INTEGRATED NUTRIENT MANAGEMENT FOR BASMATI RICE (*Oryza sativa* L.) PRODUCTION

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DECLARATION

I hereby declare that this thesis entitled **"Integrated nutrient management for Basmati rice (*Oryza sativa* L.) production"** 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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Certified that this thesis entitled **"Integrated nutrient management for Basmati rice (*Oryza sativa* L.) production"** is a record of research work done independently by **Miss. Tulasi, T. (2005-11-145)** 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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Dedicated to my
Beloved God and
Parents

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LIST OF ABBREVIATIONS

@	-	At the rate of
°C	-	Degree Celsius
%	-	Percent
A.C.	-	Absolute control
AE	-	Agronomic efficiency
APE	-	Agro physiological efficiency
ARE	-	Apparent recovery efficiency
BCR	-	Benefit cost ratio
BLB	-	Bacterial Leaf Blight
CD	-	Critical difference
cm	-	Centimetre
DMP	-	Dry matter production
et al.	-	And others
Fig.	-	Figure
FYM	-	Farm yard manure
g	-	Grams
ha^{-1}	-	Per hectare
HI	-	Harvest index
hill^{-1}	-	Per hill
INM	-	Integrated nutrient management
K	-	Potassium
kg^{-1}	-	Per kilogram
LAI	-	Leaf area index
Min	-	Minutes
M.S.	-	Market sample
m^{-2}	-	Per metre square
MOP	-	Muriate of potash
N	-	Nitrogen
NH_3	-	Ammonia
NS	-	Non-significant
NUE	-	Nitrogen use efficiency
panicle^{-1}	-	Per panicle
PE	-	Physiological efficiency
P	-	Phosphorus
RD	-	Recommended dose
RDF	-	Recommended dose of fertilizers
Rs.	-	Rupees
SE	-	Standard error
S.P.	-	Standard practice
SDF	-	Standard dose of fertilizers
S	-	Significant
t	-	Tonnes
UE	-	Utilization efficiency
viz.	-	Namely

Introduction

1. INTRODUCTION

Rice, popularly referred to as the 'global grain' is the first ever agricultural commodity to acquire an year designated as 'International' in its honour. Over the centuries, rice has sculpted the culture and for more than half of the humanity, rice is life. According to IRRI (1994), the number of people relying on rice as their major source of food would go upto 3.9 billion by 2025. Rice statistics of 2004-2005 shows that India producing 87.88 million tones of rice from 43.08 million ha, ranked first in area and second in production (Subbaiah, 2006). Projection of India's rice production target for 2025 A.D. is 140 million tonnes, which can be achieved only by increasing the productivity to 3.20 t ha^{-1} from the present level of 2.04 t ha^{-1} (Subbaiah, 2006).

In Kerala, despite considerable investment and special attention given to rice, the fact remains that the area and production of the crop continues to decline. According to FIB (2007) the rice area of the state has drastically declined from 4.71 lakh ha (1995-'96) to 2.96 lakh ha (2004-'05) with the production declining from 9.53 lakh tonnes to 6.67 lakh tonnes. Many reasons have been attributed to this declining trend like low profit, marginal and sub marginal nature of farming, scarcity of labour, vagaries of monsoon, etc. (Ajithkumar and Anitha, 2006). The increase in input cost at a pace far ahead to that of the price of the produce and the resulting low profit realized in rice cultivation is one of the main reasons for the large scale conversion of paddy lands for growing crops like coconut, banana, cassava and vegetables. This has threatened the very sustainability of the most traditional farming system of Kerala.

At a time when the traditional paddy fields are being wantonly reclaimed for real estate development and cultivation of other crops, attempts are needed for retaining the rice areas so as to serve for food security and environment security. The policy makers have identified basmati rice as one of the lucrative options, which can offer better returns to the farmers. The fine grain, pleasant aroma, soft texture and extra elongation on cooking, endow basmati rice a special place in the domestic and international market (Siddiq, 1990). In India, basmati rice is cultivated in about 0.7 – 0.8 million ha, which accounts for about 1.7 – 1.8 percent of the total area under rice. The production of basmati rice is about 1.2 million tonnes with a productivity varying from 1.5 – 1.8 t ha^{-1} (Rani et al., 2006). Earlier it was believed that basmati could grow and produce quality grains, only in specific geographical areas of India and Pakistan. However, research efforts have shown that basmati can be successfully cultivated in other parts of India including Kerala (Sheena, 2002; George et al., 2005). The main criticism against scented rices like basmati is their low yield potential. But the high price of grains usually compensates for this. At present, the high demand for scented rices in Kerala is met by bringing aromatic rice from the neighbouring states of Tamil Nadu, Karnataka and Andhra Pradesh (Leenakumary et al., 2003).

The burgeoning population on one hand and the progressive shrinking of per capita availability of agricultural land on the other, have led to temporal and spatial intensification in agriculture, leading to the repeated use of chemical fertilizers in high amounts. The three major nutrients *viz.* nitrogen, phosphorus and potassium tend to flood the soil solution at the expense of minor ones and produce a situation of imbalanced nutrient supply. Natural resistance and fertility of the soil, dwindles and the soil demands more and more fertilizers to produce the same yield (Prakash et al., 2003). This trend of decline in land productivity is quite visible in Kerala where rice and rice based cropping systems are in vogue. Neglecting the importance of soil organic matter in crop production and prolonged over use of soluble chemical fertilizers, apart from lowering the land productivity, have also increased pest and disease infestation, human health hazards and environmental pollution. Long-term fertilizer experiments in India have clearly demonstrated that in addition to fertilizers, the use of organic manures is essential to sustain crop productivity. At present, on an average, about 2 t ha^{-1} of organic manures are being used annually, which is far below the general recommendation of 10 – 20 t ha^{-1} (IFA, 2007). The poor availability, imbalanced and inconsistent nutrient content and high cost of transport, pose problems in promoting organic nutrition. Thus the conjunctive use of chemical fertilizers and organic materials in soil fertility management is considered as the alternative to come out of the 'vicious spiral' of agrochemical menace (Palaniappan and Annadurai, 1999). Integrated nutrient management is defined as a system approach wherein, all the possible components such as on-site resource generation, mobilization of off-site nutrient resources, resource integration and management are given equal importance (Agrawal, 2006).

The application of organic matter itself is often regarded as a panacea to sustain higher levels of productivity coupled with environmental safety (Verma et al., 2006). Integrated use of organics with inorganics enables to conserve the nutrients, release nutrients at a slower rate and improve the physico-chemical and biological conditions of the soil. However, the variations in the quantity and proportion of N, P and K limit the efficiency of organic manures. Hence, the challenge is to combine organic manures of different quality with chemical fertilizers to optimize nutrient availability (Palm et al., 1997). Basmati rice responds well to integrated plant nutrient supply systems, in terms of yield, quality and aroma (Dutta et al., 1999). Organic farming is reported to have favourable effects on rice qualities under long term application.

Keeping all the above in view, the present investigation was undertaken to evaluate the impact of integrated nutrient management on the productivity and quality of the scented rice variety, Pusa Basmati-1.

The objectives of the study were

☐ To evaluate the efficiency of different nutrient management practices on the yield and quality of basmati rice.

☐ To assess the effect of adopting organic nutrition in basmati rice, in terms of yield and quality.

☐ To study the impact of integrated nutrient management on soil fertility.

☐ To assess the economic feasibility of adopting integrated nutrient management in basmati rice.

Review of Literature

2. REVIEW OF LITERATURE

Aromatic or scented rice constitute a small but special group of rice, which are considered best in quality. Among these, basmati is the costliest rice in the world. An experiment was undertaken to study the impact of integrated nutrient management on the productivity and quality of basmati rice and to compare its feasibility as against the standard practice. The research work done in these aspects is reviewed in this chapter. Since the research work done on integrated nutrient management with special reference to basmati rice is very limited, relevant literature on integrated nutrient supply systems in non-basmati rice was also reviewed, with emphasis on the effect of levels and sources of organics.

Increased interest in the practice of integrated nutrient management and organic agriculture was evinced during the last twenty five years and has generated world wide debate on the possibility of sustainable systems, which can be viable alternatives to conventional agriculture (USDA, 1980; Bezdicek and Power, 1984). Chemical residues were a major problem in modern agriculture and could be minimized by resorting to organic agriculture (Sharma and Mittra, 1990).

The basmati type among them is accepted as characterized by superfine slender grain, exquisite aroma, sweet taste, soft texture and extra elongation with a least breath wise swelling on a cooking. Efforts are underway for the characterization and conservation of aromatic varieties (KAU, 1989; George et al., 2005). Aromatic or scented rices have occupied a prime position in Indian society not only because of their high quality but also because they have been considered auspicious (Ahuja et al., 1995). Significant yield increase was observed in rice crop following incorporation of organic wastes relative to control (Velayudham et al., 1996). Use of organic materials not only improves the status of the soil but also helps to improve the physical, chemical and biological properties of soils leading to betterment of soil quality and also increase the fertilizer use efficiency (Dick and Gregorich, 2004).

2.1 EFFECT OF ORGANIC MANURES ON THE GROWTH AND YIELD OF RICE

2.1.1 Effect on growth attributes

Incorporation of organic residues @ 10 t ha^{-1} could influence the DMP in rice at maturity stage (Subbaiah et al., 1983). Satyanaryana (1986) and Budhar et al. (1991) reported significant effect of farm wastes and increasing levels of nitrogen on plant height and dry matter production. Sharma (1994) opined that plants with FYM application were taller with more tillers and dry matter than those grown without FYM.

Significant increase in plant height and LAI, of medium duration rice variety Pavizham with FYM @ 10 t ha^{-1} has been reported by Babu (1996). He also observed enhanced dry matter accumulation in rice with organic matter addition. 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 but showed significant influence on DMP at all growth stages of rice.

Singh et al. (2000) reported that application of FYM @ 6.5 t ha^{-1} on dry weight basis increased the root length and root density significantly over control. Bridgit and Potty (2002a) stated that raising FYM levels increased the root number per plant and average root length and thereby paved way for improved crop growth.

Application of FYM @ 10 t ha^{-1} produced better growth in terms of taller plants and more dry matter accumulation (Singh et al., 2002). The favourable effect of organic manures in improving the growth attributes of rice has also been reported by Kumar et al. (2002) and Mahavishnan et al. (2004).

2.1.2 Effect on yield attributes

Prakash et al. (1990) observed considerable reduction in the chaff percentage of rice due to organic manure addition. FYM as a source of organic manure was effective in increasing the number of panicle m^{-2} in rice (Zia et al., 1992).

Pramanik and Mahapatra (1994) reported that neem cake blended urea significantly influenced the yield attributes and yield. Sharma and Sharma (1994) and Rathore et al. (1995) observed significantly higher grain number $panicle^{-1}$ and panicle number m^{-2} in rice with FYM application. Rathore et al. (1995) observed significant increase in the thousand grain weight of rice with FYM application.

Deepa (1998) recorded higher number of panicles in organically fertilized plots compared to untreated and inorganically fertilized ones. Organic manuring in rice could increase the thousand grain weight. Ranwa and Singh (1999) and Dwivedi and Thakur (2000) reported that organic manure application had no significant effect on thousand grain weight.

