)
4.	Organic carbon	1.70 per cent	High	Walkley and Black rapid titration method (Jackson, 1973)
5.	Soil pH	5.40	Acidic	1 : 2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)

3.1.2 Climate

The experimental site enjoys a humid tropical climate. The data on various weather parameters during the cropping period are given in the Appendix I and illustrated in Fig. 1.

3.1.3 Cropping History of the Field

The experimental area was under a bulk crop of rice prior to the lay out of the experiment.

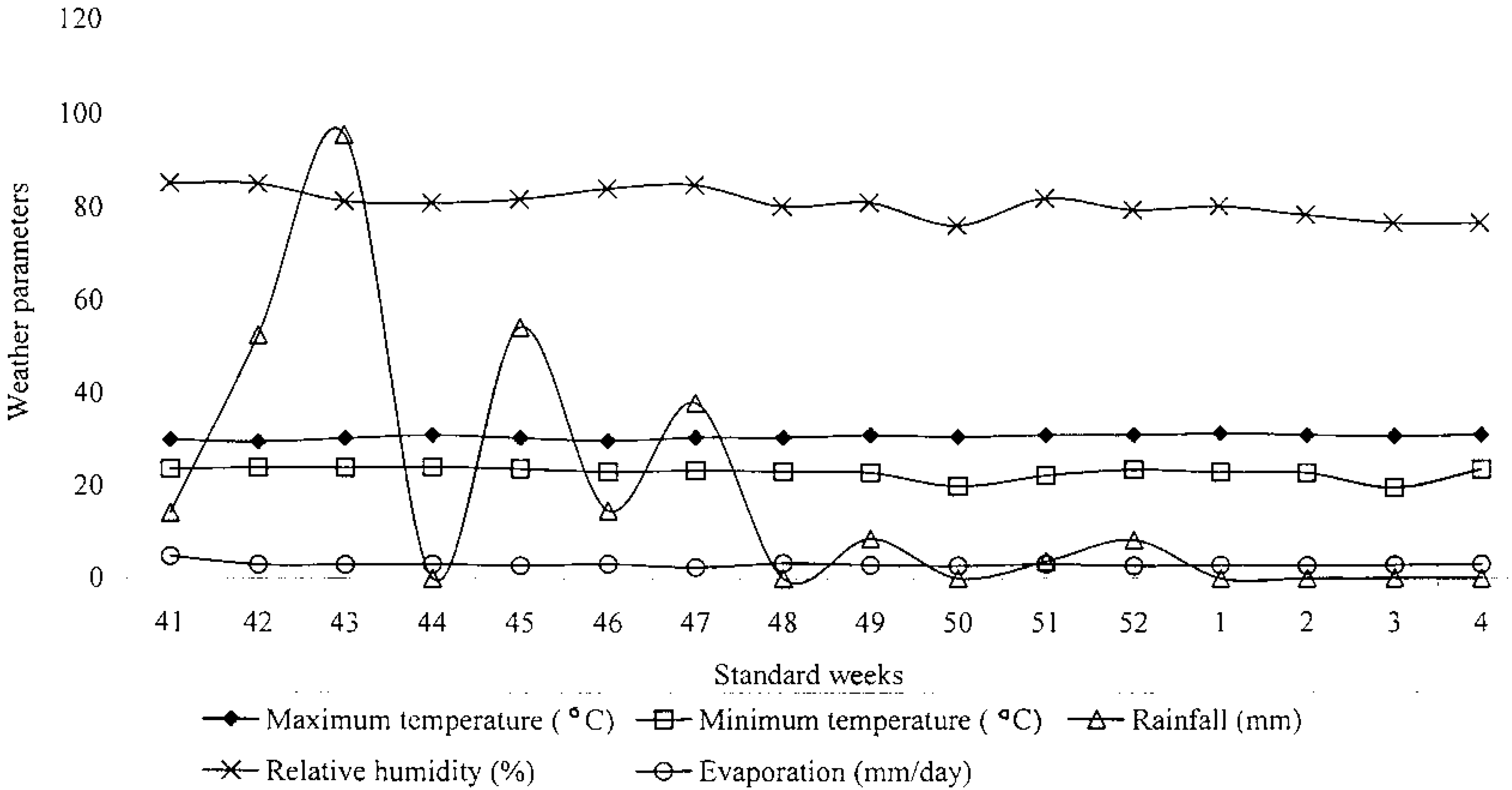

Fig. 1. Weather data for the cropping period
(September 2001-January 2002) - weekly averages

3.1.4 Season

The field experiment was conducted during the early second crop season (September to January) of the year 2001-2002.

3.2 MATERIALS

3.2.1 Seeds

The basmati rice variety, selected for the experiment was 'Pusa Basmati-1' released from Indian Agricultural Research Institute, New Delhi with duration of 130-135 days. The variety is resistant to brown spot and susceptible to sheath blight. The seeds for the study were obtained from National Seeds Corporation, Karamana.

3.2.2 Manures and Fertilizers

FYM (0.35 per cent N) and vermicompost (0.75 per cent N) were used as organic sources. Fertilizer sources like urea (46 per cent N), super phosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as the inorganic sources for the experiment.

3.3 METHODS

3.3.1 Design and Layout

The experiment was laid out in RBD as 3 x 2 x 2 factorial experiment. The layout plan of the experiment is given in Fig. 2 (Plate 1). The details of the layout are given below.

Number of treatment combinations	: 12 + 1 (Absolute control)
Replications	: 3
Total number of plots	: 39
Gross plot size	: 5 x 4 m
Net plot size	: 4.6 x 3.8 m
Spacing	: 20 x 10 cm

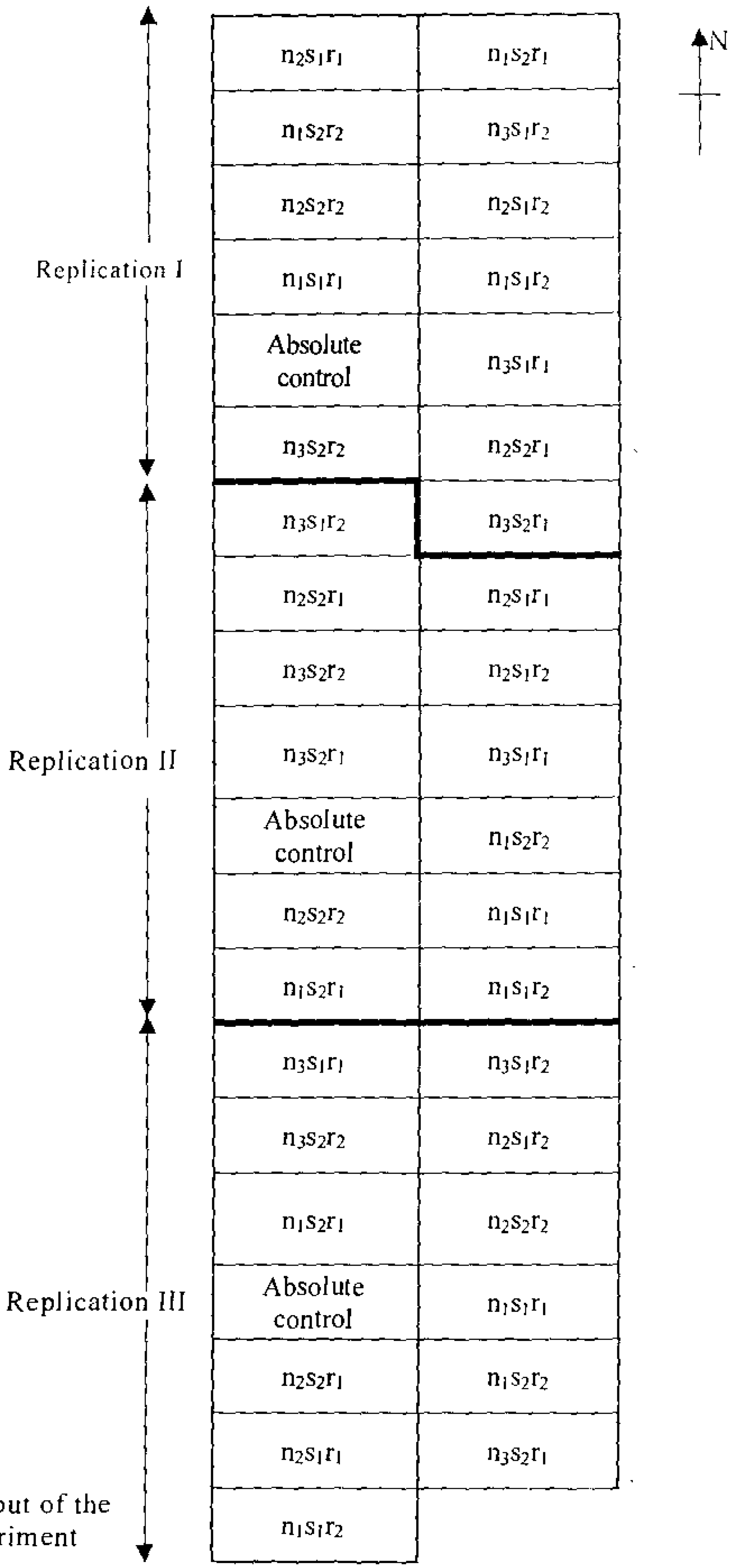

Fig. 2. Layout of the experiment

Plate 1. General view of the experimental field

3.3.2 Treatments

The treatments consisted of combinations of levels of N, sources of N and NPK ratios.

Factors

A. Levels of nitrogen (N)

n_1 : 60 kg ha^{-1}

n_2 : 90 kg ha^{-1}

n_3 : 120 kg ha^{-1}

B. Sources of nitrogen (S)

s_1 : 50 per cent N as FYM and 50 per cent N as chemical fertilizer

s_2 : 50 per cent N as vermicompost and 50 per cent N as chemical fertilizer.

C. NPK ratios (R)

r_1 : 2 : 1 : 1

r_2 : 2 : 1 : 1.5

3.3.3 Treatment Combinations

T_1 : $n_1s_1r_1$ (60 : 30 : 30 kg NPK ha^{-1})

T_2 : $n_1s_1r_2$ (60 : 30 : 45 kg NPK ha^{-1})

T_3 : $n_1s_2r_1$ (60 : 30 : 30 kg NPK ha^{-1})

T_4 : $n_1s_2r_2$ (60 : 30 : 45 kg NPK ha^{-1})

T_5 : $n_2s_1r_1$ (90 : 45 : 45 kg NPK ha^{-1})

T_6 : $n_2s_1r_2$ (90 : 45 : 67.5 kg NPK ha^{-1})

T_7 : $n_2s_2r_1$ (90 : 45 : 45 kg NPK ha^{-1})

T_8 : $n_2s_2r_2$ (90 : 45 : 67.5 kg NPK ha^{-1})

T_9 : $n_3s_1r_1$ (120 : 60 : 60 kg NPK ha^{-1})

T_{10} : $n_3s_1r_2$ (120 : 60 : 90 kg NPK ha^{-1})

T_{11} : $n_3s_2r_1$ (120 : 60 : 60 kg NPK ha^{-1})

T_{12} : $n_3s_2r_2$ (120 : 60 : 90 kg NPK ha^{-1})

T_{13} : Absolute control

3.4 CROP HUSBANDRY

3.4.1 Nursery

3.4.1.1 Land Preparation

The experimental area for nursery was ploughed, puddled and levelled after removing the weeds and stubbles.

3.4.1.2 Seeds and Sowing

Pre-germinated seeds @ 80 kg ha^{-1} were broadcasted on the nursery area during the last week of September 2001. After 25 days, healthy seedlings were pulled out from the nursery.

3.4.2 Main Field

3.4.2.1 Land Preparation

The experimental area was ploughed, puddled and levelled. Weeds and stubbles were removed by hand picking. Initial soil samples were taken for analysis. Individual plots of size 5 x 4 m were laid out and were perfectly levelled before transplanting.

3.4.2.2 Transplanting

Transplanting was done in a thin film of water in the field. Twenty five days old seedlings were transplanted at a spacing of 20 x 10 cm with two seedlings hill^{-1}.

3.4.2.3 Application of manures and fertilizers

FYM (0.35 per cent N) and vermicompost (0.75 per cent N) were incorporated at the time of first ploughing. Urea (46 per cent N), super phosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were applied to each plot as per the treatments after leveling the field. Full dose of P and half dose of N and K were applied as basal and 25 per cent of N and K were applied as topdressing both at tillering stage and one week before panicle initiation stage.

3.4.2.4 Maintenance of the Crop

Subsequently after transplanting, the water level was raised to about five cm. Two hand weedings were given at 20 and 45 days after transplanting. Sevin 50 per cent WP (Carbaryl) was sprayed @ 2 kg a.i. ha^{-1} against rice leaf roller in the vegetative stage of the crop and one spraying with Hinosan 50 Ec (Ediphenphos) at 0.1 per cent concentration was given after panicle initiation stage against sheath blight disease. Attack by rats was a common menace of the locality and they were controlled by the use of Roban.

3.4.2.5 Plant Sampling

Samples were collected from the area left for sampling. Four hills were selected randomly from the net plot area to record biometric observations. Two rows from all sides were left as border rows and the net plot area was 4.6 x 3.8 m.

3.4.2.6 Harvest

The crop was harvested at full maturity. The border and sampling rows were harvested separately. Net plot area of individual plots was harvested and the weight of grain and straw were recorded separately.

3.5 OBSERVATIONS

3.5.1 Observations on Growth Parameters

3.5.1.1 Height of Plant

Height of plant (cm) was recorded at maximum tillering, 50 per cent flowering and at harvest. Height of sample plants were measured from the base of the plant to the tip of the longest leaf or to the tip of the longest ear head whichever was taller.

3.5.1.2 Tiller Number Hill^{-1}

Tiller number was counted at maximum tillering, 50 per cent flowering and at harvest from sample hills, the mean values worked out and recorded.

3.5.1.3 Leaf Area Index

Leaf area at maximum tillering, 50 per cent flowering and at harvest was calculated using the length width method suggested by Gomez (1972). Accordingly, leaf area = k x l x w, where k is an adjustment factor, l is the length and w is the maximum width. LAI was worked out using the formula,

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

3.5.1.4 Dry Matter Production

Dry matter production at maximum tillering, 50 per cent flowering and harvest stage were recorded. The sample plants were uprooted, washed, sun dried and oven dried at 80°C to constant weight. Dry matter production was computed for each treatment and expressed in t ha^{-1}.

3.5.2 Observations on Yield Attributes and Yield

3.5.2.1 Number of Productive Tillers Hill^{-1}

Number of productive tillers was counted in four sample hills and the mean number was worked out at harvest.

3.5.2.2 Length of Panicle

Ten panicles were collected from the sample plants in each plot, length measured from the neck to the tip and the average expressed in cm.

3.5.2.3 Weight of Panicle

Ten panicles collected from the sample plants in each plot were weighed separately, the mean weight worked out and expressed in grams.

3.5.2.4 Number of Spikelets Panicle^{-1}

The spikelets were removed from each panicle, counted and the mean number of spikelets panicle^{-1} was recorded.

3.5.2.5 Number of Filled Grains Panicle^{-1}

The filled grains were then separated; counted and mean number was recorded.

3.5.2.6 Thousand Grain Weight

The weight of one thousand grains from the samples drawn from the cleaned produce from each plot was recorded in grams.

3.5.2.7 Grain Yield

The grains harvested from each net plot were dried to constant weight, cleaned, weighed and expressed in t ha^{-1}.

3.5.2.8 Straw Yield

The straw harvested from each net plot was dried to constant weight under sun and the weight was expressed in t ha^{-1}.