Sudha (1999) observed that organic manure application at different levels and through different sources could not produce any significant impact on the total and filled grains $panicle^{-1}$ in rice. Pandey et al. (2001) observed the beneficial effect of organic manures in influencing the panicle weight of rice.

Bridgit and Potty (2002b) observed significant influence of FYM in increasing the number of filled grains and filling percentage. Treatment with neemsaar (mixture of oilcakes and cowdung, in which neem oil cake dominates) resulted in the highest number of panicles m^{-2} and filled grains in rice (Bhattacharya et al., 2004).

2.1.3 Effect on Yield

2.1.3.1 Grain yield

Kuppuswamy et al. (1992) observed that application of FYM @ 10 t ha^{-1} increased the grain yield to 7.33 t ha^{-1} from 6.61 t ha^{-1} and also significantly enhanced the straw yield. Sharma and Mitra (1992) have also reported increase in rice grain yield by FYM. Zia et al. (1992) reported higher grain yields of rice with organic manuring through FYM.

Anilkumar et al. (1993) reported that continuous application of cattle manure alone in the first crop season gave 24 percent more yield than the complete chemical fertilizer source. Brar and Dhillon (1994) observed that grain yield of rice reached up to 6.7 t ha^{-1} using 4 t ha^{-1} of FYM as against 4.1 t ha^{-1} in control plot. To maintain soil fertility at higher levels and to obtain higher rice yields, FYM should be applied each year in split doses rather than a single dose.

Porwal et al. (1994) reported that performance of neem cake blended urea and nimin coated urea applied either at planting or planting and panicle initiation stages, might be due to delayed conversion of ammonia form to nitrite form, there by improving and prolonging the availability of N to the rice crop.

Sharma (1994) stated 26 percent increase in yield of rice with the application of 10 t ha^{-1} of FYM. Sharma and Sharma (1994) also obtained significantly higher grain yields of rice through FYM incorporation.

Rathore et al. (1995) reported significantly higher grain yield of rice with FYM addition.

There was a linear increase in the yield of rice with the increasing levels of FYM, the maximum being with FYM at 10 t ha^{-1} (Tiwari et al., 2001).

Application of neemsaar (mixture of oilcakes and cow dung, in which neem oil cake dominates) increased the grain yield of rice over chemical fertilizers (Bhattacharya et al., 2004) Chaudhary et al. (2006) recorded significantly higher grain yield with neem cake blended urea, applied either at planting or panicle initiation compared to application of prilled urea at planting.

Roul and Mahapatra (2006) observed that application of N as granulated compost gave the highest grain yield of rice, and produced maximum number of panicle m^{-2}, filled spikelets $panicle^{-1}$ and test weight. They also inferred that basal application of 40 kg N as FYM-conditioned urea in upland rice produced 62.2 percent higher yield compared to basal application of 40 kg N ha^{-1} as urea.

2.1.3.2 Straw yield and harvest index

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. 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, he could not observe any significant impact on harvest index. Sudha (1999) and Sindhu (2002) reported that different levels and sources of organic manures could not significantly influence straw yield and harvest index.

2.1.4 Effect on grain quality

Difference in quality characters of aromatic rice cultivars consequent to organic manure application have been reported by Tripathi et al. (1995) and Singh et al. (1997). Hemalatha et al. (2000) observed higher crude protein content in rice grains from plots treated with organic manures *viz.* 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 EFFECT OF ORGANIC MANURES ON NITROGEN USE EFFICIENCY AND NUTRIENT UPTAKE

2.2.1 Nitrogen use efficiency

Reddy and Prasad (1975) reported that neem cake possesses nitrification inhibitory properties and thus help in increasing the nitrogen use efficiency.

Rao and Prasad (1980) observed that neem cake + urea reduced leaching losses of nitrogen. It was also shown to reduce NH_3 volatilization losses and thus improve the nitrogen use efficiency (Reddy and Mishra, 1983).

Padmaja and Veeraraghavaiah (1998) reported that addition of FYM @ 5 t ha^{-1} improved the nitrogen use efficiency. Bandhyopadhyay and Sarkar (2003) revealed that 50 percent urea could be supplemented through FYM for higher NUE.

Singh and Singh (1994) reported that NUE in rain fed low lands might be improved with application of slow release nitrogen fertilizers like neem cake blended urea.

2.2.2 Nutrient uptake

Tiwari et al. (1980) reported an increase in the nitrogen uptake due to application of organic manure application. Varma and Dixit (1989) and Sharma and Mittra (1991) reported that in rice based cropping systems incorporation of FYM with or without chemical nitrogen, increased the NPK uptake in rice. Pramanik and Mahapatra (1994) reported that neem coated urea increased N uptake in rice. Dhillon (1998) observed higher NPK uptake in rice – wheat cropping system, with the application of FYM as compared to absolute control and graded levels of nitrogen.

Rathore et al. (1995) reported that application of organic manures including FYM could increase NPK uptake in rice. On the contrary, Babu (1996) reported that the uptake of N, P and K by rice was not influenced by the application of organic manures, even @ 10 t ha^{-1}. Tiwari et al. (2001) reported that the concentration of N,P and K in grain and straw increased significantly with the application of FYM@ 5 t ha^{-1}.

Application of 10 t of FYM ha^{-1} to component *Rabi* crops (potato, mustard and wheat) in rice based cropping systems could supplement 25 percent NPK requirement of all component crops and increased the uptake of N, P and K by the crops (Khanda et al., 2005). Khan et al. (2006) observed that the application of FYM increased the total nitrogen uptake and attributed it to the favourable effects of organic manures on the physico-chemical properties of the soil

2.3 EFFECT OF ORGANIC MANURES ON THE AVAILABLE NUTRIENT STATUS OF THE SOIL

Muthuvel et al. (1990) reported higher available N contents of soils under FYM application. More (1994) noted that the application of organic wastes and manures enhanced the soil organic carbon and available P and K.

Waghmer (1998) reported higher available NPK content in soil and with the application of FYM @ 10 t ha^{-1}. Considerable improvement in available N status of soil due to the application of FYM has been reported by Gupta et al. (1998). Chellamuthu et al. (1998) found that K availability in soils was increased significantly by FYM application.

Application of organic wastes, irrespective of the sources recorded higher available K status of soil over no organics (Chithra and Janaki, 1999). Dubey and

Verma (1999) could observe the highest available N, P and K with poultry manure application. 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. Further, organic manure applied plots maintained a higher level of K in the soil after the experiment.

Charjan and Gaikwad (2005) stated that application of nutrients through organic manures reduced the losses of nutrients and ultimately increased the NPK balance of the soil. Application of FYM significantly increased the ammoniacal nitrogen content of soil and the increase reported was from 30.1 to 110.1 mg kg^{-1} soil (Duha et al., 2005). Another report by Singh et al. (2005) suggested that lowest amount of K was leached from FYM treatment (1.8 %) as compared to poultry manure (17.3 %), fertilizer K (15.8 %) and rice straw (14.4 %), thus conserving its availability in soil.

Roul and Mahapatra (2006) reported a continuous supply of nitrogen by organic manures and tying up of inorganic soil nitrogen, preventing its loss through denitrification, volatilization or leaching. Further, nitrogen enriched manures maintained a higher level of available N and P in soil for a longer period than fertilizer alone. They also found that cattle manure improved the organic carbon, P and K contents of soil. Khan et al. (2006) also reported an enhanced soil nitrogen supply due to FYM application.

2.4 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON THE GROWTH, YIELD AND QUALITY OF RICE

Nutrient supply is the key factor in crop production. But imbalanced fertilization is a matter of concern for sustained production. In spite of heavy inputs the crop yields are declining because of limitation of one or more micro nutrients (Swarup et al., 1998). Use of organic manures has been prescribed as the remedy to this declining trend in yield. However, organic sources alone cannot meet the total nutrient requirement of modern agriculture and hence integrated use of nutrients is regarded as appropriate (Gawai and Pawar, 2006). Application of organic materials along with inorganic fertilizers led to increased productivity of the system and also sustained the soil health for longer period (Hegde and Dwivedi, 1992). Integrated nutrient management involves the judicious use of organic, chemical and / or microbial sources so as to sustain optimum yields and to improve or sustain the soil health to provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe (Ahlawat, 1997).

2.4.1 Effect on growth attributes

In an experiment conducted on INM at Regional Agricultural Research Station, Pattambi, Mathew et al. (1994) observed higher plant height and tiller count in rice with the combined use of FYM @ 10 t ha^{-1} along with chemical fertilizers. Peeran and Sreeramulu (1995) found that application of FYM along with urea gave significantly taller plants than urea alone. Babu (1996) observed that integration of FYM @ 10 t ha^{-1}along with chemical fertilizers could increase the plant height, tiller count, LAI and DMP of rice.

Jadhav et al. (1997), in a pot culture experiment conducted on rice with INM, observed that the DMP was highest with 25 percent substitution of urea with organic manure.

Integrated application of organic manure, inorganic fertilizers and biofertlizers significantly increased the growth and yield attributes of rice (Jeyabal, 1997).

Singh et al. (2000) opined that the combined application of FYM @ 6.5 t ha^{-1} and RD of NPK (120:60:40 kg N, P_2O_5, K_2O) produced almost double the root mass than NPK alone. The growth parameters *viz.*, plant height, number of tillers and dry matter content were significantly improved by the application of 100 percent RDN through urea + 25 percent RDN through FYM. This was attributed to the adequate quantity of nitrogen made available to the crop, which in turn favoured vigourous and luxuriant growth.

Application of organic manure promoted growth of rice by increasing plant height (Bayan, 2000). Jha et al. (2004) reported that the application of inorganic fertilizers at 30:20:15 kg NPK ha^{-1} in combination with cow dung urine mix at 3 t ha^{-1} significantly increased the plant height.

Integrated use of organic and inorganic manures accelerated the growth components compared to inorganic fertilizer application. The growth was more with NPK + FYM as compared to 100 percent NPK. Organic manures in combination with inorganic fertilizers were superior to application of inorganic fertilizers alone, in promoting growth of rice (Ganapathy et al., 2006).

2.4.2 Effect on yield attributes

Mathew et al. (1994) and Mondal 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. Singh et al. (1998) noted an increase in the grain number panicle^{-1} and thousand grain weight of rice with high NPK rates along with 7.5 t ha^{-1} FYM. Panicle length, number of filled grains panicle^{-1} and 1000 grain weight increased significantly due to combined application of 100 percent RDN through urea + 25 percent RDN through FYM (Dwivedi and Thakur, 2000). Bastia (2002) reported that the number of panicles m^{-2}, weight panicle^{-1}, total grain panicle^{-1}, filled grains panicle^{-1}, test weight and grain yield were maximum for the treatment, FYM (5 t ha^{-1}) + half the RD of fertilizers (30:15:15 kg NPK ha^{-1}). Incorporation of composted coir pith @12.5 t ha^{-1} along with inorganic fertilizers increased the productive tillers hill^{-1}, grains panicle^{-1}and test weight of rice (Parasuraman et al., 2003).

2.4.3 Effect on yield

Higher yield with integrated use of organic and inorganic fertilizers has been reported by many workers (Kundu and Pillai, 1992; Pandey et al., 1995; Chettri et al., 1998; Baggie and Bah, 2001; Pandey et al., 2001).

2.4.3.1 Grain yield

Saxena et al. (1983) observed that plots treated with neem cake-urea mixture (2:10) resulted in significantly higher grain yield than control. Combined use of organic and inorganic sources of N yielded better than inorganic sources alone. Budhar and Palaniappan (1997) reported that partial substitution of chemical fertilizers with green manure recorded yields, which were similar, or comparable with those obtained by the application of the entire RDF through 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. Dhillon (1998) obtained the highest production under 100 kg N ha^{-1} as urea combined with 5 t of FYM.

Dubey and Verma (1999) revealed that the grain and straw yields of first and second season rice, obtained from the combined application of 50 percent NPK + 50 percent poultry manure or FYM were statistically comparable with NPK alone. Lakpale et al. (1999) noticed that pre-conditioning of urea with FYM and soil (1:3:1) gave significantly higher number of effective tillers, thousand grain weight and grain yield, than prilled urea. 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 and Verma (1999) also reported that FYM+50 percent recommended NPK application gave the highest rice yields.

The increased tiller number, panicle m^{-2}, panicle length and grains per panicle observed under integrated nutrition leads to increased grain and straw yields. (Dixit and Gupta, 2000; Pandey et al., 2001). The results of long term trial in a rice-rice cropping system in Kerala, Orissa and Andhra Pradesh revealed that the application of 25-50 percent fertilizers in organic form gave the best yield stability (Katyal et al., 2000). Raju and Reddy (2000) found that application of 50:50 and 75:25 (compost N: inorganic N) produced 8.5 percent and 5.7 percent more rice grain yield than 100 percent inorganic N.

Singh et al. (2000) observed that FYM with recommended dose of NPK (120:60:40 kg ha^{-1}) gave the highest grain yield. Combined application of FYM contributed to yield increase of up to 50 percent than recommended NPK.

Neem cake blended urea + P and K resulted in significantly higher grain yield of rice, because of slow releasing and nitrification – inhibition action of neem cake which maintained a synchronized supply of nitrogen, in pace with the crop demand (Singh and Singh, 1994; Singh et al., 2001b). Fifty percent and 75 percent substitution of RDF with organic sources did not result in significant yield reduction (Sujathamma et al., 2001).

Sindhu (2002) observed that a fertilizer dose of 90:45:67.5 kg NPK ha^{-1} with 50 percent N applied as FYM and 50 percent as chemical fertilizer could be recommended for maximizing yield in basmati rice. Prakash et al. (2003) in their study on INM in basmati rice, var. Pusa Basmati-1, observed that application of organic manure including oil cakes, on balancing with chemical fertilizers to supply recommended dose of NPK favoured high dry matter production and grain yield as compared to application of chemical fertilizers alone.

Chettri and Mondal (2005), in a field experiment conducted at Kalyani, observed that the maximum grain yields of both rainy season (4.66 t ha^{-1}) and winter (5.47 t ha^{-1}) rice were observed with 75 percent of RD of nitrogen, phosphorus and potassium through fertilizers along with FYM @ 10 t ha^{-1}.

Higher yield and N uptake in rice crop could be achieved by the combined application of 100 percent RDN through urea + 25 percent RDN through FYM (Mrudhula et al., 2005). The conjunctive use of 75 percent N through fertilizer and 25 percent N through bulky organic manures like FYM or vermicompost, significantly increased the mean rice yield as compared to the application of recommended nitrogen as fertilizer (Aruna and Mohammad, 2005).

Barik et al. (2006) observed that the highest grain and straw yields were obtained in crops under 50 percent recommended fertilizer dose along with 10 tonnes of vermicompost per ha, which was significantly higher than 100 percent recommended NPK fertilizers. Application of organic manures was reported to maintain soil fertility and to sustain higher crop yield levels in rice-rice crop sequence. (Reddy et al., 2006). Integrated use of organic and inorganic fertilizers was found to be effective in enhancing the productivity of the cropping systems (Roul and Mahapatra, 2006).

Substituting 50 percent of the inorganic nitrogen with neem cake was found to increase the grain yield in rice (Singh et al., 2006a). Panda et al. (2007) reported that higher yield was obtained in the NPK + FYM treatment and also concluded that balanced use of N, P and K fertilizers in conjunction with FYM was the best nutrient management option for obtaining higher and sustainable rice yield and for promoting soil health.

2.4.3.2 Straw yield

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} FYM along with chemical fertilizers in comparison to chemical fertilizers alone.

Babu (1996) observed significant increase in the straw yield of medium duration rice variety Pavizham up to 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 percent recommended N through FYM and the rest through NPK fertilizers (Deepa, 1998; Pandey et al., 2001). Sudha (1999) reported that different levels and sources of organic manures could not significantly influence the straw yield. Lower straw yields by FYM treatments rather than 50 percent FYM + NP treatment have been reported by Sengar et al. (2000).

2.4.4 Effect on grain quality

Unnever et al. (1992) reported that rice grain quality was a multi dimensional character, composed of many components such as eating quality, cooking quality and nutritional quality. Nitrogen application at higher dosage increased the amylose content in long slender varieties (Rao et al., 1993). Suwanarit et al. (1996) reported that application of nitrogenous fertilizers adversely affected cooking and eating qualities of rice *viz.* aroma, softness, whiteness, stickiness and glossiness.

Singh et al. (1997) concluded that lengthwise expansion of rice on cooking without increase in girth could be considered as highly desirable trait in higher quality rice. Quality was defined as the degree of excellence possessed by the grain (Srivastava, 1997). Hemalatha 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 observed to be influenced by the treatments. Veenapal and Pandey (2000) could not observe any definite trend in the rice quality with the application of different sources of nutrients. According to the farmers' perception, organic manures produce grains of better quality compared to inorganics (Singh and Singh, 2003). Organic farming has been reported to favorably affect the rice qualities under long term application (Dhiman et al., 2003). Integrated nitrogen management resulted in higher values of quality parameters as compared to control (Adhikari et al., 2005).

2.4.4.1 Cooking characteristics

Juliano and Sakurai (1985) reported a definite relationship between the physico-chemical characters and cooking quality of rice varieties. Bandhyopadhyay and Roy (1992) defined cooking quality as the time required for proper cooking. Organic manures had no effect on rice cooking qualities (Jeong et al., 1996). Juliano (1998) quoted that gelatinization temperature and amylose content are important starch properties which influence cooking and eating characteristics, the others being kernel elongation and aroma.

2.4.4.1.1 Optimum cooking time, grain elongation and volume expansion ratio

Govindaswamy and Ghosh (1970) observed a positive correlation between the cooking time and protein content of rice. Juliano (1979) observed that volume expansion, water absorption and resistance to disintegration of milled rice during cooking were directly related to amylose – amylopectin ratio of starch. Juliano and Perez (1984) defined grain elongation ratio as the ratio of the length of cooked grain to that of raw grain. A study conducted by Gupta (1990) in West Bengal, revealed that the grain elongation and volume expansion ratios ranged between 1.22 to 1.74 and 3.81 to 5.45 respectively. Vardharaju et al. (2001) found that cooking time of raw rice samples ranged between 22 and 25 minutes. Lengthwise expansion without an increase in girth has been reported to be a highly desirable trait in high quality rice like basmati (Graham, 2002). Sindhu (2002) reported that the different sources on nitrogen, like FYM and vermicompost, had no significant effect on the optimum cooking time, grain elongation and volume expansion ratios of basmati rice. Reddy and Reddy (2003) could not notice any statistically significant variation in the elongation ratio of rice due to different nitrogen management practices. Organic nutrient sources *viz.* FYM and compost performed comparatively well as inorganic fertilizers, in improving the cooking quality and grain elongation ratio of aromatic rice (Saha et al., 2007).

2.4.4.2 Nutritional composition

Chatterjee and Maiti (1985) reported that there is an ever growing need for grain to meet the energy and protein requirements. Rice provides up to 75 percent of dietary energy and protein for 2.5 billon people and specifically meets 68 percent of the total energy and 69 percent of the total dietary protein requirements in South Asia (Juliano, 1990).

2.4.4.2.1 Crude protein, total starch, amylose and amylopectin content of rice

Kumari and Padmavathi (1991) found that volume expansion during cooking is directly affected by amylose content. Sikka et al. (1993) found that with increasing doses of nitrogen fertilizer, there was an increase in protein content. Singh (1993) stated that starch is a mixture of amylose and amylopectin. Aberg (1994) found that starch is the nutritional reservoir in plants. Degree of flakiness and volume expansion were observed to be determined by amylose content (Chikkalingaiah et al., 1997). Devi et al. (1997) stated that proteins present in food were a mixture of several fractions and each fraction varied in its solubility. Juliano (1998) reported starch as the major constituent of rice and as such, starch and protein accounted for 98.5 percent of the constituents of milled rice. Amylose content ranged from 9-37 percent in the starch, corresponding to 63-91 percent amyopectin. Amylose content was therefore regarded as an index of amylose/ amylopectin ratio (Dela and Khush, 2000).

Pillai (1998) observed higher crude protein in rice, with 75 percent of the RD of nitrogen as inorganics and 25 percent as FYM. Sources of nitrogen did not produce any significant difference in the protein content of rice (Sindhu, 2002). The protein and amylose content varied significantly with the application of FYM in conjunction with chemical fertilizers (Reddy and Reddy, 2003).

2.4.4.3 Organoleptic qualities

The ratio of amylose to amylopectin in starch, as influenced by amylose content is the chief influence on eating quality (Araullo et al., 1976). It correlates negatively with taste panel scores for cohesiveness, tenderness and gloss of the boiled rice (Chatterjee and Maiti, 1985). According to Fumio (2000), the main ingredients that affect the taste of rice are protein, starch, water and fat content. The author found that lower the protein content, better the taste. Lower amylose content meant more viscosity and vice versa. Yifang and Corke (2002) stated that amylose content influenced the texture of cooked rice.

2.4.5 Seed quality

Naidu (1987) concluded that, in cowpea, the application of FYM + NPK recorded the highest germination percentage and seedling vigour. Girija et al. (1993) observed that seed quality, though a genotypic character, was greatly influenced by manuring practices. Integrated application of organics along with inorganics increased the seed viability. Isaac (1995) reported significant influence of organic manures on the vigour of okra seeds. Seed quality attributes like germination and vigour index remained unaffected with application of FYM, in groundnut (Hunje et al.,2006). Paramasivam and Balamurugan (2006) observed that the paddy seeds from the organic manure applied plots did not vary significantly in their germination percentage. Yadav and Srivastava (2006) found that germination and vigour index of organic wheat seed was more than seeds obtained from standard cultural and nutritional management.

2.5 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON NITROGEN USE EFFICIENCY AND NUTRIENT UPTAKE

2.5.1 Nitrogen use efficiency

The ARE of flooded rice grown in Asia has been reported as ranging from 22 - 40 percent of applied nitrogen (De Datta et al., 1988; Schnier et al., 1990). In some of these studies the values ranged from 34-64 percent. Prasad et al. (1992) reported that integrated N management was desirable for achieving higher NUE. Apparent recovery of nitrogen was highest with INM, indicating the benefits of integration of organic and chemical supplements.

Hussain et al. (2000) reported that while the ARE in low land rice grown in Philppines was 36 percent, the AE was 18 kg grain per kg of nitrogen applied. Green manure in combination with fertilizers increased the production capacity per kg of N applied (Chakraborty et al., 2001).