3.5.2.9 Harvest Index

Harvest index was calculated using the data on grain yield and straw yield as per the formula.

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.5.3 Chemical Analysis

3.5.3.1 Protein Content of Grains

Protein percentage was computed by multiplying the nitrogen content of the grain with the factor 6.25 (Simpson *et al.*, 1965).

3.5.3.2 Plant Analysis

Sample plants collected from each plot at harvest were sun dried, oven dried to constant weight, ground, digested and nutrient content estimated. The N content (modified microkjeldahl method), P content (Vanado-molybdo-phosphoric yellow colour method) and K content (Flame photometer method) were estimated for plant samples from each plot separately (Jackson, 1973). Plant nutrient uptake was calculated by multiplying the nutrient content of plant samples with the respective dry weights at harvest stage and expressed in kg ha^{-1}.

3.5.3.3 Soil Analysis

Samples collected before and after the experimentation were dried in shade, seived through 2 mm sieve and analysed to determine the available N content of the soil by alkaline permanganate method (Subbiah and Asija, 1956), available P by Bray's method and available K by ammonium acetate method (Jackson, 1973).

3.5.4 Nitrogen Use Efficiency

3.5.4.1 Agronomic Efficiency

The grain yield produced per kg of applied N was calculated using the formula and expressed as kg grain kg^{-1} N.

$$\text{Agronomic efficiency} = \frac{\text{Grain yield from N applied plot} - \text{Grain yield from control plot}}{\text{N applied in kg ha}^{-1}}$$

3.5.4.2 Apparent Recovery

The percentage of N absorbed by the plant, of the total N applied was found out and expressed as percentage.

$$\text{Apparent recovery} = \frac{\left[\begin{array}{ll}\text{Total N uptake in} & - \text{ Total N uptake in} \\ \text{nitrogen applied plot} & \text{control plot}\end{array}\right]}{\text{N applied in kg ha}^{-1}} \times 100$$

3.5.5 Cooking Quality of Grains

3.5.5.1 Optimum Cooking Time

Grain samples from the harvested lot of each plot were analysed and optimum cooking time was determined by the method suggested by Hirannaiah *et al.* (2001).

For determining optimum cooking time of grain samples, milled rice was screened visually and whole sound grains were collected. Samples of 10 g of rice samples were taken in a 250 ml beaker containing 150 ml slow boiling water over an electric stove (1.5 kw). The cooking time was determined using glass plate opaque-core method by withdrawing few grains periodically and pressing between two glass slides till no opaque portion or white core remained.

3.5.5.2 Volume Expansion Ratio

The volume expansion after cooking of milled rice samples was worked out by cooking definite amount of milled rice in uniform sized test tubes and the ratio of increase in volume was calculated.

3.5.5.3 Elongation Ratio

Elongation ratio of grain samples was evaluated by the method suggested by Juliano and Perez (1984).

Elongation ratio of grains was expressed as the ratio of length of cooked kernels to raw kernels. The length of ten cooked kernels and ten raw kernels was measured and mean length of cooked kernels was divided by mean length of raw kernels.

3.5.6 Economic Analysis

Economic analysis was done for the experiment after taking into account the cost of cultivation and prevailing market price of basmati rice and straw.

3.5.6.1 Net Returns

Net returns were calculated using the formula.

Net returns (Rs ha^{-1}) = Gross income – Total expenditure

3.5.6.2 Benefit : Cost Ratio (BCR)

Benefit : cost ratio was worked out using the formula.

$$\text{BCR} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.5.7 Scoring of Major Pests Like Rice Bug, Stem Borer and Leaf Roller and Diseases Like Sheath Blight, Blast and Bacterial Leaf Blight

Blast, bacterial leaf blight and stem borer attack were not found in the field. Leaf roller and rice bug were found in the field in very low intensities and their count was not significant to be scored.

Sheath blight was severe in the field and scoring of sheath blight incidence was done by following a 0 to 9 scoring system (IRRI, 1980).

Score		Description
0	–	No incidence
1	–	Lesions limited to lower 1/4th of leaf sheath area
3	–	Lesions on lower half of leaf sheath area
5	-	Lesions present on more than half of lower leaf sheath area
7	–	Slight infection on upper leaves (mainly on flag and second leaf)
9	–	Lesions reaching top of tillers, severe infection on all leaves and some plants killed.

Disease index was worked out by the formula,

$$\text{Disease index} = \frac{\text{Sum of numerical ratings x 100}}{\text{Total number of plants observed x Maximum disease category}}$$

3.5.8 Statistical Analysis

The data generated for the characters studied under different treatments were subjected to analysis of variance (Panse and Sukhatme, 1985). Whenever the results were significant, the critical difference was worked out at five or one per cent probability.

RESULTS

4. RESULTS

An experiment was conducted at the Instructional Farm, College of Agriculture from September 2001 to January 2002 to derive an optimum package for nutrient management for basmati rice in wetland condition. The trial was laid out in factorial RBD with 13 treatments and three replications. The experimental data were statistically analysed and the results are presented in this chapter.

4.1 GROWTH PARAMETERS

4.1.1 Height of Plant (Tables 4.1.1a and 4.1.1b)

Main effects of N, S and R were significant in influencing plant height. Nitrogen levels significantly influenced plant height except at the maximum tillering stage. At 50 per cent flowering and harvest stages the effect was significant and an increase in N level brought out an increase in plant height. The n_3 level of N (120 kg N ha^{-1}) recorded the maximum plant height. The different sources of N produced significant influence on plant height. Plots applied with s_2 recorded taller plants than those applied with s_1. However no interaction was observed for sources of N over different periods of observation. Application of N, P and K in two different ratios produced a marked difference in plant height at 50 per cent flowering and harvest stages. But at the maximum tillering stage, this effect was not observed.

Among the interactions, N x R was found to be significant in influencing plant height. At maximum tillering stage, the ratios did not produce any significant change. But at the next two stages of observation, plants treated with r_2 produced taller plants. The interactions viz., N x S, R x S and N x S x R were not significant.

Table 4.1.1a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on plant height, cm

Treatments	Maximum tillering stage (p_1)	50 per cent flowering stage (p_2)	Harvest stage (p_3)
Levels of nitrogen (N)			
n_1	40.69	81.38	90.62
n_2	41.13	89.48	98.92
n_3	41.59	95.48	104.17
Sources of nitrogen (S)			
s_1	40.65	87.92	97.36
s_2	41.62	89.64	98.44
NPK ratios (R)			
r_1	40.60	87.27	96.50
r_2	41.67	90.29	99.31

Interactions	F	SE	CD
P x N	$F_{4, 52}$: 53.14**	0.52	1.463
P x S	$F_{2, 52}$: 0.46	0.42	1.194
P x R	$F_{2, 52}$: 3.27*	0.42	1.194

*Significant at 5 per cent level **Significant at 1 per cent level

Table 4.1.1b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on plant height, cm

Treatments	Maximum tillering stage (p_1)	50 per cent flowering stage (p_2)	Harvest stage (p_3)
n_1s_1	40.58	80.03	90.18
n_1s_2	40.79	82.72	91.05
n_2s_1	40.71	88.76	98.33
n_2s_2	41.54	90.19	99.51
n_3s_1	40.67	94.95	103.58
n_3s_2	42.52	96.00	104.76
n_1r_1	40.25	78.59	88.26
n_1r_2	41.13	84.16	92.97
n_2r_1	40.79	88.43	98.42
n_2r_2	41.46	90.52	99.42
n_3r_1	40.77	94.78	102.81
n_3r_2	42.42	96.17	105.53
s_1r_1	40.25	86.46	96.20
s_1r_2	41.06	89.37	98.52
s_2r_1	40.96	88.07	96.79
s_2r_2	42.28	91.20	100.09

Interactions	F	SE	CD
P x N x S	$F_{4, 52}$: 0.68	0.73	-
P x N x R	$F_{4, 52}$: 1.80	0.73	2.069
P x S x R	$F_{2, 52}$: 0.10	0.60	-

4.1.2 Tiller Number Hill^{-1} (Tables 4.1.2a and 4.1.2b)

The tiller number hill^{-1} was significantly influenced by the main effects of N and R. An increase in the N level resulted in an increase in the tiller number hill^{-1} at all stages of growth and n_3 (120 kg N ha^{-1}) recorded the maximum value throughout the growth period. The different sources of N did not produce any significant result. But the application of N, P and K in two different ratios produced a marked difference in tiller number and r_2 treated plots recorded higher values at all growth stages. However no interaction was observed for any of the treatments over different periods of observation.

The interactions of N, S and R were not significant in influencing the tiller count.

4.1.3 Leaf Area Index (Tables 4.1.3a and 4.1.3b)

Among the treatments, levels of N had significant influence on LAI at all stages. An increase in the N level resulted in an increase in the LAI of rice at all stages and n_3 recorded the maximum LAI throughout the growth period. But the different sources of N did not produce any significant result. Different NPK ratios had no significant influence on LAI at any of the stages except the harvest stage and r_2 (2 : 1 : 1.5) recorded higher LAI than r_1 (2 : 1 : 1).

None of the interactions were found to have significant effect on LAI at any growth stage of basmati rice.

4.1.4 Dry Matter Production (Tables 4.1.4a and 4.1.4b)

Different levels of N showed significant influence on DMP at all stages. In general, increased DMP was noticed with increase in the levels of N and the highest level of N (n_3) produced the maximum dry matter at all growth stages. Different N sources produced significant influence on DMP and s_2 treated plots registered higher DMP at all growth stages. The two NPK ratios differ significantly in dry matter accumulation and r_2 gave higher DMP at all growth stages.

Table 4.1.2a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on tiller number hill^{-1}

Treatments	Maximum tillering stage (p_1)	50 per cent flowering stage (p_2)	Harvest stage (p_3)
Levels of nitrogen (N)			
n_1	8.76	12.66	12.59
n_2	9.46	13.92	13.53
n_3	10.60	14.38	14.04
Sources of nitrogen (S)			
s_1	9.52	13.60	13.31
s_2	9.69	13.71	13.46
NPK ratios (R)			
r_1	9.37	13.45	13.18
r_2	9.84	13.85	13.60

Interactions	F	SE	CD
P x N	$F_{4,52}$: 1.94	0.15	0.429
P x S	$F_{2,52}$: 0.03	0.12	-
P x R	$F_{2,52}$: 0.05	0.12	0.350

Table 4.1.2b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on tiller number $hill^{-1}$

Treatments	Maximum tillering stage (p_1)	50 per cent flowering stage (p_2)	Harvest stage (p_3)
n_1s_1	8.68	12.62	12.48
n_1s_2	8.84	12.69	12.70
n_2s_1	9.50	13.94	13.44
n_2s_2	9.42	13.90	13.63
n_3s_1	10.38	14.23	14.01
n_3s_2	10.83	14.54	14.06
n_1r_1	8.39	12.57	12.50
n_1r_2	9.13	12.74	12.68
n_2r_1	9.38	13.70	13.35
n_2r_2	9.54	14.14	13.72
n_3r_1	10.33	14.09	13.69
n_3r_2	10.87	14.68	14.39
s_1r_1	9.26	13.50	13.10
s_1r_2	9.78	13.69	13.53
s_2r_1	9.48	13.40	13.26
s_2r_2	9.91	14.01	13.67

Interactions	F	SE
P x N x S	$F_{4, 52}$: 0.37	0.21
P x N x R	$F_{4, 52}$: 0.70	0.21
P x S x R	$F_{2, 52}$: 0.61	0.18

Table 4.1.3a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on leaf area index

Treatments	Maximum tillering stage	50 per cent flowering stage	Harvest stage
Levels of nitrogen (N)			
n_1	3.68	4.99	4.54
n_2	4.41	5.86	5.54
n_3	4.91	6.20	5.74
$F_{2, 24}$	66.06**	64.58**	108.19**
SE	0.08	0.08	0.06
CD	0.223	0.227	0.181
Sources of nitrogen (S)			
s_1	4.28	5.66	5.24
s_2	4.39	5.70	5.31
$F_{1, 24}$	1.48	0.18	0.85
SE	0.06	0.06	0.05
NPK ratios (R)			
r_1	4.26	5.62	5.12
r_2	4.41	5.75	5.43
$F_{1, 24}$	3.00	2.26	18.41**
SE	0.06	0.06	0.05
CD	-	-	0.148

**Significant at 1 per cent

Table 4.1.3b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on leaf area index

Treatments	Maximum tillering stage	50 per cent flowering stage	Harvest stage
n_1s_1	3.54	4.97	4.51
n_1s_2	3.81	5.00	4.57
n_2s_1	4.40	5.84	5.47
n_2s_2	4.41	5.89	5.62
n_3s_1	4.89	6.18	5.75
n_3s_2	4.93	6.21	5.73
$F_{2, 24}$	0.90	0.01	0.48
SE	0.11	0.11	0.09
n_1r_1	3.67	4.94	4.36
n_1r_2	3.68	5.03	4.72
n_2r_1	4.32	5.79	5.49
n_2r_2	4.49	5.94	5.60
n_3r_1	4.78	6.12	5.51
n_3r_2	5.05	6.28	5.98
$F_{2, 24}$	0.73	0.05	2.27
SE	0.11	0.11	0.09
s_1r_1	4.19	5.60	5.10
s_1r_2	4.37	5.73	5.39
s_2r_1	4.32	5.63	5.15
s_2r_2	4.45	5.77	5.47
$F_{1, 24}$	0.07	0.01	0.05
SE	0.09	0.09	0.07

Table 4.1.4a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on dry matter production, t ha^{-1}

Treatments	Maximum tillering stage	50 per cent flowering stage	Harvest stage
Levels of nitrogen (N)			
n_1	1.12	6.72	8.69
n_2	1.28	7.49	10.33
n_3	1.48	8.29	11.30
$F_{2, 24}$	28.13**	77.22**	270.35**
SE	0.03	0.09	0.08
CD	0.099	0.261	0.234
Sources of nitrogen (S)			
s_1	1.21	7.28	9.90
s_2	1.38	7.72	10.31
$F_{1, 24}$	19.64**	18.70**	19.74**
SE	0.03	0.07	0.07
CD	0.081	0.213	0.191
NPK ratios (R)			
r_1	1.25	7.25	9.97
r_2	1.34	7.75	10.25
$F_{1, 24}$	5.09*	23.02**	9.25**
SE	0.03	0.07	0.07
CD	0.081	0.213	0.191

*Significant at 5 per cent level **Significant at 1 per cent level

Table 4.1.4b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on dry matter production, t ha^{-1}

Treatments	Maximum tillering stage	50 per cent flowering stage	Harvest stage
n_1s_1	1.04	6.54	8.51
n_1s_2	1.21	6.90	8.87
n_2s_1	1.17	7.11	10.19
n_2s_2	1.39	7.87	10.46
n_3s_1	1.41	8.18	11.00
n_3s_2	1.55	8.40	11.60
$F_{2,24}$	0.35	2.55	1.09
SE	0.05	0.13	0.11
n_1r_1	1.07	6.40	8.52
n_1r_2	1.18	7.04	8.86
n_2r_1	1.24	7.11	10.23
n_2r_2	1.32	7.86	10.42
n_3r_1	1.45	8.25	11.14
n_3r_2	1.52	8.33	11.46
$F_{2,24}$	0.07	3.98*	0.27
SE	0.05	0.13	0.11
CD	-	0.369	-
s_1r_1	1.12	6.88	9.72
s_1r_2	1.29	7.68	10.08
s_2r_1	1.38	7.63	10.21
s_2r_2	1.38	7.82	10.41
$F_{1,24}$	4.80*	8.73**	0.88
SE	0.04	0.10	0.09
CD	0.114	0.301	

*Significant at 5 per cent level **Significant at 1 per cent level

No significant interaction was observed in DMP when different levels of N were combined with different N sources. When the ratio of application of NPK changed to r_2, at n_1 and n_2 levels an increase in DMP was seen at 50 per cent flowering stage. But with higher dose of N (n_3) there was no significant difference in DMP with r_2. The initial and final stages of crop however did not respond to the increased ratio.