Bandhyopadhyay and Sarkar (2003) revealed that 50 percent of urea-N could be supplemented through FYM for higher NUE. The variety Pusa Basmati-1 responded to application of N, half as urea and half as FYM and resulted in the highest fertilizer N recovery by the crop (30.6 %) and the highest retention of fertilizer N in soil (39.1 %). While substituting the RD of nitrogen with FYM and vermicompost did not result in significant difference in the AE of applied nitrogen, the ARE was higher with vermicompost (Sindhu, 2002). Khan et al. (2006) reported that integrated use of urea with organic sources increased NUE in rice.

2.5.2 Nutrient uptake

Babu (1996) observed higher N and P uptake by medium duration rice with the integration of higher fertilizer dose along with 10 t ha $^{-1}$ FYM. Deepa (1998) reported the highest N and K uptake, when 50 percent N was supplied through

FYM + 50 percent N through inorganic fertilizers and the highest P uptake, when 25 percent of N was supplied through inorganic fertilizers, in the *Kharif* season.

Prilled urea with FYM + soil (1:3:1) built up higher N status in soil than prilled urea alone (Lakpale et al., 1999). FYM proved superior to biofertilizer with respect to nutrient uptake (Kumari et al., 2000). Combined use of organic manures and inorganic fertilizers was found to be significantly better than inorganic fertilizers alone for N uptake (Pandey et al., 2001).

Singh et al. (2001a) reported that the available soil N in case of 100 percent N treated plots was higher than urea + FYM plots after rice harvest. But the organic carbon trend was reverse. The authors also found that substituting 50 percent of the recommended N through various sources like FYM and green manure did not show any significant variation in the total uptake of N, P and K by rice.

Sujathamma et al. (2001) recorded the highest P uptake with 25 percent substitution with organic source. Ranjini (2002) reported that the highest uptake of nitrogen and potassium registered when 90 kg N ha^{-1} was applied with 25 percent substitution through vermicompost whereas maximum phosphorus uptake was obtained upon the application of 90 kg ha^{-1} with 50 percent substitution through vermicompost. Sindhu (2002) could not observe significant difference in the NPK uptake with different sources and levels of nitrogen.

Chettri and Mondal (2005) reported that N, P and K uptake was highest when the rice crop was fertilized with 75 percent of the recommended dose of N, P and K through chemical fertilizers along with 10 t ha^{-1} FYM applied at both *Kharif* and *Boro* seasons.

2.6 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON AVAILABLE NUTRIENT STATUS OF THE SOIL

Sharma and Mittra (1991) and Padmaja et al. (1993) reported that the application of FYM in combination with chemical fertilizers, improved the soil fertility appreciably over the initial content. It improved the organic carbon and available NPK status of the soil. Varghese (1993) observed that the organic carbon content of the soil remained unaltered with organic farming. Bellaki et al. (1998) concluded that 75 percent RDF + 25 percent through organic sources had better influence on P and K status of the soil. Dubey and Verma (1999) reported that available N increased to 276 kg ha^{-1} under 50 percent NPK + 50 percent poultry manure over the initial value of 220 kg ha^{-1}. FYM used alone or in combination with chemical fertilizers improved the available N and P status of soil than the initial status (Bellaki et al., 1998; Chettri and Mondal, 1998; Sengar et al., 2000).

Singh et al.(2001b) 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 applied solely through prilled urea.

Katyal et al. (2001) showed that application of FYM at 5 t ha^{-1} in addition to RD of nitrogen @ 120 kg ha^{-1} tended to increase the available soil P and K. While Sindhu (2002), in her study with different sources and levels of nitrogen in basmati rice, observed significant variation in the available K status of the soil, whereas, the available N and P remained unaffected.

Selvi et al. (2003) reported that the total nitrogen content, exchangeable Ca and Mg, available P and available K increased in plots receiving combined application of 100 percent NPK (90:45:17.5 kg ha^{-1}) + FYM (10 t ha^{-1}).

Jha et al. (2004) observed the highest potassium solubilisation in the treatments where inorganic fertilizers (60: 40:30 NPK kg ha^{-1}) were applied in conjunction with FYM @ 5t ha^{-1}. Increase in organic carbon and available phosphorus was pronounced in the treatments receiving organic manures in combination with chemical fertilizers (Reddy et al., 2006).

2.7 DISEASE INCIDENCE

Ito and Sakamoto (1942) opined that the vulnerability of plants to disease with heavy N application is due to the accumulation of soluble N in plants, for unfavourable N and carbohydrate balance in plants.

Parcer and Chahal (1963) reported that heavy application of nitrogenous fertilizers increased the incidence of fungal diseases of rice. Phenolic and other compounds produced during decomposition of organic matter absorbed by the plants, conferred protection against pathogenic organisms (Flaig, 1984). Reddy et al. (1989) observed that the aromatic rice variety, Pusa Basmati-1 is highly susceptible to BLB. Bacterial leaf blight disease was found to be more serious under irrigated conditions and was a widely distributed and devastating disease of aromatic rice (Devadath, 1992).

Bhadoria et al. (2003) reported that the tolerance of rice plants to pathogens, measured in terms of grain yield was highest in the treatments with FYM. Integrated use of organics and inorganics, in general, reduced the incidence of most of the diseases in rice (Khan et al., 2004).

2.8 ECONOMICS OF CULTIVATION

Hussain et al. (1991) reported the highest input cost for the application of 10 t $ha^{-1}$of FYM alone than integrated approach in rice cultivation. Mathew et al. (1994) noted the highest gross income, net income and BCR with the use of 66 percent of recommended N, K_2O and 33 percent P_2O_5 + 5 t FYM ha^{-1} as compared to 100 percent recommended N, P_2O_5 and K_2O and all the other inorganic - organic combinations. Tripathi and Chaubey (1996) opined that incorporation of FYM in combination with inorganic fertilizers economized the fertilizer need.

Sudha (1999) reported that different levels and sources of organic manures had no significant influence on the benefit cost ratio and the highest BCR of 1.59 was recorded with the application of FYM @ 5t ha^{-1}. Sindhu (2002) observed the highest BCR when 50 percent of the RD of nitrogen was applied as FYM. Balasubramaniyan (2004) stated that INM resulted in highest net returns and BCR. Higher gross and net returns and net return per rupee invested were observed under 50:50 ratio of poultry manure or FYM combined with chemical N in comparison to N applied as urea alone (Roul and Mahapatra, 2006). Singh et al. (2006b) observed that even though the cost of cultivation was marginally higher, integrated use of organic and inorganic fertilizers resulted in higher net income and BCR due to higher grain and straw yields.

In general, the perusal of the research done on integrated nutrient management showed that the integrated use of organics and inorganics helped in improving the productivity of rice and increased the returns realized by the farmers, without impairing, but maintaining or improving the soil fertility status.

Materials and Methods

3. MATERIALS AND METHODS

The investigation entitled "Integrated nutrient management for Basmati rice (*Oryza sativa* L.) production" was taken up at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala, during September 2006 to January 2007. The main objective of the study was to assess the impact of integrated nutrient management on basmati rice in terms of productivity, quality, nutrient utilization efficiency and economics. The details regarding the materials used and the methods adopted for the study are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted in the wetlands of the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, a sub-station under the NARP (Southern Region), Kerala Agricultural University. The research station is located at 8° 29'N latitude and 76° 58' E longitude, at an altitude of 33 m above mean sea level.

3.1.1 Soil

Prior to the experiment, composite soil samples were drawn from 0 - 15 cm layer of the soil and analyzed for its mechanical composition and chemical properties. The data on the mechanical composition and chemical nature of the soil of the experimental site are presented in Tables 1a and 1b respectively.

The soil of the experimental site was sandy clay loam, belonging to the taxonomical order Oxisol. It was acidic in reaction, high in organic carbon content, medium in available nitrogen, high in available phosphorus and low in available potassium status.

Table 1a. Mechanical composition of the soil of the experimental site

Sl.No.	Fractions	Content in soil (%)	Method used
1	Coarse sand	72.0	Bouyoucos hydrometer method (Bouyoucos ,1962)
2	Silt	7.1	
3	Clay	20.0	

Textural class: Sandy clay loam

Table 1b. Chemical properties of the soil of the experimental site

Sl. No.	Fractions	Content in soil	Method used
1	Available N (kg ha^{-1})	351.60 (Medium)	Alkaline Permanganate Method (Subbiah and Asija, 1956)
2	Available P_2O_5 (kg ha^{-1})	90.21 (High)	Bray Colorimetric Method (Jackson,1973)
3	Available K_2O (kg ha^{-1})	107.52 (Low)	Ammonium Acetate method (Jackson,1973)
4	Organic carbon (%)	1.94 (High)	Walkley and Black Rapid Titration Method (Jackson,1973)
5	Soil reaction (pH)	5.3 (Acidic)	1:2.5 Soil solution ratio using pH meter with glass electrode (Jackson,1973)

3.1.2 Cropping history of the field

The area was under a bulk crop of rice before the experiment.

3.1.3 Season

The experiment was conducted during the second crop season from September 2006 to January 2007.

3.1.4 Weather conditions

A warm humid tropical climate prevailed during the experimental period.

Data on weather parameters like temperature, rainfall, relative humidity and evaporation were obtained from the meteorological observatory at College of Agriculture, Vellayani. The average values of weather parameters recorded during the cropping period are given in Appendix-I and graphically presented in Fig.1. The mean maximum and minimum temperature ranged between 29.4°C and 32.2°C and 19.9°C to 23.4°C respectively. The mean relative humidity ranged from 77.2 to 89.2 percent. A total rainfall of 1094.2 mm was recorded during the cropping period. The mean evaporation during the cropping period was 3.50 mm day^{-1}.

3.2 MATERIALS

3.2.1 Crop variety

The basmati rice variety selected for the experiment was 'Pusa Basmati-1', the first ever non-lodging, semi dwarf, substantially photoperiod insensitive variety reported to have a potential yield of 4.5 t ha^{-1}, released from the Indian Agricultural Research Institute, New Delhi. The variety is a hybrid derivative (F_5 generation) of the cross between Pusa 150 x Taroari Basmati. It has a duration of 130-135 days and is reported to be resistant to brown leaf spot but susceptible to sheath blight and bacterial leaf blight.

3.2.2 Source of seed material

The seeds for the study were obtained from the National Seeds Corporation, Karamana, Thiruvananthapuram, Kerala.