S x R interaction was found to have no significant influence on DMP at harvest stage, but at maximum tillering and 50 per cent flowering stages, s_1 applied in r_2 ratio resulted in an increase in DMP. The treatment combination s_2r_2 produced maximum dry matter but was on par with s_1r_1 and s_2r_1.

4.2 YIELD ATTRIBUTES (TABLES 4.2a, 4.2b, 4.2c and 4.2d)

4.2.1 Number of Productive Tillers Hill^{-1}

Number of productive tillers hill^{-1} was significantly influenced by N levels and NPK ratios. Among the N levels, 120 kg ha^{-1} (n_3) recorded maximum number of productive tillers hill^{-1} (12.10) while no significant difference was seen at n_1 and n_2 levels. Different sources of N however did not produce any significant influence on number of productive tillers hill^{-1}. Among the NPK ratios, more number of productive tillers were seen with r_2 and was significantly superior to r_1.

Number of productive tillers hill^{-1} was not influenced by any of the interactions viz., N x S, N x R, S x R and N x S x R.

4.2.2 Length of Panicle

Among the treatments, N levels favourably influenced the panicle length. But an increase in N level beyond n_2 did not result in increasing the panicle length. Application of 90 kg N ha^{-1} (n_2) recorded the maximum value of 26.14 cm which was on par with the value at 120 kg N ha^{-1} (n_3). Different sources of N and NPK ratios did not produce any significant influence on the panicle length.

Table 4.2a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on number of productive tillers $hill^{-1}$, length of panicle and weight of panicle

Treatments	Number of productive tillers $hill^{-1}$	Length of panicle, cm	Weight of panicle, g
Levels of nitrogen (N)			
n_1	10.67	24.88	2.06
n_2	11.66	26.14	2.44
n_3	12.10	25.65	2.52
$F_{2, 24}$	70.89**	5.50*	58.98**
SE	0.09	0.27	0.03
CD	0.255	0.794	0.094
Sources of nitrogen (S)			
s_1	11.47	25.62	2.31
s_2	11.49	25.49	2.37
$F_{1, 24}$	0.04	0.16	2.66
SE	0.07	0.22	0.03
NPK ratios (R)			
r_1	11.19	25.48	2.25
r_2	11.77	25.64	2.43
$F_{1, 24}$	33.22**	0.25	24.54**
SE	0.07	0.22	0.03
CD	0.208	-	0.077

*Significant at 5 per cent level **Significant at 1 per cent level

Table 4.2b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on number of productive tillers hill^{-1}, length of panicle and weight of panicle

Treatments	Number of productive tillers hill^{-1}	Length of panicle, cm	Weight of panicle, g
n_1s_1	10.65	24.77	2.03
n_1s_2	10.69	24.99	2.09
n_2s_1	11.66	26.35	2.39
n_2s_2	11.67	25.93	2.49
n_3s_1	12.09	25.774	2.51
n_3s_2	12.11	25.57	2.53
$F_{2, 24}$	0.01	0.35	0.44
SE	0.12	0.38	0.05
n_1r_1	10.33	24.81	1.94
n_1r_2	11.01	24.95	2.18
n_2r_1	11.41	26.12	2.40
n_2r_2	11.92	26.16	2.48
n_3r_1	11.82	25.50	2.41
n_3r_2	12.38	25.80	2.64
$F_{2, 24}$	0.24	0.06	1.78
SE	0.12	0.38	0.05
s_1r_1	11.20	25.57	2.20
s_1r_2	11.74	25.68	2.42
s_2r_1	11.18	25.39	2.29
s_2r_2	11.79	25.60	2.45
$F_{1, 24}$	0.10	0.02	0.68
SE	0.10	0.31	0.04

None of the interactions were found to have significant influence on the length of panicles.

4.2.3 Weight of Panicle

Different levels of N and NPK ratios produced a marked difference in the weight of panicle. Upto n_2 level of N, the weight of panicles exhibited an increasing trend but a further increase was not resulted in a positive response. The sources of N did not produce any significant influence on the weight of panicles. Among the NPK ratios, r_2 treated plots resulted in a significant increase in panicle weight (2.43 g) than r_1 treated plots.

The interactions of N, S and R did not influence the panicle weight significantly.

4.2.4 Number of Spikelets Panicle^{-1}

The different N levels produced significant effect on number of spikelets panicle^{-1}. The number of spikelets panicle^{-1} showed an increasing trend with an increase in the level of applied N and application of 120 kg N ha^{-1} (n_3) recorded the highest value (113.09). Different sources of N did not produce any significant difference on number of spikelets panicle^{-1}. The two NPK ratios significantly influenced the number of spikelets panicle^{-1} and r_2 treated plants recorded more number of spikelets (106.46) than r_1 (103.66) treated plots.

The number of spikelets panicle^{-1} was not influenced by any of the interactions viz., N x S, N x R, S x R and N x S x R.

4.2.5 Number of Filled Grains Panicle^{-1}

Nitrogen levels influenced the number of filled grains panicle^{-1} significantly. With an increase in N levels, there was a substantial increase in number of filled grains panicle^{-1} and n_3 recorded the highest value of 96.48 which was significantly superior to n_2 and n_1. The N sources did not produce any significant difference in the number of filled grains panicle^{-1}. But the NPK ratios produced favourable influence on the number of filled grains panicle^{-1}. Maximum value of 90.66 was recorded by r_2 and was significantly superior to r_1.

Table 4.2c Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and thousand grain weight

Treatments	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	1000 grain weight, g
Levels of nitrogen (N)			
n_1	95.51	81.49	21.30
n_2	106.57	91.00	21.64
n_3	113.09	96.48	21.37
$F_{2, 24}$	102.27**	91.66**	0.70
SE	0.88	0.79	0.22
CD	2.565	2.311	-
Sources of nitrogen (S)			
s_1	104.79	89.35	21.39
s_2	105.32	89.96	21.48
$F_{1, 24}$	0.28	0.44	0.12
SE	0.72	0.65	0.18
NPK ratios (R)			
r_1	103.66	88.66	21.44
r_2	106.46	90.66	21.44
$F_{1, 24}$	7.61*	4.79**	0.00
SE	0.72	0.65	0.18
CD	2.095	1.887	-

*Significant at 5 per cent level **Significant at 1 per cent level

Table 4.2d Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and thousand grain weight

Treatments	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	1000 grain weight, g
n_1s_1	95.26	81.15	21.27
n_1s_2	95.76	81.84	21.33
n_2s_1	106.51	90.97	21.79
n_2s_2	106.63	91.04	21.50
n_3s_1	112.60	95.95	21.13
n_3s_2	113.58	97.00	21.61
$F_{2,24}$	0.06	0.10	0.78
SE	1.24	1.12	0.31
n_1r_1	94.30	80.24	21.13
n_1r_2	96.71	82.75	21.47
n_2r_1	105.83	89.81	21.80
n_2r_2	107.31	92.20	21.48
n_3r_1	110.83	95.93	21.38
n_3r_2	115.35	97.03	21.36
$F_{2,24}$	0.78	0.24	0.56
SE	1.24	1.12	0.31
s_1r_1	103.40	88.42	21.34
s_1r_2	106.17	90.29	21.45
s_2r_1	103.91	88.90	21.53
s_2r_2	106.74	91.02	21.43
$F_{1,24}$	0.01	0.01	0.16
SE	1.01	0.91	0.25

None of the interactions could significantly influence the number of filled grains panicle^{-1}.

4.2.6 Thousand Grain Weight

None of the factors alone or their interactions did influence the thousand grain weight.

4.3 YIELD (TABLES 4.3a and 4.3b)

4.3.1 Grain Yield

Varying the N levels significantly influenced the grain yield. There was an increase in grain yield when N was increased from 60 to 90 kg ha^{-1} and then to 120 kg ha^{-1}. Application of 120 kg N ha^{-1} (n_3) recorded the maximum grain yield of 4.49 t ha^{-1} which was on par with n_2 level (90 kg N ha^{-1}). Nitrogen level of 90 (n_2) and 120 kg ha^{-1} (n_3) registered 43.38 and 48.67 per cent increase in grain yield respectively over n_1 (60 kg N ha^{-1}).

Different sources of N were not significant in influencing the grain yield. But the two NPK ratios had a significant influence on the grain yield and higher grain yield of 4.02 t ha^{-1} was recorded by r_2.

Interaction effects were not significant.

4.3.2 Straw Yield

Straw yield was favourably influenced by N levels and the highest straw yield of 6.81 t ha^{-1} was recorded by 120 kg N ha^{-1} (n_3) which was significantly superior to n_1 and n_2. Nitrogen level of 90 (n_2) and 120 kg ha^{-1} (n_3) registered 5.82 and 20.10 per cent increase in straw yield respectively over n_1 (60 kg N ha^{-1}). The different sources of N also had significant influence on straw yield and s_2 treated plots recorded more straw yield (6.32 t ha^{-1}) than s_1 treated plots. Among the two NPK ratios tried, the application of N, P and K in 2 : 1 : 1.5 ratio (r_2) recorded the highest straw yield of 6.23 t ha^{-1}.

Table 4.3a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on yield

Treatments	Grain yield, t ha^{-1}	Straw yield, t ha^{-1}	Harvest index
Levels of nitrogen (N)			
n_1	3.02	5.67	0.35
n_2	4.33	6.00	0.42
n_3	4.49	6.81	0.40
$F_{2, 24}$	231.02**	110.11**	90.87**
SE	0.05	0.06	0.00
CD	0.155	0.163	0.011
Sources of nitrogen (S)			
s_1	3.90	6.00	0.39
s_2	4.00	6.32	0.39
$F_{1, 24}$	2.56	23.78**	1.84
SE	0.04	0.05	0.00
CD	-	0.133	-
NPK ratios (R)			
r_1	3.87	6.09	0.39
r_2	4.02	6.23	0.39
$F_{1, 24}$	5.74*	4.32*	1.23
SE	0.04	0.05	0.00
CD	0.127	0.133	-

*Significant at 5 per cent level **Significant at 1 per cent level

Table 4.3b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on yield

Treatments	Grain yield, t ha^{-1}	Straw yield, t ha^{-1}	Harvest index
n_1s_1	2.99	5.52	0.35
n_1s_2	3.05	5.82	0.34
n_2s_1	4.26	5.93	0.42
n_2s_2	4.40	6.06	0.42
n_3s_1	4.45	6.55	0.40
n_3s_2	4.54	7.06	0.39
$F_{2, 24}$	0.12	2.92	1.20
SE	0.08	0.09	0.01
n_1r_1	2.95	5.57	0.35
n_1r_2	3.09	5.77	0.35
n_2r_1	4.27	5.96	0.42
n_2r_2	4.39	6.03	0.42
n_3r_1	4.40	6.74	0.39
n_3r_2	4.59	6.87	0.40
$F_{2, 24}$	0.09	0.35	0.14
SE	0.08	0.09	0.01
s_1r_1	3.81	5.91	0.39
s_1r_2	3.99	6.10	0.39
s_2r_1	3.94	6.28	0.38
s_2r_2	4.05	6.35	0.39
$F_{1, 24}$	0.28	0.73	0.01
SE	0.06	0.06	0.00

None of the interactions were found to have significant influence on the straw yield.

4.3.3 Harvest Index

Nitrogen levels favourably influenced HI and the plots treated with 90 kg N ha^{-1} (n_2) recorded the maximum harvest index. From the data it is evident that the HI of rice increased with an increase in N level upto n_2 but there was a reduction in HI with n_3 level of nitrogen. The different N sources and NPK ratios had no influence on HI of basmati rice.

The HI was not influenced by the interactions of N, S and R.

4.4 QUALITY CHARACTERS OF GRAINS

4.4.1 Protein Content of Grains (Tables 4.4.1a and 4.4.1b)

An increase in N level resulted in an increase in protein content of grains. 120 kg N ha^{-1} (n_3) applied plants registered the highest grain protein content of 6.61 per cent and was significantly superior to that obtained when treated with n_2 and n_1. Sources of N did not produce any significant difference on the protein content of grains. The two NPK ratios exhibited marked difference in the protein content of grains with r_2 treated plants recording more grain protein content (6.06 per cent).

4.4.2 Cooking Quality of Grains (Tables 4.4.2a and 4.4.2b)

4.4.2.1 Optimum Cooking Time

The optimum cooking time of grains was significantly influenced by different levels of N and the grains obtained from higher doses of N treated plots took more cooking time than n_1 applied plots. The different sources of N and NPK ratios had no significant influence on optimum cooking time of grains.

None of the interactions were found significant in influencing the optimum cooking time of grains.

Table 4.4.1a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on protein content of grains, per cent

Treatments	Protein content of grains
Levels of nitrogen (N)	
n_1	5.17
n_2	6.11
n_3	6.61
$F_{2, 24}$	158.78**
SE	0.06
CD	0.170
Sources of nitrogen (S)	
s_1	5.96
s_2	5.97
$F_{1, 24}$	0.07
SE	0.05
NPK ratios (R)	
r_1	5.87
r_2	6.06
$F_{1, 24}$	8.54**
SE	0.05
CD	0.139

**Significant at 1 per cent level

Table 4.4.1b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on protein content of grains, per cent

Treatments	Protein content of grains
n_1s_1	5.16
n_1s_2	5.18
n_2s_1	6.12
n_2s_2	6.11
n_3s_1	6.60
n_3s_2	6.63
$F_{2,24}$	0.03
SE	0.08
n_1r_1	5.08
n_1r_2	5.26
n_2r_1	6.08
n_2r_2	6.14
n_3r_1	6.44
n_3r_2	6.79
$F_{2,24}$	1.52
SE	0.08
s_1r_1	5.87
s_1r_2	6.04
s_2r_1	5.87
s_2r_2	6.08
$F_{1,24}$	0.09
SE	0.07

Table 4.4.2a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on cooking quality of grains

Treatments	Optimum cooking time, minute	Volume expansion ratio	Elongation ratio
Levels of nitrogen (N)			
n_1	15.13	4.46	1.42
n_2	16.13	4.46	1.45
n_3	17.09	4.50	1.45
$F_{2, 24}$	484.64**	0.79	3.39
SE	0.04	0.02	0.00
CD	0.130	-	-
Sources of nitrogen (S)			
s_1	16.14	4.46	1.44
s_2	16.10	4.49	1.44
$F_{1, 24}$	0.66	0.90	0.00
SE	0.04	0.01	0.00
NPK ratios (R)			
r_1	16.12	4.48	1.44
r_2	16.12	4.47	1.44
$F_{1, 24}$	0.00	0.48	0.37
SE	0.04	0.01	0.00

**Significant at 1 per cent level

Table 4.4.2b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on cooking quality of grains

Treatments	Optimum cooking time, minute	Volume expansion ratio	Elongation ratio
n_1s_1	15.17	4.45	1.42
n_1s_2	15.09	4.48	1.42
n_2s_1	16.19	4.46	1.45
n_2s_2	16.08	4.47	1.44
n_3s_1	17.06	4.48	1.45
n_3s_2	17.12	4.51	1.45
$F_{2, 24}$	0.97	0.10	0.16
SE	0.06	0.03	0.01
n_1r_1	15.12	4.47	1.42
n_1r_2	15.14	4.46	1.43
n_2r_1	16.13	4.49	1.46
n_2r_2	16.14	4.44	1.44
n_3r_1	17.09	4.49	1.45
n_3r_2	17.08	4.50	1.45
$F_{2, 24}$	0.06	0.49	1.30
SE	0.06	0.03	0.01
s_1r_1	16.14	4.48	1.44
s_1r_2	16.14	4.44	1.44
s_2r_1	16.09	4.48	1.45
s_2r_2	16.10	4.49	1.43
$F_{1, 24}$	0.00	0.97	0.76
SE	0.05	0.02	0.01

4.4.2.2 Volume Expansion Ratio

Perusal of the mean values revealed that the volume expansion ratio of grains was not influenced by different levels of N, sources of N, NPK ratios and their interactions.

4.4.2.3 Elongation Ratio

The elongation ratio of grains was not influenced by various treatments viz., levels of N, sources of N, NPK ratios and their interactions.

4.5 UPTAKE OF NUTRIENTS AT HARVEST (TABLES 4.5a and 4.5b)

4.5.1 Uptake of Nitrogen

Perusal of the data revealed that the different levels of N, sources of N and NPK ratios significantly influenced the uptake of nitrogen. An increase in N level resulted in an increase in N uptake and n_3 (120 kg N ha^{-1}) recorded the maximum N uptake which was significantly superior to n_2 and n_1. Among the two N sources, s_2 applied plots exhibited higher value of N uptake (91.57 kg ha^{-1}) than s_1 treated plots. The two NPK ratios also had significant influence on N uptake and r_2 treated plots registered more N uptake (91.96 kg ha^{-1}) values.

None of the interactions could significantly influence the N uptake.

4.5.2 Uptake of Phosphorus

Uptake of P had also been influenced by the application of N at different levels. Application of 120 kg N ha^{-1} (n_3) recorded the maximum P uptake (48.24 kg ha^{-1}) and was significantly superior to those applied with lower levels of nitrogen. Different sources of N also significantly influenced the P uptake and s_2 recorded the highest P uptake value (36.22 kg ha^{-1}). Among the NPK ratios, application of N, P and K in 2 : 1 : 1.5 ratios (r_2) registered significantly superior P uptake than r_1.

The P uptake was not influenced by the interactions of N, S and R.

Table 4.5a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on uptake of nutrients at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
Levels of nitrogen (N)			
n_1	65.18	23.06	80.47
n_2	91.92	34.52	117.63
n_3	110.53	48.24	138.66
$F_{2, 24}$	760.54**	810.72**	1187.99**
SE	0.83	0.44	0.85
CD	2.413	1.292	2.495
Sources of nitrogen (S)			
s_1	86.85	34.32	111.27
s_2	91.57	36.22	113.23
$F_{1, 24}$	24.47**	13.79**	3.96
SE	0.67	0.36	0.70
CD	1.970	1.055	-
NPK ratios (R)			
r_1	86.45	34.70	109.24
r_2	91.96	35.84	115.26
$F_{1, 24}$	33.42**	4.94*	37.21**
SE	0.67	0.36	0.70
CD	1.970	1.055	2.037

*Significant at 5 per cent level **Significant at 1 per cent level

Table 4.5b Interaction effect of different levels of nitrogen. sources of nitrogen and NPK ratios on uptake of nutrients at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
n_1s_1	63.38	22.85	79.37
n_1s_2	66.97	23.27	81.57
n_2s_1	88.97	32.98	116.61
n_2s_2	94.87	36.05	118.65
n_3s_1	108.19	47.14	137.84
n_3s_2	112.86	49.34	139.48
$F_{2,24}$	0.49	2.32	0.03
SE	1.17	0.63	1.21
n_1r_1	63.50	22.57	77.27
n_1r_2	66.86	23.55	83.67
n_2r_1	88.21	34.64	114.53
n_2r_2	95.62	34.40	120.73
n_3r_1	107.64	46.91	135.93
n_3r_2	113.41	49.57	141.39
$F_{2,24}$	1.51	2.71	0.08
SE	1.17	0.63	1.21
s_1r_1	84.20	33.34	108.23
s_1r_2	89.49	35.31	114.31
s_2r_1	88.70	36.07	110.25
s_2r_2	94.44	36.37	116.22
$F_{1,24}$	0.05	2.63	0.00
SE	0.95	0.51	0.99

4.5.3 Uptake of Potassium

Potassium uptake increased with increase in level of N and n_3 (120 kg N ha^{-1}) recorded the maximum value (138.66 kg ha^{-1}) which was significantly superior to lower levels. The two different sources of N did not have significant influence on K uptake. But K uptake was significantly influenced by the NPK ratios and r_2 recorded higher K uptake value (115.26 kg ha^{-1}).

None of the interactions were significant in influencing the K uptake.

4.6 SOIL NUTRIENT STATUS AFTER THE EXPERIMENT (TABLES 4.6a and 4.6b)

4.6.1 Nitrogen Status

The available N status of the soil was improved after experimentation than initial status in all the plots. An increase in the level of N significantly improved the available N status of soil and n_3 (120 kg N ha^{-1}) recorded the maximum value (379.08 kg N ha^{-1}). However different sources of N and NPK ratios had no influence on the available N status of the soil.

The interaction effects failed to produce any significant influence on the available N status of soil.

4.6.2 Phosphorus Status

On comparing the mean values with the initial P status of the soil, it was found that the available P status of the soil was improved in most of the plots after experimentation except in plots treated with 60 kg N ha^{-1} (n_1). Application of 120 kg N ha^{-1} (n_3) recorded the highest value of 35.59 kg ha^{-1} and it was superior to n_1 and n_2. The different sources of N and NPK ratios had no significant influence on the available P status of soil.

Table 4.6a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on soil nutrient status after the experiment, kg ha^{-1}

Treatments	Available N	Available P_2O_5	Available K_2O
Levels of nitrogen (N)			
n_1	349.30	30.75	177.98
n_2	366.43	33.79	188.19
n_3	379.08	35.59	203.12
$F_{2, 24}$	44.58**	38.50**	189.98**
SE	2.24	0.39	0.92
CD	6.534	1.150	2.678
Sources of nitrogen (S)			
s_1	362.79	33.57	186.40
s_2	367.09	33.18	193.13
$F_{1, 24}$	2.75	0.71	40.36**
SE	1.83	0.32	0.75
CD	-	-	2.186
NPK ratios (R)			
r_1	367.43	33.24	187.34
r_2	362.45	33.52	192.19
$F_{1, 24}$	3.70	0.38	20.96**
SE	1.83	0.32	0.75
CD	-	-	2.186

**Significant at 1 per cent

Table 4.6b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on soil nutrient status after the experiment, kg ha^{-1}

Treatments	Available N	Available P_2O_5	Available K_2O
n_1s_1	348.57	30.67	177.64
n_1s_2	350.03	30.84	178.32
n_2s_1	364.43	33.88	187.83
n_2s_2	368.44	33.71	188.55
n_3s_1	375.36	36.17	193.72
n_3s_2	382.79	35.00	212.51
$F_{2, 24}$	0.45	0.78	32.39**
SE	3.17	0.56	1.30
CD	-	-	3.787
n_1r_1	351.11	30.38	175.94
n_1r_2	347.48	31.13	180.02
n_2r_1	369.12	33.78	185.88
n_2r_2	363.74	33.81	190.49
n_3r_1	382.04	35.55	200.19
n_3r_2	376.11	35.62	206.05
$F_{2, 24}$	0.07	0.27	0.24
SE	3.17	0.56	1.30
s_1r_1	365.41	33.45	184.53
s_1r_2	360.17	33.69	188.27
s_2r_1	369.44	33.02	190.15
s_2r_2	364.73	33.35	196.11
$F_{1, 24}$	0.02	0.01	1.10
SE	2.58	0.45	1.06

**Significant at 1 per cent level

None of the interactions were found to be significant in influencing the available P status of soil.

4.6.3 Potassium Status

The available K status of the soil was improved in all the plots after experimentation. The N levels had a profound impact on the available K status of soil. An increase in available K status of the soil was recorded by enhancing the levels of N and maximum value of 203.12 kg ha^{-1} was recorded with n_3 (120 kg N ha^{-1}) level. Effect of different sources of N was also found to be significant in influencing the available K status of soil and vermicompost treated plots (s_2) recorded superior value (193.13 kg ha^{-1}). Among the two different NPK ratios, r_2 (2 : 1 : 1.5) recorded significantly higher available K status (192.19 kg ha^{-1}) than r_1 (2 : 1 : 1).

The combinations of different levels of N and different sources of N were significant in influencing the available K status of the soil. At n_1 and n_2 levels, the different sources of N did not result in any change in the availability of K in the soil, but with n_3 level, s_2 treated plots registered a significantly higher availability of K in the soil.

The interactions of N x R, S x R and N x S x R could not significantly influence the available K status of the soil.

4.7 NITROGEN USE EFFICIENCY (TABLES 4.7a and 4.7b)

4.7.1 Agronomic Efficiency

The applied N levels had a marked effect on the agronomic efficiency of applied nitrogen. An increase in N upto n_2 (90 kg N ha^{-1}) level increased the agronomic efficiency of applied N and recorded the maximum value (25.06 kg grain kg^{-1} N). Thereafter a reduction in agronomic efficiency was observed with an increase in N to 120 kg N ha^{-1} (n_3). The two sources of N had no significant influence on the agronomic efficiency of applied nitrogen. But the plots treated with r_2 ratio recorded more agronomic efficiency than the plots treated with r_1.

Table 4.7a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on nitrogen use efficiency

Treatments	Agronomic efficiency, kg grain kg^{-1} N	Apparent recovery, per cent
Levels of nitrogen (N)		
n_1	15.70	60.36
n_2	25.06	69.94
n_3	20.14	67.96
$F_{2, 22}$	47.07**	26.33**
SE	0.68	0.99
CD	2.002	2.889
Sources of nitrogen (S)		
s_1	19.73	63.34
s_2	20.86	68.83
$F_{1, 24}$	2.05	23.32**
SE	0.56	0.80
CD	-	2.360
NPK ratios (R)		
r_1	19.43	62.98
r_2	21.17	69.18
$F_{1, 24}$	4.87*	26.69**
SE	0.56	0.80
CD	1.635	2.360

*Significant at 5 per cent level **Significant at 1 per cent level

Table 4.7b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on nitrogen use efficiency

Treatments	Agronomic efficiency, kg grain kg^{-1} N	Apparent recovery, per cent
n_1s_1	15.14	57.34
n_1s_2	16.25	63.37
n_2s_1	24.28	66.66
n_2s_2	25.83	73.21
n_3s_1	19.78	66.01
n_3s_2	20.50	69.91
$F_{2, 24}$	0.09	0.51
SE	0.97	1.39
n_1r_1	14.50	57.58
n_1r_2	16.89	63.13
n_2r_1	24.41	65.82
n_2r_2	25.71	74.05
n_3r_1	19.38	65.55
n_3r_2	20.90	70.37
$F_{2, 24}$	0.18	0.83
SE	0.97	1.39
s_1r_1	18.67	60.11
s_1r_2	20.79	66.56
s_2r_1	20.19	65.86
s_2r_2	21.54	71.81
$F_{1, 24}$	0.24	0.05
SE	0.79	1.14

The interactions of N, S and R had no significant influence on the agronomic efficiency of applied nitrogen.

4.7.2 Apparent Recovery

The levels of applied N had a significant influence on the apparent recovery of applied nitrogen. The apparent recovery value increased with an increase in N level upto n_2 (90 kg N ha^{-1}) and recorded the maximum value of 69.94 per cent. Though the apparent recovery value decreases with further increase in N level upto n_3 (120 kg N ha^{-1}), it was found to be on par with n_2 level. The two different sources of N had a marked effect in influencing the apparent recovery of applied N and s_2 treated plots exhibited the maximum value (68.83 per cent). NPK ratios also had a significant influence on the apparent recovery of applied N and r_2 recorded superior value (69.18 per cent) than r_1.

Interaction effects were not significant.

4.8 SHEATH BLIGHT INCIDENCE (TABLES 4.8a and 4.8b)

The results revealed that there was a substantial increase in disease incidence with increase in N level. But the different sources of N did not produce any effect in disease incidence.

When the NPK ratio was changed from r_1 to r_2, a significant reduction in disease incidence was observed. But the decrease in disease incidence at higher NPK ratio (r_2) was only seen at lower levels of nitrogen. The disease incidence was on par at the two ratios of NPK with higher N level (n_3). The other interactions viz., N x S., S x R and N x S x R were found non-significant in influencing the disease incidence.

Table 4.8a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on sheath blight incidence

Treatments	Disease index
Levels of nitrogen (N)	
n_1	30.63 (5.62)
n_2	39.88 (6.39)
n_3	50.29 (7.16)
$F_{2, 24}$	93.53**
SE	0.08
CD	0.232
Sources of nitrogen (S)	
s_1	40.12 (6.41)
s_2	39.62 (6.37)
$F_{1, 24}$	0.18
SE	0.06
NPK ratios (R)	
r_1	44.14 (6.72)
r_2	35.82 (6.07)
$F_{1, 24}$	50.24**
SE	0.06
CD	0.189

Figures in parentheses are transformed values

**Significant at 1 per cent level

Table 4.8b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on sheath blight incidence

Treatments	Disease index
n_1s_1	30.00 (5.57)
n_1s_2	31.27 (5.68)
n_2s_1	40.68 (6.46)
n_2s_2	39.08 (6.33)
n_3s_1	51.05 (7.21)
n_3s_2	49.54 (7.11)
$F_{2, 24}$	0.68
SE	0.11
n_1r_1	37.66 (6.22)
n_1r_2	24.31 (5.03)
n_2r_1	42.15 (6.57)
n_2r_2	37.67 (6.22)
n_3r_1	53.31 (7.37)
n_3r_2	47.36 (6.95)
$F_{2, 24}$	8.55**
SE	0.11
CD	0.328
s_1r_1	43.86 (6.70)
s_1r_2	36.55 (6.13)
s_2r_1	44.42 (6.74)
s_2r_2	35.10 (6.01)
$F_{1, 24}$	0.77
SE	0.09

Figures in parentheses are transformed values

**Significant at 1 per cent level

4.9 RESPONSE SURFACE AND STANDARDIZATION OF RESPONSE TO APPLIED NUTRIENTS (TABLE 4.9).

4.9.1 Grain Yield

The fitted quadratic response is as follows :

$$Y = -3.060608 + 0.1397\ X - 0.0006\ X^2$$

F for regression = 225.4672

$R^2 = 93.20\ \%$

The physical optimum dose of nitrogen for grain yield was estimated as 109.24 kg ha^{-1}.

4.9.2 Straw Yield

The linear response equation fitted for straw yield is as follows :

$$Y = 5.022219 + 0.5679X$$

F for regression = 92.71259

$R^2 = 73.17\ \%$

4.9.3 Agronomic efficiency

The fitted quadratic response is as follows

$$Y = -45.86318 + 1.5019\ X - 0.0079\ X^2$$

F for regression = 40.81538

$R^2 = 71.20\ \%$

The physical optimum dose of nitrogen for NUE was found to be 94.67 kg ha^{-1}.

Table 4.9 Physical optimum dose of nitrogen for basmati rice, kg ha^{-1}

Character	Physical optimum dose
Grain yield	109.24
Agronomic efficiency	94.67

4.10 ECONOMICS OF CULTIVATION (TABLES 4.10a and 4.10b)

4.10.1 Net Returns

The different levels of N, sources of N and NPK ratios had significant influence on net returns. The results revealed that, an increase in N level increased the net returns ha^{-1} and n_3 (120 kg N ha^{-1}) recorded the maximum net returns (Rs. 64636.53 ha^{-1}), but it was on par with the n_2 (90 kg N ha^{-1}) level (Rs. 63489.73 ha^{-1}). Among the two sources of N tried in the experiment, s_1 treated plots registered higher net returns (Rs. 60205.25 ha^{-1}) than s_2 (Rs. 49910.09 ha^{-1}) treated plots. Application of the major nutrients N, P and K in r_2 ratio (2 : 1 : 1.5) resulted in more net returns (Rs. 56802.47 ha^{-1}) than r_1 (2 : 1 : 1).