3.2.3 Manures and fertilizers

Farm yard manure (0.50 percent N, 0.31 percent P_2O_5, 0.22 percent K_2O) and neem cake (2.57 percent N, 0.60 percent P_2O_5, 0.90 percent K_2O) were used

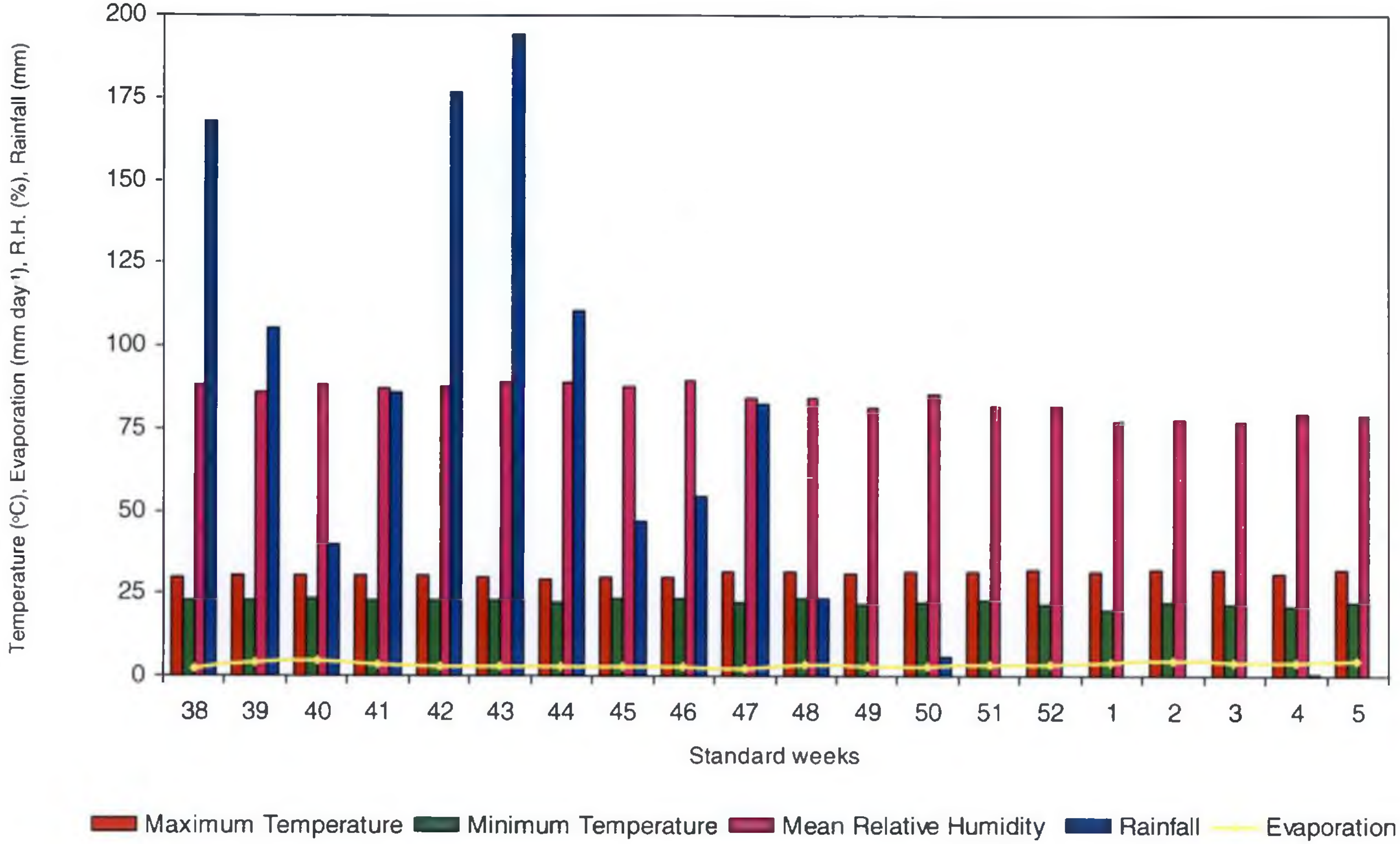


Fig. 1. Mean weather parameters during the cropping period (September 2006 to January 2007)

as the organic sources. Urea (46 percent N), Ultraphos (33 percent P_2O_5) and Muriate of Potash (60 percent K_2O) were used as the inorganic sources for the experiment. The deficiency of phosphorus and potassium computed while substituting the chemical fertilizers on nitrogen equivalent basis was compensated with Ultraphos and ash (4.2 percent K_2O) respectively.

3.3 METHODS

3.3.1 Design and layout

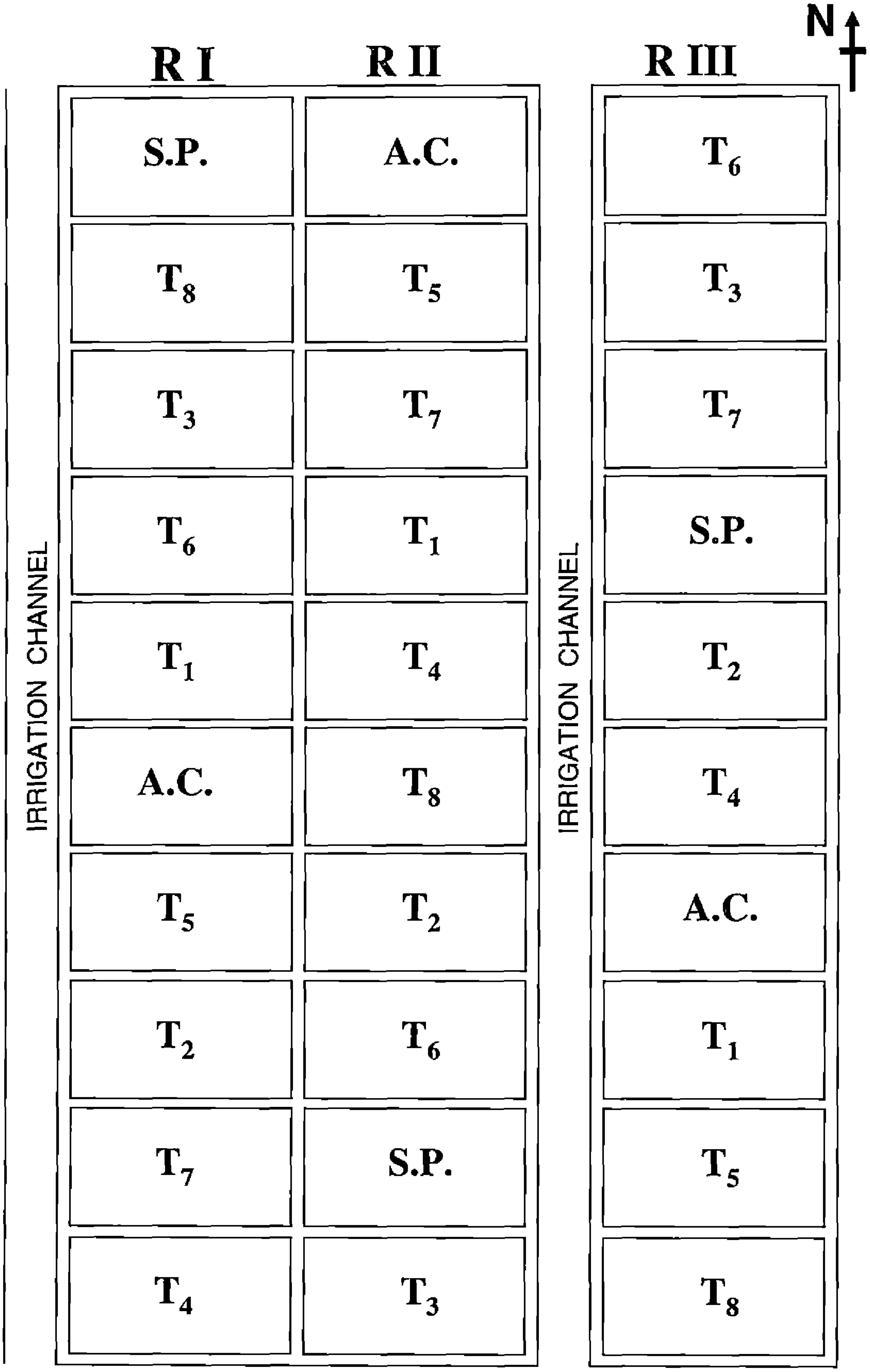
The experiment was laid out in randomised block design with 10 treatment combinations, replicated thrice. The layout plan of the experiment is given in Fig.2.

The details of the layout are given below.

Design : Randomised Block Design (RBD)
Treatments : (4 x 2) +2 = 10
Replications : 3
Gross plot size : 5 x 4m
Net plot size : 4.6 x 3.8m

3.3.2 Treatments

Treatments comprised combinations of two organic sources and four levels of inorganic substitution with organics compared against two controls. The controls were an absolute control (no organic or inorganic source of nutrients) and the standard dose of fertilizers (SDF).



R I	R II	R III
S.P.	A.C.	T_6
T_8	T_5	T_3
T_3	T_7	T_7
T_6	T_1	S.P.
T_1	T_4	T_2
A.C.	T_8	T_4
T_5	T_2	A.C.
T_2	T_6	T_1
T_7	S.P.	T_5
T_4	T_3	T_8

S.P. – Standard practice A.C. – Absolute control

Fig. 2. Layout of field experiment

A. Organic sources

M_1 : Farm yard manure (FYM)
M_2 : Farm yard manure + Neem cake

B. Levels of inorganic substitution with organics

L_1 : 25 percent substitution
L_2 : 50 percent substitution
L_3 : 75 percent substitution
L_4 : 100 percent substitution

C. Controls

C_0 : Absolute control
C_1 : Standard dose of fertilizers (SDF)

The standard dose of fertilizers was fixed based on the standard nutrient dose of 90 : 45 : 67.5 kg N, P_2O_5, K_2O ha^{-1} as reported by Sindhu (2002) , based on the research work conducted at Vellayani.

3.3.3 Treatment combinations

l_1m_1 : 25 percent SDF as FYM + 75 percent as chemical fertilizers (T_1)
l_1m_2 : 25 percent SDF as (FYM + neem cake) + 75 percent as chemical fertilizers (T_2)
l_2m_1 : 50 percent SDF as FYM + 50 percent as chemical fertilizers (T_3)
l_2m_2 : 50 percent SDF as (FYM + neem cake) + 50 percent as chemical fertilizers (T_4)
l_3m_1 : 75 percent SDF as FYM + 25 percent as chemical fertilizers (T_5)
l_3m_2 : 75 percent SDF as (FYM + neem cake) + 25 percent as chemical fertilizers (T_6)
l_4m_1 : 100 percent SDF as FYM (T_7)
l_4m_2 : 100 percent SDF as (FYM + neem cake) (T_8)
C_0 : Absolute control (T_9)
C_1 : Standard dose of fertilizers / Standard practice (T_{10})

3.4 CROP HUSBANDRY

3.4.1 Nursery

3.4.1.1 Land preparation

The nursery area 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 broadcast in the nursery area. during the third week of September, 2006. After 25 days, healthy seedlings were pulled out from the nursery and transplanted in the main field.

3.4.2 Main field

3.4.2.1 Land preparation

The experimental area was ploughed twice, puddled, levelled and weeds and stubbles were removed. The plots were laid out into three blocks with 10 plots each. The plots and blocks were separated with bunds of 30 cm width. Irrigation channels of 30 cm width were provided between the blocks.

3.4.2.2 Manures and fertilizers

FYM @ 5t ha^{-1} was applied basally to all the plots except absolute control. FYM and neem cake (as per the treatments) were also incorporated at the time of first ploughing. Urea, Ultraphos and MOP were applied to each plot as per the treatments after levelling the field. The entire dose of phosphorus and half the dose of nitrogen and potassium were applied basally. The remaining nitrogen and potassic fertilizers were applied in two

Plate 1. Nursery with 15 day old seedlings of Pusa Basmati-1

Plate 2. Main field at 20 days after transplanting

equal splits, at maximum tillering and panicle initiation stage respectively. Ultraphos and ash were used to balance the deficiency of P and K, since the substitution of the SDF was done on nitrogen equivalent basis. Cow's urine, diluted 20 times with water, was sprayed at fortnightly intervals upto the flowering stage, in all the treatments except controls.