None of the interactions were found to have significant influence on net returns from basmati rice cultivation.

4.10.2 Benefit : Cost Ratio

The N levels were found to be highly significant in influencing the benefit : cost ratio. From the result it was clear that an increase in N level showed an increase in the BCR upto n_2 (90 kg N ha^{-1}) level followed by a reduction at higher level of nitrogen (n_3). However the BCR at n_2 and n_3 levels were statistically on par. The highest BCR was recorded with s_1 which was found to be significantly superior to s_2. Different NPK ratios also had a significant effect in influencing the BCR with r_2 (2 : 1 : 1.5) recording a better BCR than r_1 (2 : 1 : 1)

Interaction effects were not significant.

Table 4.10a Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on economics of cultivation

Treatments	Net returns, Rs. ha^{-1}	BCR
Levels of nitrogen (N)		
n_1	37046.77	1.86
n_2	63489.73	2.36
n_3	64636.53	2.29
$F_{2, 24}$	163.81**	102.79**
SE	1219.52	0.03
CD	3559.694	0.078
Sources of nitrogen (S)		
s_1	60205.25	2.44
s_2	49910.09	1.90
$F_{1, 24}$	53.45**	301.47**
SE	995.73	0.02
CD	2906.473	0.064
NPK ratios (R)		
r_1	53312.88	2.13
r_2	56802.47	2.20
$F_{1, 24}$	6.14*	5.36*
SE	995.73	0.02
CD	2906.473	0.064

*Significant at 5 per cent level

**Significant at 1 per cent level

Cost of cultivation per ha excluding the treatments	=	Rs. 34037.00
Cost of 1 t FYM	=	Rs. 360.00
Cost of 1 t vermicompost	=	Rs. 3000.00
Cost of 1 kg nitrogen	=	Rs. 11.00
Cost of 1 kg phosphate	=	Rs. 26.00
Cost of 1 kg potassium	=	Rs. 9.50
Cost of 1 kg paddy straw	=	Rs. 2.00
Cost of 1 kg Basmati rice	=	Rs. 30.00
Conversion factor for grains to rice	=	0.65

Table 4.10b Interaction effect of different levels of nitrogen, sources of nitrogen and NPK ratios on economics of cultivation

Treatments	Net returns, Rs. ha^{-1}	BCR
n_1s_1	40563.36	2.03
n_1s_2	33530.17	1.68
n_2s_1	68204.25	2.64
n_2s_2	58775.21	2.07
n_3s_1	71848.16	2.64
n_3s_2	57424.90	1.94
$F_{2, 24}$	2.39	11.73**
SE	1724.66	0.04
CD	-	0.11
n_1r_1	35254.71	1.82
n_1r_2	38838.82	1.89
n_2r_1	62129.77	2.32
n_2r_2	64849.69	2.39
n_3r_1	62554.15	2.25
n_3r_2	66718.90	2.33
$F_{2, 24}$	0.90	0.03
SE	1724.66	0.04
s_1r_1	58020.97	2.38
s_1r_2	62389.55	2.49
s_2r_1	48604.80	1.88
s_2r_2	51215.40	1.92
$F_{1, 24}$	0.39	0.90
SE	1408.18	0.03

**Significant at 1 per cent level

DISCUSSION

5. DISCUSSION

Nutrient management has got profound influence on basmati rice with regard to yield and quality. For sustainable production of this export quality, aromatic and fine grain variety, much attention should be given for eco-friendly farming practices with emphasis on integrated use of organic and inorganic sources of nutrients.

In view of these facts, a study on "nutrient management for basmati rice in wetlands" was taken up to derive an optimum package for nutrient management for basmati rice in wetland condition. The field experiment was conducted during September 2001 to January 2002 at the Instructional Farm, College of Agriculture, Vellayani. The salient findings of the study are discussed in this chapter.

5.1 GROWTH CHARACTERS

Results of the study indicated that different N levels and NPK ratios had a positive influence on the growth characters of plants. Nitrogen sources had no influence on different growth characters except that it exerted a significant influence on plant height and DMP.

The influence of N levels, sources of N and NPK ratios was pronounced during the later stages of growth with respect to plant height. Increasing levels of N, NPK ratios and use of vermicompost for substituting 50 per cent of N significantly increased the plant height except at the active tillering stage. The highest value for plant height was recorded by the highest level of N (120 kg ha^{-1}) when combined with 2 : 1 : 1.5 ratios of NPK. This better response might be due to the increased availability of nutrients to plants. The influence of N fertilization in encouraging vegetative growth of plants, particularly plant height is a well established fact. An adequate supply of N was reported to increase plant height and deficiency resulted in stunted growth of rice plants (Roy *et al*., 1980). Significant influence of N in enhancing the plant height in rice was established by Gupta (1996), Dwivedi (1997), Behera (1998) and Chopra and Chopra (2000).

Higher plant height obtained by the substitution of 50 per cent of N with vermicompost is attributed to the rapid meristematic activity triggered by plant nutrients especially N (Crowther, 1935). A similar increase in plant height by vermicompost application was reported by Shuxin *et al.* (1991) in sugarcane and soyabean. Higher plant height obtained with the application of NPK in 2 : 1 : 1.5 ratio over 2 : 1 : 1 ratio may be due to the beneficial effect of K in encouraging the growth of plants. It is well known that K promotes the growth of meristematic tissues (Tisdale *et al.*, 1995). According to Barooah and Ahamed (1964), the application of K helped to increase the growth significantly at later stages with no effect in the earlier stages. Eventhough K is not considered to be essential for promoting the vegetative growth directly, it might be possible that this nutrient might have an influence in increasing the uptake of N which in turn, might result in increasing the plant height as observed by Tisdale *et al.* (1995). Increase in plant height due to increased application of K was also reported by Anu (2001).

Tiller number hill^{-1} was significantly influenced by N levels and NPK ratios. Increasing N levels and NPK ratios showed an increasing trend in tiller number hill^{-1} at all growth stages of the crop. According to Datta and Surjith (1981), N increased tiller number and K increased P response and favoured tillering in rice. Potassium, being an element favouring protein production of plants, might have exerted some influence on growth and tiller production (Vexkull, 1976). Significant influence of N in enhancing tiller count in rice was established by Dalai and Dixit (1987) and Munda (1989) and K by Anu (2001).

A general observation about LAI is that, LAI was maximum at 50 per cent flowering stage and afterwards it showed a declining trend. This might be due to the reduction in tiller number and production of small sized leaves during later stages. Nitrogen application increased the LAI in rice due to its favourable influence on tiller number and leaf size (Vexkull, 1976). Increase in plant height and tiller number has contributed to a corresponding increase in the number of leaves which in turn might have influenced LAI. In many crops, the amount of leaf area available for photosynthesis is roughly proportional to the amount of N supplied (Russel, 1973). Increase in LAI of rice due to N was also reported by Prasad *et al.* (1992), Babu (1996) and Jaiswal and Singh (2001). NPK application in 2 : 1 : 1.5 ratio showed higher LAI than 2 : 1 : 1 ratio. So it is inferred that application of K in higher dose has a favourable effect in enhancing the vegetative growth of plants. Application of K in higher doses with high dose of N is essential for proper carbohydrate metabolism. Potassium being an element favouring protein production of plants might have exerted some influence on growth and tiller production and it may also exert its influence in increasing LAI.

The data of DMP (Fig. 3) clearly indicate a progressive increase in DMP with increasing levels of N from 60 to 120 kg ha^{-1}. Nitrogenous compounds constitute a significant part of the total dry weight of plants. The overall growth contributing factors like plant height and tiller count increased with higher levels of N application. According to Russel (1973), as the N supply increases, the extra protein produced allows the plant leaves to grow larger and hence to have more surface area for photosynthesis, which resulted in better NUE of plant and enhanced growth. Along with the overall growth, the increase in the uptake of nutrients might have contributed to the total DMP. The results are in agreement with the findings of Reddy *et al.* (1986), Subbiah and Palaniappan (1988), Hari *et al.* (1997), Kumari *et al.* (2000) and Singh and Singh (2000a).

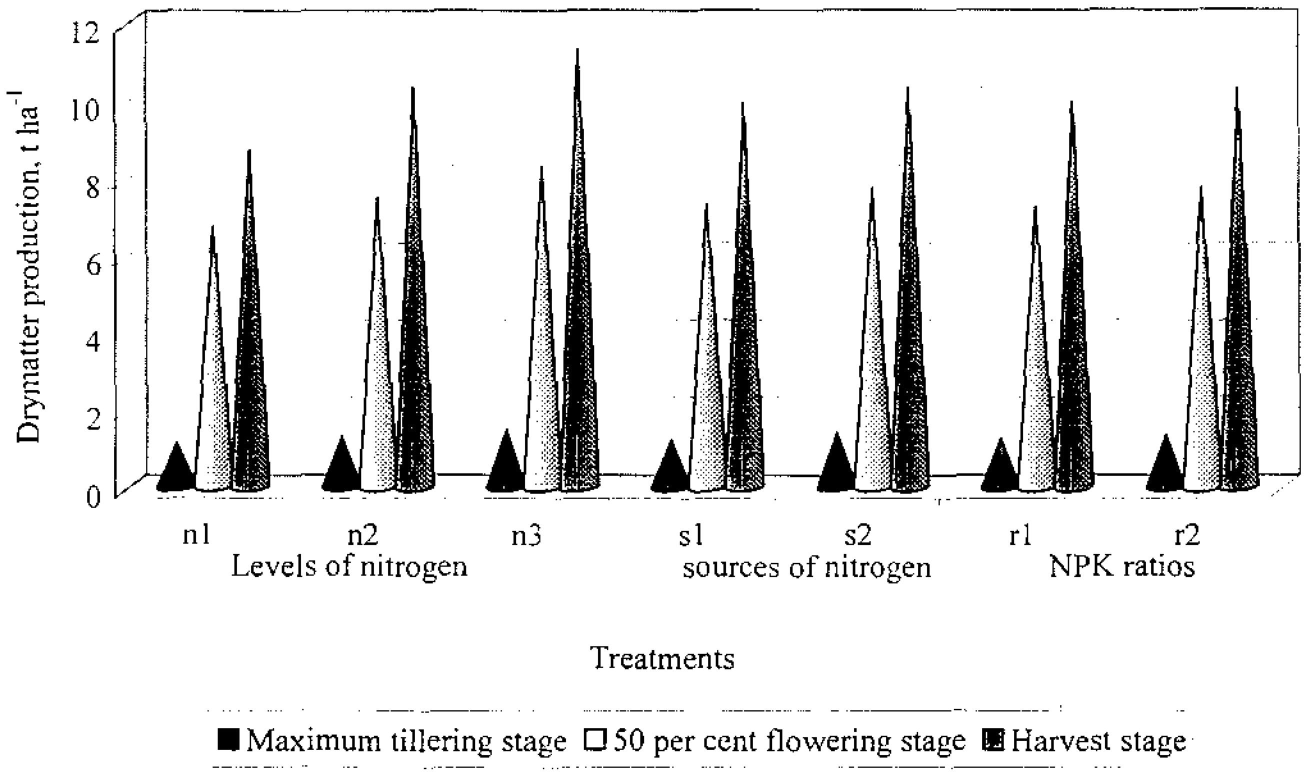

Fig. 3. Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on dry matter production, t ha^{-1}

Higher DMP was noticed by the substitution of 50 per cent of N through vermicompost than through FYM. It is seen from Table 4.1.1a and 4.1.3a that the height of plants and LAI were more when vermicompost was used and this could be the reason for enhanced DMP. The nutrient uptake also was favourably influenced by the use of vermicompost. Unlike other organic manures, vermicompost addition has got the added advantage of quick nutrient absorption by plants which also improved dry matter accumulation. So substitution of part of N requirement through vermicompost resulted in increased DMP. Similar findings were previously reported by Jadhav *et al.* (1997) and Rani and Srivastava (1997).

Enhanced K level in 2 : 1 : 1.5 ratio over 2 : 1 : 1 ratio might be responsible for the higher DMP with 2 : 1 : 1.5 ratio. Potassium is known to play a significant role in the activation of more than 60 enzymes which catalyse various metabolic processes and uptake and translocation of photosynthates and assimilation of carbon dioxide. K is also involved in meristematic growth of plants where most of the enzymes are abundant (Jacobe *et al.*, 1973). So higher K application increased the ability of plants to grow well and thus accumulate more dry matter. Increase in DMP of rice with enhanced K levels has also been reported by Kurmi and Das (1993), Kale and Chavan (1996) and Rani *et al.* (1997). The higher NPK ratio (2 : 1 : 1.5) in combination with 120 kg N ha^{-1} or substituting 50 per cent of N by vermicompost registered higher DMP. Increased N level, substituting part of N with vermicompost, might have increased the availability of nutrients leading to higher uptake which inturn resulted in the improvement of growth of plants and thereby DMP.

5.2 YIELD ATTRIBUTES

Different yield attributing characters of basmati rice was favourably influenced by higher N levels and higher NPK ratio.

Different N levels progressively increased the number of productive tillers hill^{-1} with a significant improvement with each increment in N level. According to Ghose *et al.* (1960), the increased absorption of N upto the panicle initiation stage increased the tillering capacity of the rice plant. Sushamakumari (1981) also noticed higher N uptake at higher levels of N application and increased tillering was resulted by this higher uptake. Similar results were obtained by Sing *et al.* (1990), Rao *et al.* (1993), Dwivedi (1997), Chopra and Chopra (2000) and Kumari *et al.* (2000).

Significant improvement in productive tiller count was observed with higher level of K application through 2 : 1 : 1.5 NPK ratio. Similar increase in number of productive tillers with higher K application is in conformity with the findings of Mahapatra (1982) and Mondal *et al.* (1987). Anu (2001) opined that significant higher number of panicles with higher levels of applied K was due to the better utilization of nutrients at higher rates of K application which inturn resulted in higher tiller count.

Panicle length increased with increasing levels of N upto 90 kg ha^{-1}. This might be due to the increased availability and uptake of nutrients in plots receiving higher levels of nitrogen. This observation is supported by the findings of Sing *et al.* (1990), Gupta (1996) and Singh *et al.* (1997).

Panicle weight showed an increasing trend with an increase in level of N application. Highest panicle weight (2.52 g) was obtained with 120 kg N ha^{-1} which was found to be on par with 90 kg N ha^{-1}. Higher panicle weight recorded with the NPK ratio of 2 : 1 : 1.5 over 2 : 1 : 1 might be due to the enhanced availability and uptake of nutrients in plots receiving higher N and K levels. These findings are supported by the findings of Velayudham and Velayudham (1991), Bhattacharya and Singh (1992) and Kurmi and Das (1993).

Nitrogen levels and NPK ratios exerted significant influence on number of spikelets and filled grains panicle^{-1}. The improved N uptake due to increased availability at higher levels might have resulted in greater number of filled grains panicle^{-1}. Sing *et al.* (1990) reported that the number of grains panicle^{-1} increased significantly with every increment in N application as noticed in the present study. Padmajarao (1995), Gupta (1996), Singh and Prasad (1999) and Kumari *et al.* (2000) also obtained similar results. Higher number of filled grains panicle^{-1} with the application of NPK in 2 : 1 : 1.5 ratio may be due to the enhanced K application with this ratio. Potassium stimulated build up and translocation of carbohydrates and grain development. The phenomena of grain filling under K application was ascribed to increasing photosynthetic activity, as K stimulates some vital bio-chemical processes like oxidative phosphorylation (Mengel, 1976). Increase in filled grain number with increase in K fertilization was also reported by Anu (2001).