3.4.2.3 Transplanting

Twenty five day old seedlings were gently uprooted from the nursery and transplanted in the main field. The seedlings were transplanted at the rate of two seedlings per hill, at a spacing of 20 x 10cm.

3.4.2.4 Weed management

Two hand weedings were done at 20 and 40 days after transplanting.

3.4.2.5 Water management

Standing water was maintained throughout the cropping period, with occasional drainage. The field was drained 15 days before harvest.

3.4.2.6 Plant protection

Incidence of bacterial leaf blight (BLB) at the grain filling stage warranted control measures. One spray of Streptocycline @ 50ppm was given for controlling BLB. Rats were common menace in the area where the experiment was laid out. They were controlled with rat poison baits containing zinc phosphide.

3.4.2.7 Harvest

The crop was harvested when the straw just turned yellow. The net plot area was harvested separately, threshed, winnowed and weight of grain and straw from individual plots recorded.

3.5 OBSERVATIONS

3.5.1 Plant sampling

Six plants were selected randomly from the net plot area of each plot as observation plants. Two rows from all sides were left as border rows.

3.5.2 Crop growth characters

3.5.2.1 Plant height

Plant height was recorded at maximum tillering, panicle initiation, flowering and at harvest stages using the method described by Gomez (1972). The height was measured from the base of the plant to the tip of the longest leaf or tip of the longest ear head, whichever was longer and the average was recorded in centimeters.

3.5.2.2 Tillers per square metre

Tiller count was taken from the tagged observation hills at maximum tillering, panicle initiation, flowering and harvest stages and the means worked out and expressed as number of tillers per square metre.

3.5.2.3 Leaf area index

LAI was computed at maximum tillering, panicle initiation, flowering and harvest stages, using the method described by Gomez (1972). The maximum width 'w' and length 'l' of all the leaves of the middle tillers of six sample hills were recorded and LAI was calculated using the relationship.

Leaf area of a single leaf = $l \times w \times k$

k - Adjustment factor (0.75 at maximum tillering, panicle initiation and flowering and 0.67 at harvest stage).

$$\text{LAI} = \frac{\text{Sum of leaf area of 6 sample hills (cm}^2\text{)}}{\text{Area of land covered by the 6 sample hills (cm}^2\text{)}}$$

3.5.2.4 Biomass partitioning

Biomass partitioning was done at harvest. The sample plants were uprooted, washed, plant parts (root, leaves, culms and panicle) separated, dried under shade and later oven dried to a constant weight. Dry weight of each plant part was recorded separately using an electronic balance, and expressed as the percentage of the total dry weight.

3.5.3 Yield and yield attributes

3.5.3.1 Productive tillers per square metre

The number of productive tillers were counted from observation hills at the flowering and harvest stages and expressed as the number of productive tillers per square metre.

3.5.3.2 Weight of panicle

The panicles were collected randomly from the net plot area, weighed and mean weight per panicle expressed in grams.

3.5.3.3 Spikelets per panicle

Number of spikelets per panicle was found out by counting the grains from the ten randomly selected panicles in each plot. The mean value was expressed as the number of spikelets per panicle.

3.5.3.4 Sterility percentage

Sterility percentage was worked out using the following relation ship.

$$\text{Sterility Percentage} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.5.3.5 Thousand grain weight

One thousand grains were counted from the cleaned and dried produce from each plot and the weight recorded in grams.

3.5.3.6 Grain yield

The net plot area was harvested individually, threshed, winnowed, dried, weighed and expressed in kg ha^{-1}.

3.5.3.7 Straw yield

Straw harvested from each net plot was dried in sun and the weight expressed in kg ha^{-1}.

3.5.3.8 Harvest index (HI)

From grain yield and straw yield values, the harvest index was worked out using the following equation suggested by Donald and Hamblin (1976).

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

3.5.4 Incidence of major pests and diseases

None of the major pests were observed beyond the economic threshold levels. There was severe incidence of bacterial leaf blight disease. The disease affected the entire plant. The percentage of disease incidence was calculated as

$$\text{Disease incidence percentage} = \frac{\text{Infected plants in each plot}}{\text{Total number of plants in each plot}} \times 100$$

3.5.5 Quality attributes

3.5.5.1 Cooking properties

3.5.5.1.1 Optimum cooking time

Grain samples from the harvested lot of each plot were analysed and optimum cooking time determined by the method suggested by Hirrannaiah et al. (2001). For determining the optimum cooking time of grain samples, milled rice was screened visually and whole grains were collected. Samples of 10 g of rice were taken in a 250 ml vessel containing 150 ml slow boiling water over an electric stove (1.5kw). The cooking time was determined using glass plate opaque – core method by drawing few grains periodically and pressing between two glass slides till no opaque portion or white core remained.

3.5.5.1.2 Volume expansion ratio

Volume expansion ratio or kernel expansion ratio was determined from the ratio between the cooked volume of rice to that of uncooked rice as per the method suggested by Pillaiyar and Mohandoss (1981).

3.5.5.1.3 Grain elongation ratio

Grain 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 the length of cooked kernels to that of the 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.

3.5.5.2 Chemical properties

3.5.5.2.1 Crude protein content

Crude protein content was computed by multiplying the nitrogen content of the grains with the factor 6.25. (Simpson et al., 1965).

3.5.5.2.2 Total starch content

Starch was estimated by the Ferric cyanide method suggested by Aminoff et al. (1970).

3.5.5.2.3 Amylose content

Amylose content was estimated by the method of Mc Cready and Hassid (1943).

3.5.5.2.4 Amylopectin content

Amylopectin content of grains was determined as the difference between the total starch content and the amylose content of the grains.

3.5.5.3 Organoleptic qualities

Organoleptic qualities play an important role in evaluating the quality of a food product. The overall acceptability of basmati rice was evaluated by preparing vegetable *pulav* and organoleptic evaluation was done by a selected panel of judges using score cards. The judges were selected by conducting triangle test (Jellink, 1964). The major quality aspects included in the score cards were appearance, colour, flavour, doneness and taste. The test was conducted as per the standard procedure prescribed by Swaminathan (1974).

3.5.6 Seed quality

3.5.6.1 Germination percentage

Pure seed fraction of the different treatments was tested for germination. Fifty seeds per treatment were sown on Whatman paper in Petri dishes of 9 cm size. The paper was kept moist throughout the test period. The germinated seeds were counted starting from the fifth day after sowing upto fourteenth day as suggested by Agrawal (1994) and the germination percentage worked out.

3.5.6.2 Seedling vigour

Seeds selected randomly from each treatment were sown on the Whatman paper in Petri dishes. The seeds were allowed to sprout with daily watering and after fourteen days they were uprooted and length of roots and shoots measured from the collar region to the root tip and from the collar region to the base of the terminal bud respectively. The mean length of the roots and shoots were worked out. The seedling vigour index (VI) was calculated by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed as a number.

$$\text{VI} = \text{Germination percentage} \times (\text{root length} + \text{shoot length})$$

3.5.7 Chemical analysis

3.5.7.1 Plant analysis

The whole plants and grains were analysed separately for their nitrogen, phosphorus and potassium contents. The samples collected from each plot at the time of harvest were dried to constant weight in an electronic hot air oven at 70^0C, ground and passed through a 0.5mm sieve. The required quantity of samples were then weighed out accurately in an electronic balance, subjected to acid digestion and nutrient contents were determined and expressed as percentage on dry weight basis.

3.5.7.1.1 Total nitrogen content

The total nitrogen was estimated by modified Microkjeldahl method (Jackson, 1973).

3. 5.7.1.2 Total phosphorus content

The total phosphorus content was estimated by Vanado molybdo phosphate yellow colour method. The intensity of colour developed was read in a Klett Summerson Photoelectric Colorimeter at 470nm (Jackson, 1973)

3. 5.7.1.3 Total potassium content

The total potassium content was determined using Flame Photometer method (Jackson, 1973).

3. 5.7.2 Uptake of nutrients

The uptake of N, P, and K by crops at harvest was calculated as the product of content of these nutrients and the respective plant dry weight and expressed in kg ha^{-1}.

3.5.7.3 Soil analysis

Composite soil samples were collected before the start of the experiment and analysed to determine the available nitrogen, phosphorus and potassium contents. The mechanical composition and the pH were also determined. After the harvest of the crop, soil samples were taken from each plot separately and analysed for organic carbon, available N, available P_2O_5 and available K_2O.

3.5.7.3.1 Organic carbon

Organic carbon content of soil was estimated by Walkley and Black's rapid titration method (Jackson, 1973) and expressed in percentage.

3.5.7.3.2 Available nitrogen

Available nitrogen content of the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}.

3.5.7.3.3 Available phosphorus

Available phosphorus content of the soil (kg ha^{-1}) was determined by Dickman and Bray's molybdenum blue method using Klett Summerson Photoelectric Colorimeter. The soil was extracted with Bray's reagent No.1 (0.03NH_4F in 0.025 N HCL) (Jackson , 1973).

3.5.7.3.4 Available potassium

Available potassium was determined in neutral normal ammonium acetate extract and estimated using flame photometer (Jackson, 1973) and expressed in kg ha^{-1}.

3.5.8 Nitrogen use efficiency

The nitrogen use efficiency of the treatments tried was computed as per the formulae suggested by Fageria and Baligar (2005).

3.5.8.1 Agronomic efficiency (AE)

$$AE = \frac{G_f - G_u}{N_a}$$

where, G_f is the grain yield of the fertilized plot (kg), G_u is the grain yield in unfertilized plot (kg) and N_a is the quantity of nitrogen applied (kg). The AE was expressed as kg grain kg^{-1} N added.

3.5.8.2 Physiological efficiency (PE)

$$PE = \frac{Y_f - Y_u}{N_f - N_u}$$

where, Y_f is the total biological yield (grain plus straw) of the fertilized plot (kg), Y_u is the total biological yield in the unfertilized plot (kg), N_f is the nitrogen accumulation in the fertilized plot in grain and straw (kg) and N_u is the nitrogen accumulation by straw and grains in the unfertilized plot (kg). The PE was expressed in kg (grain+straw) kg^{-1} N uptake.

3.5.8.3 Agro physiological efficiency (APE)

$$APE = \frac{G_f - G_u}{N_f - N_u}$$

where G_f is the grain yield in the fertilized plot (kg), G_u is the grain yield in the unfertilized plot (kg) N_f is the nitrogen accumulation in the fertilized plot in grain and straw (kg) and N_u is the nitrogen accumulation by straw and grains in the unfertilized plot (kg). The APE was expressed as kg grain kg^{-1} N uptake.

3.5.8.4 Apparent recovery efficiency (ARE)

$$ARE = \frac{N_f - N_u}{N_a} \times 100$$

where N_f is the nutrient accumulation by the total biological yield (straw plus grain) in the fertilized plot (kg), N_u is the nitrogen accumulation by the total biological yield (straw plus grain) in the unfertilized plot (kg) and N_a is the quantity of nitrogen applied (kg). The ARE was expressed in percentage.

3.5.8.5 Utilization efficiency (UE)

The utilization efficiency was worked out as the product of ARE and PE and expressed as kg (grain+straw) kg^{-1} N added.

3.5.9 Economics of cultivation

The economics of cultivation was worked out based on the costs of the various inputs and products at the time of experimentation.

3.5.9.1 Net income

Net income was computed using the formula.

$$\text{Net income (Rs. ha}^{-1}) = \text{Gross income} - \text{Total expenditure}$$

3.5.9.2 Benefit cost ratio

Benefit Cost Ratio was computed using the formula

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

3.5.10 Statistical analysis

The data generated from the field trial were subjected to analysis of variance (ANOVA) as applied to Randomized Block Design (Panse and Sukhatme, 1985). Whenever the results were significant, the critical difference was worked out at five percent probability. The significance of the control treatments with the other treatment combinations was also tested. The scores obtained in the organoleptic test, being non-parametric in nature, were subjected to chi-square test and the mean ranks worked out.

Results

4. RESULTS

The experiment entitled "Integrated Nutrient Management for Basmati Rice (*Oryza sativa* L.) Production" was taken up at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, during September, 2006 to January, 2007. The main objective of the study was to evaluate the relative efficiency of different integrated nutrient management practices on the yield and quality of basmati rice. The results of the experiment are presented in this chapter.

4.1 CROP GROWTH CHARACTERS

4.1.1 Plant height

The results on the plant height at different stages of crop growth *viz.* maximum tillering, panicle initiation, flowering and harvest are presented in Table 2.

The perusal of data showed that the organic sources did not have any significant influence on plant height at all stages of growth. Among the different levels of substitution, L_4 (100 percent substitution with organics) recorded significantly greater plant height (61.42cm) at maximum tillering stage. In contrast, the levels of substitution had no impact on plant height at other stages of crop growth.

The organic sources and its interaction with the different levels of substitution had no significant influence on plant height. Comparing treatments with controls all the treatment combinations were significantly superior to the controls at the panicle initiation stage. Between the controls, in general, the absolute control was inferior to the standard practice. However, significant difference was observed at maximum tillering and flowering stages.

Table 2. Effect of organic sources, levels of substitution and their interaction on plant height (cm)

Treatments	Maximum tillering	Panicle initiation	Flowering	Harvest
Organic sources				
M_1	58.06	77.63	90.89	98.65
M_2	56.59	77.71	89.27	97.39
Levels of substitution				
L_1	56.20	74.70	86.87	95.28
L_2	56.00	79.53	87.82	96.09
L_3	55.68	73.77	91.33	97.81
L_4	61.42	82.68	94.30	102.90
Interaction effects				
l_1m_1	55.67	71.82	91.87	100.91
l_1m_2	57.14	81.67	86.85	94.23
l_2m_1	54.53	71.80	92.87	98.58
l_2m_2	64.90	85.23	91.97	100.90
l_3m_1	56.73	77.59	81.87	89.66
l_3m_2	54.87	77.40	88.78	97.95
l_4m_1	56.83	75.73	89.78	97.04
l_4m_2	57.93	80.12	96.63	104.91
Treatment mean	57.32	77.67	90.07	98.02
Controls				
Absolute control	51.46	67.03	85.29	93.18
Standard practice	58.43	66.43	95.70	102.16
Control mean	54.95	66.73	90.50	97.67
SE : M	1.060	1.989	1.561	1.559
L	1.499	2.813	2.208	2.200
LM	2.121	3.979	3.123	3.111
CD : M	NS	NS	NS	NS
L	4.456	NS	NS	NS
LM	NS	NS	NS	NS
Treatments *Vs* Controls	NS	S	NS	NS
Between controls	S	NS	S	NS
Between treatments (including controls)	6.302	NS	NS	NS

The comparison made between the treatment combinations including controls, revealed significant difference in plant height only at the maximum tillering stage. The plants in the treatment combination l_2m_2 (50 percent substitution with FYM and neem cake) were significantly taller (64.90cm) than the other treatments. The plant height at all other levels of substitution was at par with standard practice.

4.1.2 Number of tillers per square metre

The number of tillers per square metre recorded at maximum tillering, panicle initiation, flowering and harvest stages are presented in Table 3.

The two organic sources, FYM and FYM + neem cake had no significant effect on the tiller number at all growth stages. However, different levels of substitution significantly influenced the tiller count at panicle initiation and flowering. L_4 (100 percent substitution with organics) resulted in significantly higher number of tillers per square meter, both at panicle initiation (637.75) and flowering (720.33). At panicle initiation L_4 was at par with L_2 (50 percent substitution with organics) and at the flowering stage, the treatments L_4, L_2 and L_1 were on a par.

There was no significant interaction between the organic sources and levels of substitution as far as the tiller number was concerned. Considering the effects of treatments against the controls it was observed that the number of tillers per square metre at panicle initiation, flowering and harvest were significantly superior. Between the controls the absolute control was inferior to the standard practice at all the growth stages.

Significant difference was observed in the tiller count when the treatment combinations were compared including the controls, at the panicle initiation, flowering and harvest stages. The treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) recorded the highest number of tillers per square metre at these three crop growth stages.

Table 3. Effect of organic sources, levels of substitution and their interaction on the number of tillers per square metre

Treatments	Maximum tillering	Panicle initiation	Flowering	Harvest
Organic sources				
M_1	436.77	558.16	690.81	678.63
M_2	426.85	559.31	662.50	640.83
Levels of substitution				
L_1	400.05	531.60	666.52	650.72
L_2	435.87	569.65	694.52	666.17
L_3	402.73	495.93	625.32	613.83
L_4	488.58	637.75	720.23	708.22
Interaction effects				
l_1m_1	416.63	516.97	682.27	668.50
l_1m_2	449.93	558.60	681.63	670.07
l_2m_1	408.30	508.17	667.03	655.17
l_2m_2	472.20	648.90	732.30	720.80
l_3m_1	383.47	546.23	650.77	632.93
l_3m_2	421.80	580.70	707.47	662.27
l_4m_1	397.17	483.70	583.60	572.50
l_4m_2	504.97	626.60	708.17	695.63
Treatment mean	431.08	558.73	676.65	659.73
Controls				
Absolute control	250.00	329.66	447.13	430.06
Standard practice	469.36	638.16	717.33	705.20
Control mean	359.68	483.91	582.23	567.63
SE : M	22.089	17.025	14.939	164.62
L	31.239	24.076	21.127	23.280
LM	44.179	34.049	29.878	32.924
CD : M	NS	NS	NS	NS
L	NS	71.538	62.773	NS
LM	NS	NS	NS	NS
Treatments *Vs* Controls	NS	S	S	NS
Between controls	S	S	S	S
Between treatments (including controls)	NS	101.171	88.776	97.827

4.1.3 Leaf Area Index

The perusal of the data on leaf area index presented in Table 4 showed that while the different organic sources did not influence the leaf area index significantly at the different growth stages, the levels of substitution had significant impact on this parameter at the harvest stage. The highest degree of substitution (L_4) recorded the highest leaf area index (5.44) and was on a par with 50 percent substitution (L_2) and 75 percent substitution (L_3).

The L x M interaction was observed to be significant at flowering and harvest. Both at flowering (6.17) and harvest (5.78) the treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) was observed to be record the highest LAI. At flowering, l_2m_2 was at par with all the other treatment combinations except l_1m_1. At harvest, l_2m_2 remained at par with l_3m_1, l_3m_2 and l_4m_1. The treatments were found to be significantly superior to the controls, at flowering and harvest stages. A comparison between the two controls showed that the standard practice was significantly better than the absolute control at all the crop growth stages. Comparison between treatments including controls showed significant difference in the LAI at the panicle initiation, flowering and harvest stages. The treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) was observed to support the highest LAI and was on a par with the standard practice.

4.1.4. Biomass partitioning

The results on biomass partitioning at harvest are presented in Table 5.

The organic sources, levels of substitution and their interaction had no significant influence on the percentage of biomass that accounted for the root weight. The absolute control was observed to be significantly superior in terms of the root weight (48.16 %) when compared to the standard practice (36.54 %). When the treatment combinations were compared after taking in to account the controls also, the absolute control had higher percent root biomass.

Table 4. Effect of organic sources, levels of substitution and their interaction on leaf area index

Treatments	Maximum tillering	Panicle initiation	Flowering	Harvest
Organic sources				
M_1	4.27	5.07	5.64	5.19
M_2	4.11	5.14	5.90	5.33
Levels of substitution				
L_1	4.10	4.87	5.49	4.96
L_2	4.10	4.98	5.85	5.34
L_3	4.05	5.12	5.85	5.32
L_4	4.51	5.44	5.89	5.44
Interaction effects				
l_1m_1	4.10	4.59	4.96	4.49
l_1m_2	4.17	4.90	5.69	5.22
l_2m_1	3.98	5.01	5.74	5.29
l_2m_2	4.83	5.78	6.17	5.78
l_3m_1	4.10	5.15	6.02	5.43
l_3m_2	4.04	5.06	6.01	5.46
l_4m_1	4.11	5.23	5.95	5.35
l_4m_2	4.18	5.12	5.61	5.10
Treatment mean	4.18	5.10	5.76	5.26
Controls				
Absolute control	2.72	3.63	4.15	3.86
Standard practice	4.86	5.78	6.07	5.43
Control mean	3.79	4.70	5.11	4.65
SE : M	0.220	0.143	0.097	0.078
L	0.311	0.203	0.137	0.110
LM	0.411	0.287	0.194	0.156
CD : M	NS	NS	NS	NS
L	NS	NS	NS	0.329
LM	NS	NS	0.576	0.466
Treatments *Vs* Controls	NS	NS	S	S
Between controls	S	NS	S	S
Between treatments (including controls)	NS	0.854	0.582	0.484

Table 5. Effect of organic sources, levels of substitution and their interaction on percentage biomass partitioning

Treatments	Biomass partitioned		
	Root weight (%)	Shoot weight (%)	Panicle weight (%)
Organic sources			
M_1	33.42	43.65	23.45
M_2	35.17	38.87	25.94
Levels of substitution			
L_1	33.60	43.28	22.96
L_2	32.92	40.00	25.76
L_3	33.70	41.29	25.28
L_4	34.97	41.97	24.77
Interaction effects			
l_1m_1	32.44	45.46	21.77
l_1m_2	34.76	41.11	24.14
l_2m_1	33.52	43.39	23.09
l_2m_2	36.32	35.25	28.43
l_3m_1	33.15	42.03	24.94
l_3m_2	34.24	40.56	25.61
l_4m_1	34.57	43.73	23.98
l_4m_2	35.37	40.20	25.57
Treatment mean	34.29	41.26	24.69
Controls			
Absolute control	48.16	34.17	16.09
Standard practice	36.54	35.92	28.17
Control mean	42.35	35.04	22.12
SE : M	0.605	0.780	0.486
L	0.855	1.104	0.688
LM	1.210	1.561	0.973
CD : M	NS	2.318	1.445
L	NS	3.279	2.043
LM	NS	NS	NS
Treatments *Vs* controls	S	S	S
Between controls	S	NS	S
Between treatments (including controls)	3.595	4.637	2.889

The organic sources and the levels of substitution significantly influenced the percentage of biomass partitioned towards the shoot portion. Between the organic sources FYM (M_1) and among the levels of substitution, L_1 (25 percent substitution with FYM) were observed to record higher percentage shoot biomass. The LxM interaction was not significant. The treatment combinations were significantly superior to the controls. But between the two controls there was no significant difference. The comparison made between the treatment combinations including controls, revealed that the percent shoot weight was highest (45.46 %) with the treatment combination, l_1m_1.