Test weight was not significantly influenced by the different treatments. According to Yoshida (1981), thousand grain weight is a stable varietal character as the grain size is rigidly controlled by hull. Hence the grains cannot grow to a size greater than that permitted by the hull despite the abundant nutrient supply.

5.3 YIELD

Results (Fig. 4) indicated a significant positive influence of N levels and NPK ratios on yield. Grain yield increased significantly with increase in N upto 90 kg ha^{-1} and further increase in N increased the yield only marginally. This increase in yield is the net result of the beneficial effect of N observed on various yield attributing characters like number of productive tillers hill^{-1}, weight of panicles and number of filled grains panicle^{-1}. Nitrogen has a definite role in photosynthesis which is directly related to starch synthesis and yield. Increasing N levels increased the grain yield and this is in line with the work of Kumar and Singh (1984). Increase in grain yield with increase in N levels is supported by

Bhattacharya and Singh (1992), Patel *et al.* (1997) and Kumari *et al.* (2000).

Grain yield recorded higher values with the NPK ratio of 2 : 1 : 1.5 and it recorded 3.88 per cent increase over 2 : 1 : 1 ratio. This is the net result of the beneficial effect of 2 : 1 : 1.5 NPK ratio observed on various yield attributing characters like number of productive tillers, number of filled grains panicle^{-1} and panicle weight. Higher uptake of nutrients due to enhanced application of K might have contributed to the enhancement of yield attributing characters which in turn improved grain yield. Potassium is mainly involved in the manufacture and translocation of starch (Russel, 1973). The increase in grain yield due to higher level of K application has also been reported by Pillai and Anasuya (1997), Pathak *et al.* (1999) and Thakur *et al.* (1999).

Appreciable increase in the straw yield was observed with increase in N levels and maximum straw yield was obtained with 120 kg N ha^{-1} (Fig. 4). Higher straw yield obtained with the highest level of N is the net result of the positive influence of higher N levels on plant height, tiller number, LAI and DMP. Higher N uptake due to the enhanced availability of N at higher levels might have also helped in the production of higher straw yield. Similar findings were also reported by Singh and Prasad (1999), Chopra and Chopra (2000), Kumari *et al.* (2000) and Chander and Pandey (2001).

Higher straw yield obtained with the substitution of 50 per cent of N with vermicompost was attributed to the better nutrient content and soil improving property of vermicompost. Vermicompost application has significantly contributed plant nutrients and growth promoting substances, which in turn have increased the uptake of nutrients and metabolic activity of plants (Nielson, 1965). The increase in straw yield due to vermicompost application is a reflection of the growth attributes viz., increased plant height, LAI and DMP as a result of increased availability

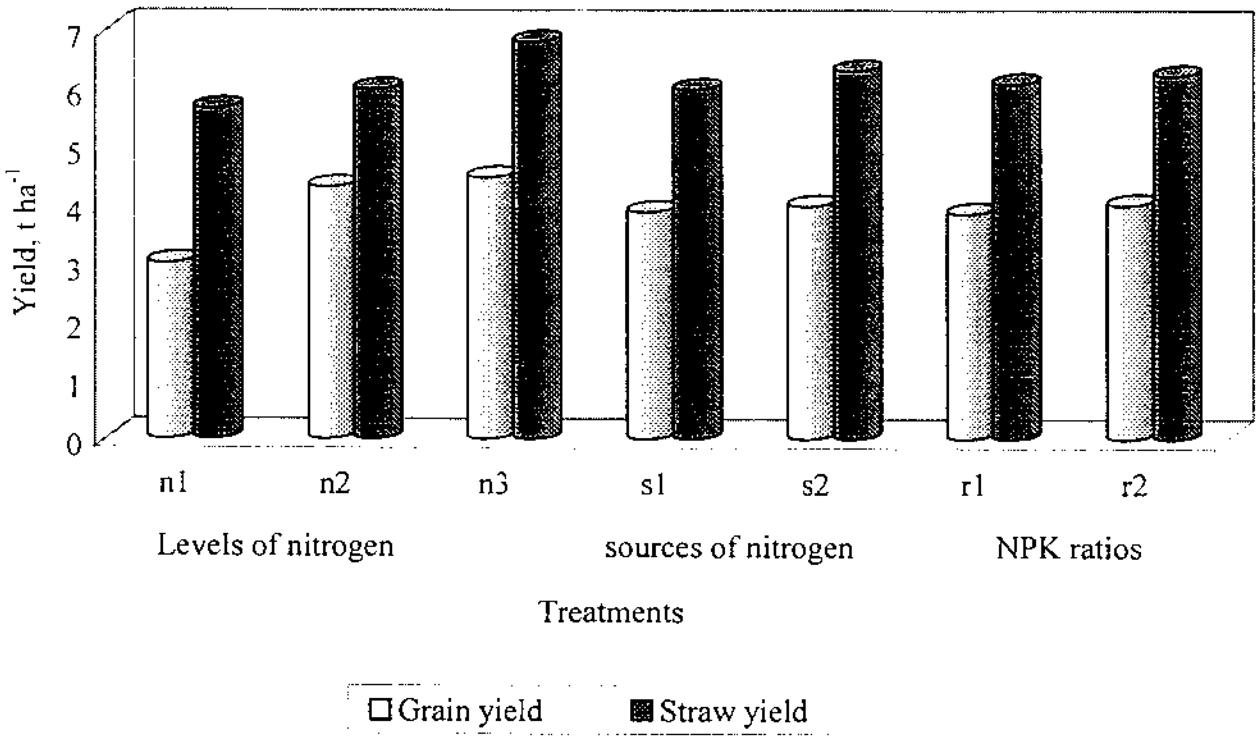

Fig. 4. Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on yield

of nutrients. The mineralization of N was supposed to be faster in the presence of vermicompost as reported by Shuxin *et al.* (1991). This has led to the increase in the leaf area of plants in plots treated with vermicompost than FYM and subsequently increased yield. Better response of field crops to vermicompost was also reported by Shroff and Devasthali (1992). Jiji and Dale (1999) also reported early availability of nutrients from vermicompost compared to cowdung and increased yield in all vermicompost treated plots of cowpea.

Higher straw yield produced by the higher NPK ratio of 2 : 1 : 1.5 was due to the higher K content and the beneficial effects of K observed on growth characters of the plant. Increase in straw yield due to increased K application has also been reported by Pillai and Anasuya (1997), Pathak *et al.* (1999) and Thakur *et al.* (1999).

Harvest index was significantly influenced by N levels. Harvest index showed an increasing trend upto 90 kg N ha^{-1} and thereafter increasing N level found to decrease harvest index. Under high input situations especially N, the vegetative growth was more. This might be the reason for increase in biological yield as compared to economic yield after 90 kg N ha^{-1} which resulted in a reduction in harvest index.

5.4 QUALITY CHARACTERS OF GRAINS

5.4.1 Protein Content of Grains

Levels of N and NPK ratios had significant effect on protein content of grains. The protein content of grains significantly increased with each increment in N level. It is a well known fact that, N is an important constituent of protein. Though the kind of protein formed is largely influenced by genetic factors, the amount of protein is governed by environmental factors, especially N supply. As more and more N is available to plants, it is metabolized to glutamic acid, which is further converted to other amino acids which are stored as proteins (Tisdale *et al.*, 1995). Similar increase in protein content of grains with increase in N supply was also reported by Singh *et al.* (1997) and Anu (2001).

Higher level of K application by applying N, P and K in 2 : 1 : 1.5 ratio resulted in significant increase in protein content of grains suggesting that K has a role in the formation of proteins. Potassium is involved in the formation of proteins through the polymerization of amino acids and other primary units in plants (Webster and Varner, 1954). Increase in grain protein at higher K level was also reported by Anu (2001).

5.4.2 Cooking Quality of Grains

Grains obtained from higher levels of N treated plots took more cooking time. This might be due to the ensured supply of nutrients which in turn resulted in higher protein content of grains with higher levels of N application. So this higher crude protein content of grains due to correct quantity of N supplied might have been responsible for the higher time required for cooking. A similar result of increase in cooking time with increase in protein content of grains was also reported by Hemaletha *et al.* (2000).

Though not significant, higher N level (90 and 120 kg N ha^{-1}) recorded a higher elongation ratio when compared to 60 kg N ha^{-1}. But the treatments could not exert any significant influence on volume expansion ratio of grains.

5.5 UPTAKE OF NUTRIENTS AT HARVEST

The results (Fig. 5) revealed a significant influence of N levels, sources of N and NPK ratios on nutrient uptake.

Varying levels of N significantly influenced the N uptake. Highest value for N uptake was obtained with the application of highest level of nitrogen. Similar results were reported by Sudhakar *et al.* (1986), Munda (1989) and Patel *et al.* (1997). It is an established fact that N absorption in rice increased with higher supply of the element and higher DMP at higher levels of N application also might have resulted in higher N uptake. Several workers have reported that under normal conditions there is a progressive increase in uptake of nutrients with every additional dose of N applied (Sahu and Murthy, 1975; Raj and Morachan, 1980; Mehta *et al.*, 1983).

Comparable higher N uptake recorded by the substitution of 50 per cent of N by vermicompost than FYM might be due to the higher DMP in vermicompost applied plots. Application of vermicompost has significantly contributed plant nutrients and growth promoting substances which in turn have increased the nutrient uptake and metabolic activity of plans (Nielson, 1965). The results of the present study are in conformity with the findings of Shuxin *et al.* (1991) and Kale *et al.* (1992).

Higher N uptake observed with the application of NPK in 2 : 1 : 1.5 ratio over 2 : 1 : 1 ratio could be attributed to the combined effect of these elements in plant parts and the higher DMP by 2 : 1 : 1.5 ratio in all the growth stages. Moreover, higher nutrient level resulted in vigorous root growth and consequently better absorption of nutrients followed by rapid translocation induced by K as reported by Sheela (1993).

The uptake of P was significantly improved by higher N levels. This may be attributed to the higher P absorption as a result of high growth rate of plants due to higher availability of nutrients. Sumneer and Farina (1986) stated that N and P had mutually synergistic effects and that resulted in growth stimulation and caused enhanced uptake of both elements. The result is in conformity with the findings of Reddy *et al.* (1986) and Anu (2001).

Substituting 50 per cent of the N with vermicompost resulted in higher P uptake than using FYM. The increased mineralization of native soil P as a result of production of organic acids during decomposition of organic matter might have increased the P uptake by plants. Earthworms

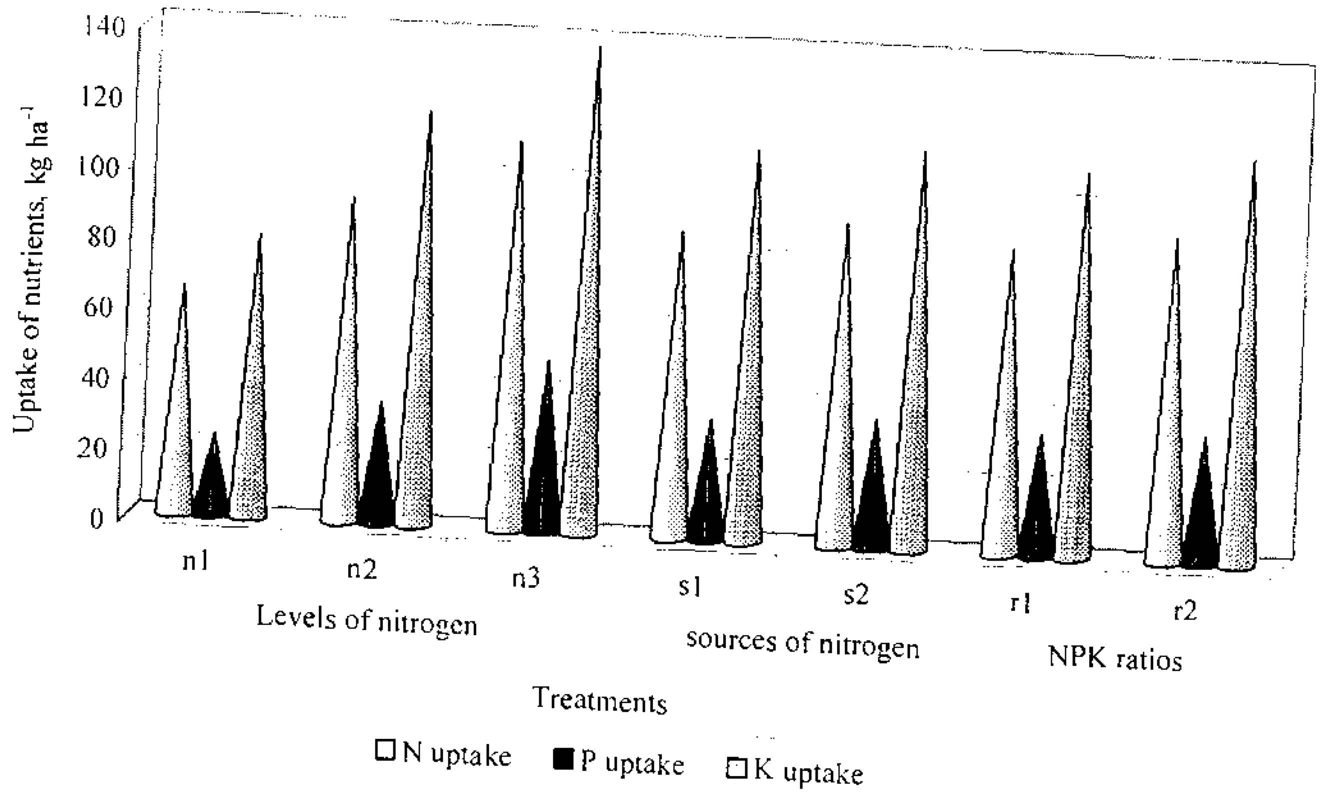

Fig. 5. Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on uptake of nutrients at harvest

stimulate P uptake by redistribution of organic matter and by increasing the enzymatic activation of phosphatase (Mackay *et al.*, 1982). Indira *et al.* (1996) revealed the presence of beneficial microbes like P solubilising bacteria and N fixing organisms in vermicompost. The P solubilising microorganisms increase the available P content of vermicompost which might have increased the uptake of P by plants.

Among the NPK ratios, the higher ratio (2 : 1 : 1.5) resulted in higher P uptake. Agarwal (1980) reported that increased K level can improve the uptake of P due to the synergistic relationship between them. The improved DMP with higher NPK ratio also might have contributed to the higher P uptake. Loganathan and Raj (1972) also previously reported such increase in P uptake in the rice variety Co-32 with enhanced application of potassium.

Higher levels of N application significantly increased the K uptake. Rathore and Vijayakumar (1978) reported that there was a consistent rise in the uptake of K due to N application as a result of increase in drymatter. Increase in K uptake at higher levels of N was also supported by the findings of Esakkimuthu *et al.* (1975), Singh and Modgal (1978) and Reddy *et al.* (1986). Similarly, application of higher level of K through NPK ratio of 2 : 1 : 1.5 also resulted in higher K uptake. Singh *et al.* (1999) also reported a similar increase in K uptake by rice grain and straw with increase in K levels.

5.6 SOIL NUTRIENT STATUS AFTER THE EXPERIMENT

The available NPK status of soil after experimentation was higher than the initial status in most of the plots except the absolute control plot and the plots treated with 60 kg N ha^{-1} in the case of available P status. It might be due to the substitution of 50 per cent of N level with organic manures like FYM and vermicompost. However, no significant difference was there between these two sources with respect to available N status of the soil. The higher build up of available N and P status of the soil is attributed to the mineralisation of organic sources or solubilising action of organic acids produced during the decomposition of organic materials on native sources of nutrients especially P which might have resulted in an enhanced release of native and applied P. Kumar and Yadav (1995), Kumar (1999) and Sudha (1999) also reported similar results of higher N and P status of soil with organic matter addition.

The available K status of the soil was improved with an increase in the level of N and it was probably due to the higher quantity of organic manures required for substituting 50 per cent of N level. Among the sources of N, vermicompost recorded significantly higher available K status of soil. Chithra and Janaki (1999) opined that application of organic wastes, irrespective of the sources, recorded higher available K status of soil over no organics. In the present study, the highest available K status was reported by 120 kg N ha^{-1} substituting 50 per cent with vermicompost and is significantly different from the treatment which received 50 per cent of N through FYM. But at lower N levels, the substitution of two sources didn't differ significantly. So it is inferred that substitution of N with higher quantities of vermicompost resulted in higher available K status of soil. Bhawalkar (1992), Vasanthi and Kumaraswamy (1996) and Sudha (1999) reported higher K status in soil with the application of vermicompost. Higher available K content in soil in vermicompost treated plots may be due to the higher K content in vermicompost. Earthworms increase the availability of K by shifting the equilibrium among the forms of K from relatively unavailable forms to more available forms.

The improvement in available K status with higher NPK ratio of 2 : 1 : 1.5 over 2 : 1 : 1 may be due to the higher level of K application through 2 : 1 : 1.5 ratio. Johnkutty (1981) stated that as a mobile cation, K is easily susceptible to loss through leaching. However K fixation counteracts the loss through leaching and converts it into slowly available fixed form. This may be the reason for the higher K status of soil due to applied potassium. Ammal and Muthiah (1995) and Mishra and Sharma (1997) also reported higher K content in soils with enhanced K addition as in the present study.

5.7 NITROGEN USE EFFICIENCY

The NUE in terms of agronomic efficiency and apparent recovery values increased upto 90 kg N ha^{-1} and thereafter an increase in N application to 120 kg ha^{-1} exerted a slight decline in the values (Fig. 6). Agronomic efficiency indicates the quantity of grain produced per unit quantity of N applied and the lower agronomic efficiency at higher levels of N (120 kg ha^{-1}) might be due to the losses of N when applied in higher quantities or due to the inefficiency of the plant in translocating this to the sink. Singh and Sreedevi (1997) and Chopra and Chopra (2000) also reported similar results of decrease in agronomic efficiency with enhanced N application. As in agronomic efficiency, apparent recovery also was higher with lower levels of N (90 kg ha^{-1}) due to the better availability of N and reduced N losses. This is in conformity with the findings of Devasenapathy and Palaniappan (2000).

Apparent N recovery in vermicompost treated plots was the highest, indicating the benefits of substituting part of N requirement with vermicompost. It may be due to the higher nutrient supplying efficiency of vermicompost which resulted in higher apparent N recovery. Higher apparent N recovery by the integration of organic and chemical sources was previously reported by Chakraborty *et al.* (2001), Pandey *et al.* (2001) and Sujathamma *et al.* (2001).

The higher N uptake resulted with the application of NPK in 2 : 1 : 1.5 over 2 : 1 : 1 further resulted in higher apparent recovery of N too. The better root growth and consequent better absorption of nutrient followed by rapid translocation induced by K due to the application of

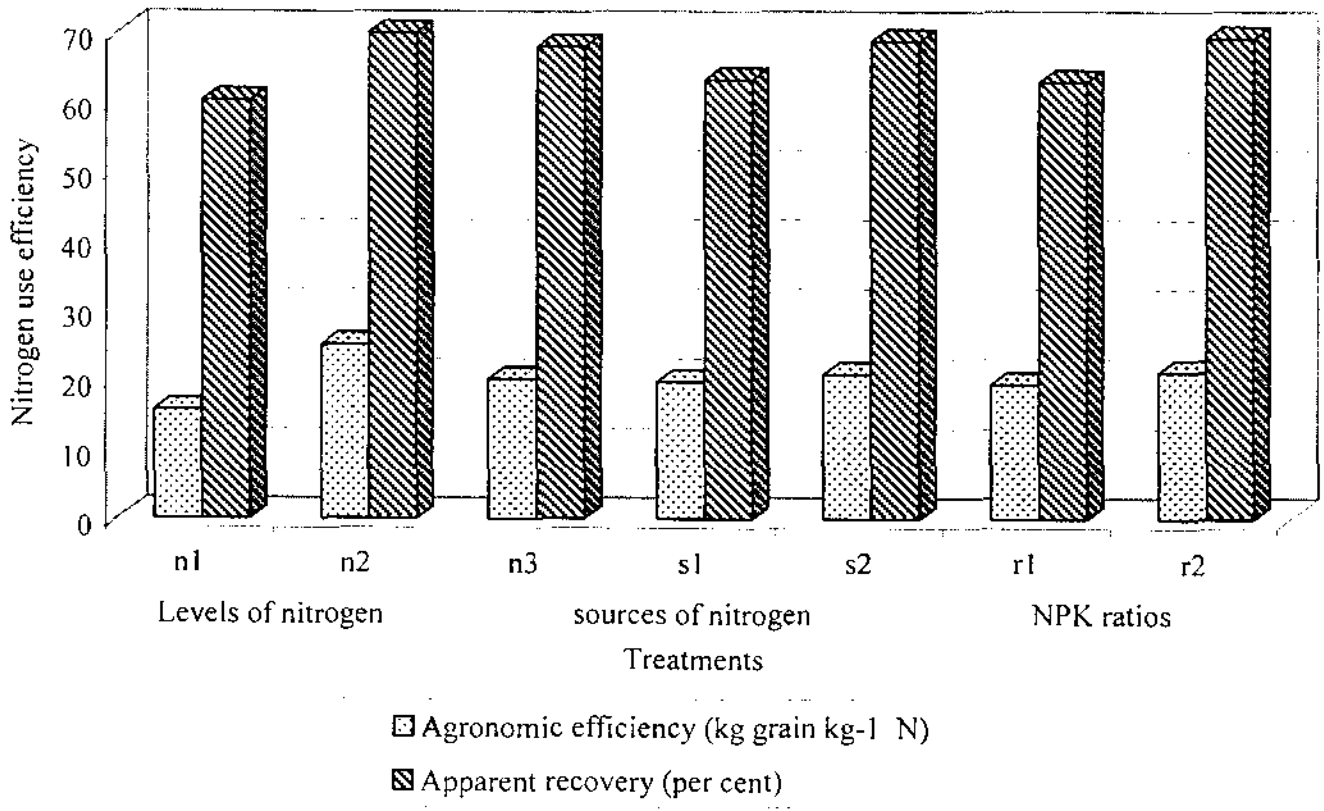

Fig. 6. Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on nitrogen use efficiency

higher level of nutrients (Sheela, 1993) might be the reason for the higher N uptake and higher apparent recovery of N as observed in the present study.

5.8 SHEATH BLIGHT INCIDENCE

The basmati rice variety used for the experiment - Pusa Basmati-1 is highly susceptible to sheath blight. It is a well known fact that the nutritional treatments increase the vulnerability of plants to the incidence of pests and diseases. In the present study, the treatments viz., N levels and NPK ratios significantly influenced sheath blight incidence (Fig. 7). The incidence of disease was aggravated by an increase in N level as observed by Musthafa and Potty (2001) in the case of sheath blight of rice. Paracer and Chahal (1963) reported that heavy application of nitrogenous fertilizers increases the incidence of fungal diseases of rice and Ito and Sakamoto (1942) opined that the vulnerability of plants to diseases with heavy N application is due to the accumulation of soluble N in plants, paving way for an unfavourable N and carbohydrate balance in plants. It was supported by the reduced incidence of sheath blight observed in absolute control plots. So reduced level of N application decreases the incidence of sheath blight disease and similar finding was also reported by Muneera (1973).

Lower disease incidence observed in plots treated with NPK ratio of 2 : 1 : 1.5 over 2 : 1 : 1 was due to the higher level of K application with the 2 : 1 : 1.5 ratio. Beneficial effects of K to give tolerance to sheath blight disease was earlier reported by Chien and Chu (1970). Significant reduction in intensity of sheath blight infection as in the present study was also reported by Muneera (1973). Different N levels in combination with 2 : 1 : 1.5 ratio of NPK recorded lower disease index than the combination with 2 : 1 :1 ratio of NPK. The highest disease index value was recorded by the treatment combination n_3r_1 and the lowest by n_1r_2. So this result is in agreement with the report of Yamada (1959), who stated that, the

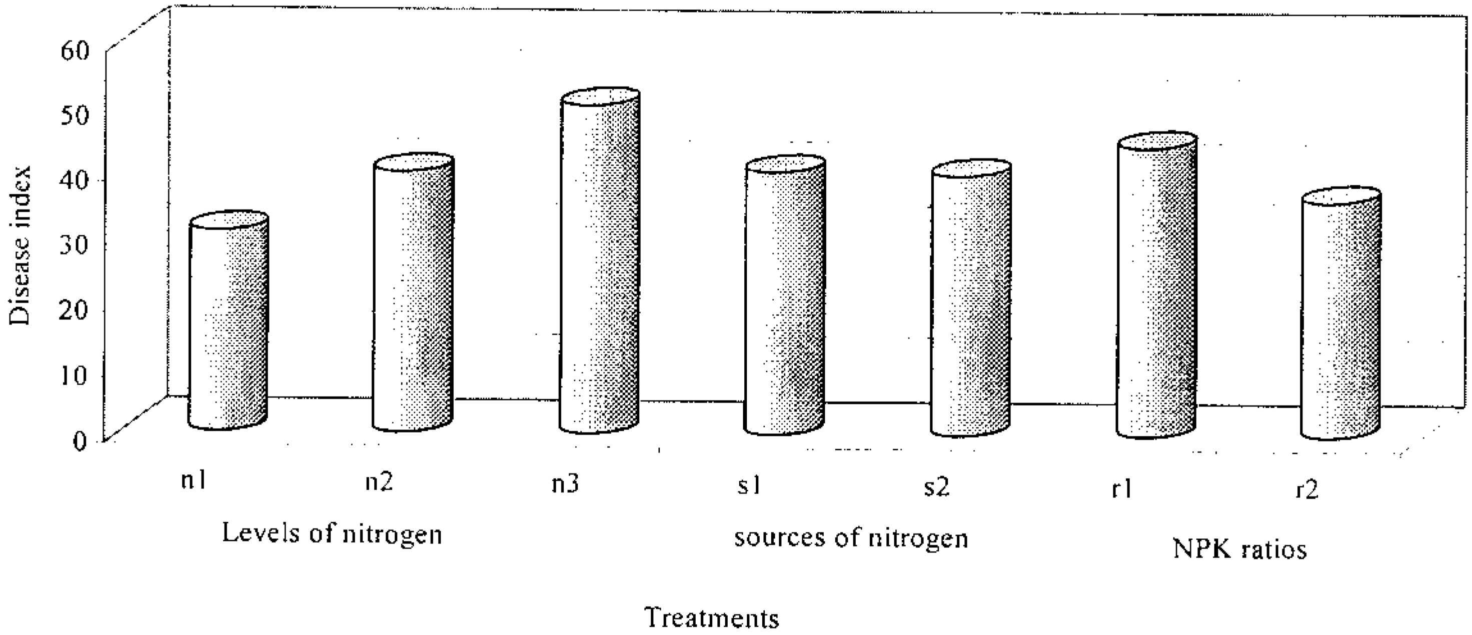

Fig. 7. Effect of different levels of nitrogen. sources of nitrogen and NPK ratios on sheath blight incidence

deficiency of K and excess of N are responsible for the disturbance of plant growth and incidence of diseases like sheath blight of rice.

5.9 RESPONSE SURFACE AND STANDARDISATION OF RESPONSE TO APPLIED NITROGEN

The relationship of applied N with grain yield, straw yield and agronomic efficiency were estimated by fitting response surfaces. The fitted response surfaces were found to be significant. Grain yield and agronomic efficiency exhibited a quadratic response, while straw yield exhibited a linear response to levels of N applied. The coefficient of determination or predictability (R^2) indicated that about 93.20 and 71.20 per cent of variation in grain yield and agronomic efficiency respectively could be explained due to the effect of applied nitrogen.

From the response surface, the physical optimum dose of nitrogen for basmati rice was estimated as 109.24 kg ha^{-1} for grain yield and 94.67 kg ha^{-1} for agronomic efficiency. In this context, it is worthwhile to note that application of nitrogen beyond 90 kg ha^{-1} has no significant effect in improving the yield of crop.

5.10 ECONOMICS OF CULTIVATION

The economics of cultivation was worked out in terms of net-income and benefit-cost ratio (Fig. 8). There was an increase in the net returns with increase in N levels, but the BCR showed a decline after 90 kg N ha^{-1}. The net returns and BCR values at 90 and 120 kg N ha^{-1} were statistically at par. This might be due to the absence of any significant increase in yield with an increase in N level beyond 90 kg ha^{-1}.

Maximum net income of Rs. 60205.25 ha^{-1} and the highest BCR of 2.44 were obtained when FYM was used as an organic source of N for substituting 50 per cent of N requirement rather than using vermicompost as the source. Vermicompost is a costly input than FYM. This might be the reason for a reduction in BCR with vermicompost.

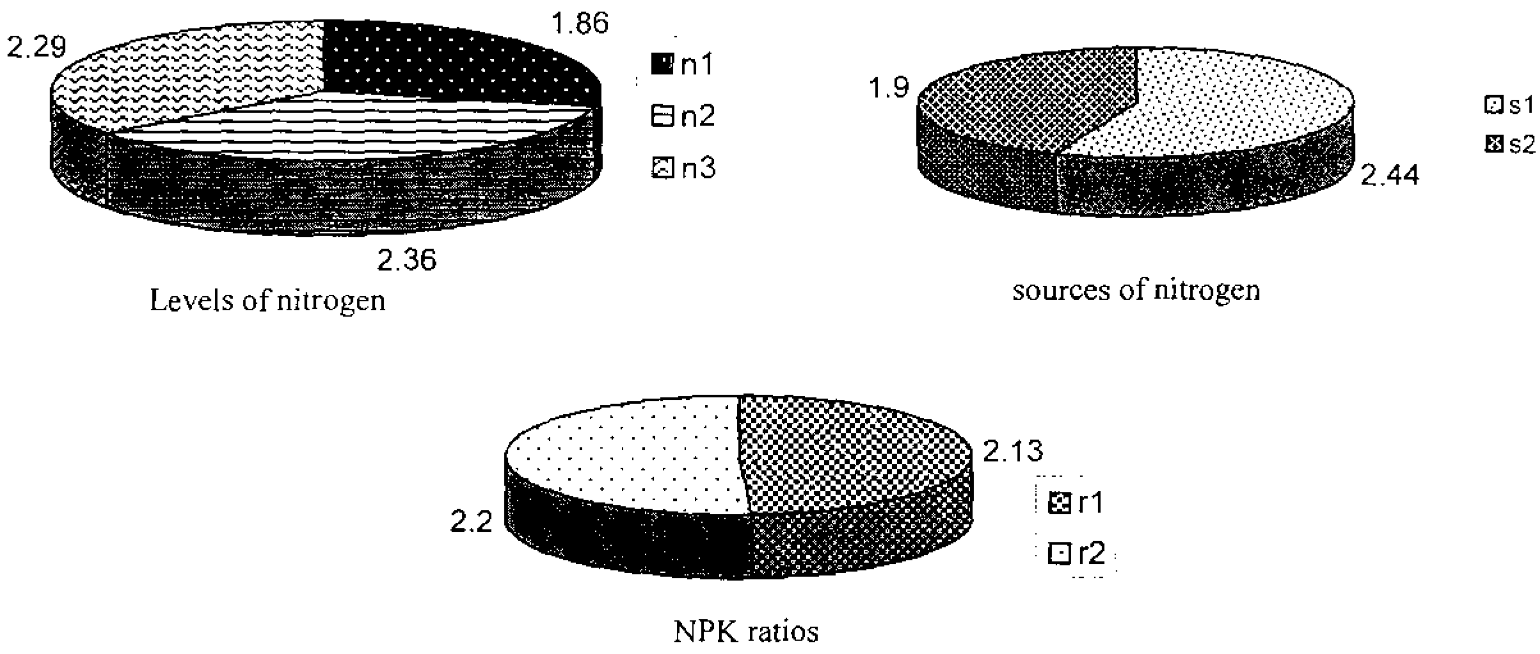

Fig. 8. Effect of different levels of nitrogen, sources of nitrogen and NPK ratios on economics of cultivation (BCR)

Significant higher net returns and BCR were obtained with higher NPK ratio of 2 : 1 : 1.5 over 2 : 1 : 1. This might be due to the significantly higher yield obtained with higher level of K application which in turn reflected in the economics of cultivation.

Substituting 50 per cent of N requirement with FYM instead of vermicompost recorded higher net returns and BCR at all levels of N and the highest BCR of 2.64 was recorded by n_2s_1 and n_3s_1. So based on the BCR, the following conclusion can be drawn.

For maximizing the yield and returns of basmati rice in wetlands, a fertilizer dose of 90 : 45 : 67.5 kg NPK ha^{-1} with 50 per cent N as FYM and 50 per cent N as chemical fertilizer can be recommended.

SUMMARY

6. SUMMARY

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from September 2001 to January 2002 to derive an optimum package for nutrient management for basmati rice in wetland condition.

The experiment was laid out in factorial RBD with three replications. The treatments consisted of three levels of N (60, 90 and 120 kg N ha^{-1}), two sources of N (s_1 : 50 per cent N as FYM and 50 per cent N as chemical fertilizer and s_2 : 50 per cent N as vermicompost and 50 per cent N as chemical fertilizer), two NPK ratios (2 : 1 : 1 and 2 : 1 : 1.5) and an absolute control thereby forming 13 treatment combinations. The salient findings of the experiment are summarised below.

Nitrogen @ 120 kg ha^{-1}, use of vermicompost for substituting 50 per cent N and application of NPK in 2 : 1 : 1.5 ratio recorded an appreciable increase in plant height over other levels. The treatment combinations of various nitrogen levels with r_2 ratio recorded significantly superior plant height.

Increased tiller count was observed with increasing levels of N application throughout the crop growth. NPK ratio of 2 : 1 : 1.5 recorded maximum tiller count.

Nitrogen @ 120 kg ha^{-1} registered appreciable increase in LAI over other levels at all stages of growth. Though the effect of NPK ratios was not significant at earlier stages, the ratio 2 : 1 : 1.5 recorded higher LAI towards the later stages of growth.

The DMP was significantly influenced by levels of N, sources of N and NPK ratios at different stages of crop growth. Nitrogen level of 120 kg ha^{-1}, use of vermicompost for substituting 50 per cent N and application of NPK in 2 : 1 : 1.5 ratio recorded an appreciable increase in

DMP over other levels. The interaction N x R influenced the DMP at 50 per cent flowering stage and the ratio 2 : 1 : 1.5 produced an increase in DMP at lower levels of N but at higher N level (120 kg ha^{-1}) there was no significant difference between the ratios. The interaction S x R was significant at maximum tillering and 50 per cent flowering stages. Use of FYM for substituting 50 per cent N and application of NPK in 2 : 1 : 1.5 ratio resulted in an increase in DMP but was on par with the treatment combinations s_2r_2 and s_2r_1.

The maximum number of productive tillers $hill^{-1}$ was observed at the highest level of N (120 kg ha^{-1}) and NPK ratio of 2 : 1 : 1.5. The N sources and interaction effects failed to influence the number of productive tillers $hill^{-1}$.

Panicle length was favourably influenced by N levels only. But an increase in the panicle length was observed only upto 90 kg N ha^{-1}.

Significantly higher panicle weight was noticed with N application at 90 kg ha^{-1}. Application of NPK in 2 : 1 : 1.5 ratio also resulted in significantly higher panicle weight.

Number of spikelets $panicle^{-1}$ and number of filled grains $panicle^{-1}$ were significantly influenced by N levels and NPK ratios. Nitrogen at 120 kg ha^{-1} and NPK ratio of 2 : 1 : 1.5 registered higher number of spikelets and filled grains per panicle.

The test weight of seeds was not influenced by any of the factors alone or their interactions.

An increase in N application resulted in an increase in grain yield and the application of 120 kg N ha^{-1} recorded the maximum grain yield which was on par with the yield at 90 kg N ha^{-1}. Among the NPK ratios, 2: 1 : 1.5 ratio recorded the maximum value for grain yield.

Straw yield was significantly influenced by N levels, N sources and NPK ratios. Nitrogen @ 120 kg ha^{-1}, use of vermicompost for substituting

50 per cent N and NPK ratio of 2 : 1 : 1.5 recorded significantly superior straw yield.

Harvest index showed an increasing trend with increasing level of N upto 90 kg ha^{-1} and thereafter a reduction was observed with further increase in N level.

The grain protein content was significantly influenced by N levels and NPK ratios. The N level of 120 kg ha^{-1} and NPK ratio of 2 : 1 : 1.5 recorded the highest grain protein content.

The optimum cooking time of grains was significantly influenced by N levels and the grains obtained from higher doses of N treated plots took more cooking time. The volume expansion ratio and elongation ratio of grains were not influenced by the treatments.

Nitrogen uptake was favourably influenced by all the three factors studied. Nitrogen @ 120 kg ha^{-1}, use of vermicompost for substituting 50 per cent N and NPK application in 2 : 1 : 1.5 ratio recorded the highest uptake. Similar trend was obtained in the case of P uptake also. The uptake of K was influenced by N levels and NPK ratios. Nitrogen @ 120 kg ha^{-1} and NPK ratio of 2 : 1 : 1.5 registered higher K uptake.

The available N and P status of the soil was influenced by various N levels to a significant extent. An increase in N application resulted in an increase in available N and P status of the soil after the experiment and maximum values were recorded with the highest level (120 kg ha^{-1}) of nitrogen. Available K status of the soil was influenced by N levels, sources of N and NPK ratios. Nitrogen @ 120 kg ha^{-1}, use of vermicompost for substituting 50 per cent N and NPK ration of 2 : 1 : 1.5 registered significantly superior available K status in the soil. N x S interaction was also found to be significant and the highest level of N (120 kg ha^{-1}) when combined with s_2 (application of 50 per cent N as vermicompost and 50 per cent as chemical fertilizer) registered a significantly higher availability of K in the soil.

The NUE in terms of agronomic efficiency and apparent recovery of applied N were significantly influenced by N levels and NPK ratios. Increasing the level of N increased the NUE upto 90 kg ha^{-1} and thereafter a slight decline in the value was observed with increase in N level. Nitrogen @ 90 kg ha^{-1} recorded the maximum value for both agronomic efficiency and apparent recovery. Application of NPK in 2 : 1 : 1.5 ratio also resulted in higher NUE. Substituting 50 per cent N with vermicompost registered significantly superior values for apparent recovery compared to FYM. However agronomic efficiency was not influenced by the sources of nitrogen.

The increase in N input caused a substantial increase in disease incidence but the application of NPK in a higher ratio (2 : 1 : 1.5) caused a substantial reduction in disease incidence. But the decrease in disease incidence at higher NPK ratio (r_2) was only seen at lower levels of N and it was on par with the highest level of N tried at the two NPK ratios.

It is evident from the response surface that the physical optimum dose of N for grain yield and agronomic efficiency were 109.24 and 94.67 kg ha^{-1} respectively. The straw yield showed a linear response with applied nitrogen. The net returns and BCR were positive for all the treatments. The N level of 120 kg ha^{-1} recorded the maximum net returns ha^{-1} and BCR and it was on par with 90 kg N ha^{-1}. Use of FYM for substituting 50 per cent of nitrogen (s_1) and NPK application in 2 : 1 : 1.5 ratio (r_2) resulted in higher net returns and BCR than other treatments.

The present investigation indicated that for maximizing the yield and returns of basmati rice in wetlands, a fertilizer dose of 90 : 45 : 67.5 kg NPK ha^{-1} with 50 per cent N as FYM and 50 per cent N as chemical fertilizer can be recommended.

Future Line of Work

1. In addition to FYM and vermicompost, other organic sources of N may be tried.
2. Long term integrated nutrient management studies are also needed to know their effect on the soil health and productivity of basmati rice varieties.
3. As basmati rice is well known for its specific quality traits, quality analysis of rice produced from organics and combinations of organic and inorganic fertilizers in comparison with that produced from chemical fertilizers alone is essential.

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*Original not seen

NUTRIENT MANAGEMENT FOR BASMATI RICE (*Oryza sativa* L.) IN WETLANDS

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8. ABSTRACT

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from September 2001 to January 2002 to derive an optimum package for nutrient management for basmati rice in wetland condition.

The experiment was laid out in factorial RBD with three replications. The treatments consisted of three levels of N (60, 90 and 120 kg N ha^{-1}), two sources of N (s_1 : 50 per cent N as FYM and 50 per cent N as chemical fertilizer and s_2 : 50 per cent N as vermicompost and 50 per cent N as chemical fertilizer), two NPK ratios (2 : 1 : 1 and 2 : 1 : 1.5) and an absolute control thereby forming 13 treatment combinations.

Results of the experiment revealed that the effect of both N levels and NPK ratios had significant influence on most of the biometric and yield attributing characters and yield of basmati rice. Nitrogen @ 120 kg ha^{-1} and NPK ratio of 2 : 1 : 1.5 were found significantly superior to lower levels. Eventhough the effect of sources of N was significant on plant height and dry matter production, the effect was not visible on the yield attributing characters and yield of the crop.

A significant linear increase in grain yield was recorded upto 90 kg N ha^{-1} and thereafter the increase in grain yield was marginal. But the straw yield increased linearly with increase in N level and was also significantly influenced by the sources of nitrogen. NPK ratio of 2 : 1 : 1.5 recorded higher grain and straw yield.

Nitrogen @ 120 kg ha^{-1} and NPK ratio of 2 : 1 : 1.5 produced the highest grain protein content. The cooking time of grains increased with increase in N level.

Nitrogen @ 120 kg ha^{-1} and NPK ratio of 2 : 1 : 1.5 recorded the highest uptake of nutrients. Use of vermicompost for substituting 50 per

cent N resulted in the highest uptake of N and P while the effect on K uptake was not significant.

An increase in N application resulted in an increase in available N and P status of the soil after the experiment. Nitrogen @ 120 kg ha^{-1}, use of vermicompost for substituting 50 per cent N and NPK ratio of 2 : 1 : 1.5 registered significantly superior available K status in the soil.

The maximum NUE in terms of agronomic efficiency and apparent recovery was observed at 90 kg N ha^{-1} and thereafter it decreased with the increase in N level. Application of NPK in 2 : 1 : 1.5 ratio also resulted in higher NUE. Sources of N were significant only with respect to apparent recovery and substituting 50 per cent N with vermicompost registered superior value.

The physical optimum dose of N for grain yield and agronomic efficiency were worked out to be 109.24 and 94.67 kg N ha^{-1} respectively. Straw yield exhibited a linear response to applied nitrogen.

An increase in N level increased the disease incidence while a significant reduction in disease incidence was observed with the NPK ratio of 2 : 1 : 1.5 over 2 : 1 : 1.

The highest net returns and BCR were recorded when FYM was used to substitute 50 per cent of nitrogen. Increase in N levels upto 90 kg ha^{-1} and application of NPK in 2 : 1 : 1.5 ratio was found profitable. So a fertilizer dose of 90 : 45 : 67.5 kg NPK ha^{-1} with 50 per cent N as FYM and 50 per cent N as chemical fertilizer can be recommended for maximizing the yield and returns of basmati rice in wetlands.

APPENDICES

APPENDIX – I

Weather data for the cropping period (September 2001 – January 2002) – weekly averages

Standard week	Temperature, °C		Rainfall, mm	Relative humidity, %	Evaporation, mm/day
	Maximum	Minimum			
41	30.00	23.70	14.20	85.30	4.80
42	29.50	24.00	52.60	85.10	3.00
43	30.30	24.00	95.70	81.40	3.00
44	31.00	24.20	-	81.10	3.10
45	30.40	23.70	54.20	81.80	2.80
46	29.70	23.10	14.60	84.10	3.10
47	30.50	23.40	37.90	84.90	2.40
48	30.50	23.20	-	80.30	3.30
49	31.00	22.90	8.60	81.10	2.90
50	30.60	20.00	-	76.20	2.70
51	31.00	22.30	3.70	82.00	3.10
52	31.00	23.50	8.30	79.50	2.70
1	31.40	23.00	-	80.30	2.90
2	31.00	22.90	-	78.40	2.70
3	30.70	19.50	-	76.60	2.80
4	31.00	23.50	-	76.60	3.00

APPENDIX – II

Mean values of absolute control treatment

	Parameters	Mean value
1.	Plant height at active tillering stage, cm	34.83
2.	Plant height at 50 per cent flowering stage, cm	66.79
3.	Plant height at harvest stage, cm	77.83
4.	Tiller number $hill^{-1}$ at active tillering stage	7.83
5.	Tiller number $hill^{-1}$ at 50 per cent flowering stage	11.15
6.	Tiller number $hill^{-1}$ at harvest stage	11.02
7.	LAI at active tillering stage	2.63
8.	LAI at 50 per cent flowering stage	4.01
9.	LAI at harvest stage	3.80
10.	DMP at active tillering stage, t ha^{-1}	0.81
11.	DMP at 50 per cent flowering stage, t ha^{-1}	4.92
12.	DMP at harvest stage, t ha^{-1}	6.54
13.	Number of productive tillers $hill^{-1}$	8.15
14.	Length of panicle, cm	23.67
15.	Weight of panicle, g	1.70
16.	Number of spikelets $panicle^{-1}$	80.27
17.	Number of filled grains $panicle^{-1}$	64.71
18.	Thousand grain weight, g	21.03
19.	Grain yield, t ha^{-1}	2.08
20.	Straw yield, t ha^{-1}	4.46
21.	Harvest index	0.32
22.	Protein content of grains, per cent	4.51
23.	Nitrogen uptake, kg ha^{-1}	28.98
24.	Phosphorus uptake, kg ha^{-1}	14.82
25.	Potassium uptake, kg ha^{-1}	32.84
26.	Available N in soil, kg ha^{-1}	284.54
27.	Available P_2O_5 content in soil, kg ha^{-1}	20.90
28.	Available K_2O content in soil, kg ha^{-1}	131.78
29.	Optimum cooking time of grains, minute	14.53
30.	Volume expansion ratio of grains	4.48
31.	Elongation ratio of grains	1.42
32.	Sheath blight – Disease index	30.00
33.	Net returns, Rs ha^{-1}	21662.86
34.	Benefit : Cost ratio	1.61