The effect of the treatments on the fraction of biomass that contributed towards the panicle weight was significant. The combined application of FYM + neem cake (M_2) and 50 percent substitution with organics (L_2) were found to be superior. The L x M interaction was not significant. The treatment combinations when compared against controls, proved to be better. The standard practice with 28.17 percent of the total biomass in the panicle was much superior to the absolute control (16.09 %). In the comparison between the treatment combinations including the controls, the treatment combinations l_2m_2, l_3m_2, l_4m_2 and the standard practice were at par.

4.2 YIELD AND YIELD ATTRIBUTES

4.2.1 Productive tillers per square metre

The data on the effect of organic sources, levels of substitution and their interaction on the number of productive tillers per square metre at flowering and harvest stages of the crop are presented in Table 6.

The results revealed that 100 percent substitution of SDF with FYM + neem cake recorded more number of productive tillers per square metre at flowering (442.38) and at harvest (404.70). At harvest, the treatment L_4 was observed to be at par with L_2 (50 percent substitution with FYM + neem cake).

Table 6. Effect of organic sources, levels of substitution and their interaction on productive tillers per square meter

Treatments	Flowering	Harvest
Organic sources		
M_1	403.87	376.24
M_2	377.89	353.03
Levels of substitution		
L_1	365.95	339.22
L_2	392.92	365.37
L_3	362.27	349.25
L_4	442.38	404.70
Interaction effects		
l_1m_1	375.57	350.53
l_1m_2	377.17	352.83
l_2m_1	380.57	347.43
l_2m_2	482.17	454.17
l_3m_1	356.33	327.90
l_3m_2	408.67	377.90
l_4m_1	343.97	351.07
l_4m_2	402.60	355.23
Treatment mean	390.87	364.64
Controls		
Absolute control	279.36	244.63
Standard practice	415.36	384.86
Control mean	347.36	314.75
SE : M	11.369	9.932
L	16.079	14.046
LM	22.739	19.864
CD : M	NS	NS
L	47.775	41.735
LM	NS	59.023
Treatments *Vs* Controls	S	S
Between controls	S	S
Between treatments (including controls)	67.564	59.023

The interactive effect of organic sources in combination with different levels of substitution was observed to be significant at harvest. The treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) recorded significantly higher number of productive tillers (454.17). The comparison of the treatments against the controls revealed that the treatments were significantly superior at flowering and harvest. The standard practice was significantly superior to the absolute control at both these stages.

In the comparison made between the treatment combinations including controls, l_2m_2 (50 percent substitution with FYM + neem cake) produced the maximum number of productive tillers both at flowering and harvest stages. At flowering the treatment combination, l_2m_2 was observed to be on a par with the standard practice.

4.2.2 Panicle weight

The perusal of the data presented in Table 7, revealed that organic sources, levels of substitution and their interaction failed to have a significant impact on panicle weight. The effect of treatments against the controls and the effect between the controls were also not significant. However the treatments were observed to be better than the controls with regard to panicle weight.

4.2.3 Spikelets per panicle

The results pertaining to the number of spikelets per panicle are presented in Table 7. The effect of the organic sources on the number of spikelets was not significant. On the other hand, significant effect was observed for the different levels of substitution, with L_4 (100 percent substitution with organics) recording the highest number of spikelets (117.63) per panicle. Further L_4 was on par with L_2 (50 percent substitution with FYM and neem cake), which recorded 112.36 spikelets per panicle.

Table 7. Effect of organic sources, levels of substitution and their interaction on panicle weight, spikelets per panicle, sterility percentage and thousand grain weight

Treatments	Panicle weight (g)	Spikelets per panicle	Sterility percentage	Thousand grain weight (g)
Organic sources				
M_1	2.16	110.47	11.79	21.56
M_2	2.35	113.30	10.69	21.68
Levels of substitution				
L_1	2.28	108.27	11.45	21.62
L_2	2.39	112.63	11.67	21.78
L_3	2.31	109.00	11.41	21.48
L_4	2.48	117.63	10.43	21.60
Interaction effects				
l_1m_1	2.10	100.00	12.64	21.47
l_1m_2	2.42	114.27	12.17	21.83
l_2m_1	2.20	105.53	12.23	21.33
l_2m_2	2.52	122.07	10.13	21.60
l_3m_1	2.48	116.53	10.26	21.77
l_3m_2	2.39	111.00	11.16	21.73
l_4m_1	2.35	112.47	10.59	21.63
l_4m_2	2.30	113.20	10.73	21.60
Treatment mean	2.40	111.88	11.23	21.62
Controls				
Absolute control	2.27	112.83	17.09	20.60
Standard practice	2.47	117.80	11.45	21.60
Control mean	2.02	115.30	14.27	21.33
SE : M	0.346	1.695	0.282	0.076
L	0.389	2.398	0.399	0.108
LM	0.478	3.391	0.564	0.153
CD : M	NS	NS	0.839	NS
L	NS	7.125	NS	NS
LM	NS	10.077	NS	NS
Treatments *Vs* Controls	NS	NS	S	S
Between controls	NS	NS	S	S
Between treatments (including controls)	NS	NS	1.678	0.455

The L x M interaction was significant. The treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) was significantly superior (122.07) and was at par with l_1m_2, l_3m_1, l_4m_1 and l_4m_2. The comparison made between treatments and controls and between the controls themselves proved to be non-significant.

4.2.4 Sterility percentage

The results on the sterility percentage as influenced by organic sources, levels of substitution and their interaction are presented in Table 7. The organic sources were found to exert significant influence on the sterility percentage. The combined application of FYM and neem cake (M_2) was observed to result in a significantly lower percentage (10.69 percent) of sterility compare to FYM (M_1) alone (11.79 percent).

The different levels of substitution as well as the L x M interaction failed to exhibit any significant influence on this parameter. The treatments when compared against controls showed significant difference. The absolute control resulted in a higher sterility percentage (17.09) as against 11.45 percent sterility in the standard practice. The analysis done on sterility percentage between the treatment combinations including controls showed significance. The percentage of sterile grains was highest in the absolute control (17.09 percent) and least (10.13 percent) in the treatment combination, l_2m_2 (50 percent substitution with FYM + neem cake).

4.2.5 Thousand grain weight

The perusal of the data presented in Table 7, revealed that the effect of organic sources, levels of substitution and their interaction were non-significant with respect to the thousand grain weight. The standard practice (21.6 g) was significantly superior to the absolute control (20.6 g).

Though significance was observed, when the treatment combinations were compared by including the controls also, all the treatment combinations were observed to be at par with the standard practice. The absolute control was significantly inferior.

4.2.6 Grain yield

The perusal of the results on grain yield presented in Table 8, showed that organic sources did not have significant impact on grain yield. Grain yield at different levels of substitution showed significant difference.

The treatment L_4 (100 percent substitution with organics) resulted in the highest grain yield (2.21 t ha^{-1}) and was on a par with L_2 (50 percent substitution with organics) with a grain yield of 2.05 t ha^{-1}. The interactive effect between the organic sources and levels of substitution was not significant.

The different treatment combinations when compared against the control showed significant variation. The absolute control was significantly inferior to the standard practice. The comparison made between the treatment combinations including controls, showed significance. The treatment combinations l_2m_2 (50 percent substitution with FYM + neem cake) resulted in the highest grain yield (2.39 t ha^{-1}) and was found to be at par with the standard practice (2.19 t ha^{-1}).

4.2.7 Straw yield

The results presented in Table 8 indicated that organic sources, levels of substitution and their interaction had no significant influence on straw yield. No significant variation was observed between treatments and controls. Between the controls there was significant variation in straw yield.

Table 8. Effect of organic sources, levels of substitution and their interaction on grain yield, straw yield and harvest index

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
Organic sources			
M_1	2.08	3.01	0.41
M_2	1.97	2.80	0.42
Levels of substitution			
L_1	1.91	2.81	0.41
L_2	2.05	2.89	0.42
L_3	1.92	2.86	0.42
L_4	2.21	3.07	0.42
Interaction effects			
l_1m_1	1.98	3.08	0.39
l_1m_2	1.99	2.80	0.42
l_2m_1	1.94	3.13	0.40
l_2m_2	2.39	3.05	0.44
l_3m_1	1.84	2.53	0.42
l_3m_2	2.10	2.98	0.41
l_4m_1	1.90	2.58	0.44
l_4m_2	2.02	3.10	0.40
Treatment mean	2.02	2.90	0.41
Controls			
Absolute control	0.74	2.09	0.27
Standard practice	2.19	3.25	0.40
Control mean	1.47	2.67	0.33
SE : M	0.046	0.149	0.010
L	0.065	0.211	0.014
LM	0.092	0.298	0.020
CD : M	NS	NS	NS
L	0.194	NS	NS
LM	NS	NS	NS
Treatments *Vs* controls	S	NS	S
Between controls	S	S	S
Between treatments (including controls)	0.276	NS	0.060

The standard practice gave higher straw yield (3.25 t ha^{-1}) compared to the absolute control (2.09 t ha^{-1}). The comparison among the treatment combinations including the controls also proved to be not significant. However, it was observed that the standard practice gave the highest straw yield followed by the treatment combinations l_2m_1 (3.13 t ha^{-1}), l_4m_2 (3.10 t ha^{-1}) and l_1m_1 (3.08 t ha^{-1}).

4.2.8 Harvest index

Data summarized in the Table 8 showed that organic sources, levels of substitution and their interaction had no significant influence on harvest index.

The treatments *versus* controls comparison proved significant. Between the two controls, the standard practice with a harvest index of 0.40 was significantly superior to the absolute control (0.27). The comparison made between treatment combinations including controls showed significance. Except l_1m_1 (25 percent substitution with FYM) and absolute control all the other treatment combinations including the standard practice were at par. The treatment combinations l_2m_2 and l_4m_1 resulted in the highest harvest index of 0.44.

4.3 INCIDENCE OF BACTERIAL LEAF BLIGHT DISEASE

The perusal of the data on the effect of organic sources, levels of substitution and their interaction on the percentage of Bacterial Leaf Blight incidence presented in Table 9, showed that none of the treatments or their interactions had any significant influence on the incidence of BLB. A simple comparison made among the means showed that the treatment l_2m_2 (50 percent substitution with FYM + neem cake) and l_4m_2 (100 percent substitution with FYM + neem cake)) had a comparatively lower percentage of disease affected plants.

All the other comparison made, like treatments *versus* controls, between controls and between treatments including controls failed to exhibit significance on the percentage of disease incidence.

Table 9. Effect of organic sources, levels of substitution and their interaction on percentage of disease incidence

Treatments	Disease incidence (%)
Organic sources	
M_1	26.24
M_2	24.24
Levels of substitution	
L_1	26.23
L_2	26.77
L_3	27.30
L_4	20.67
Interaction effects	
l_1m_1	26.60
l_1m_2	23.27
l_2m_1	27.47
l_2m_2	19.63
l_3m_1	30.27
l_3m_2	25.87
l_4m_1	27.13
l_4m_2	21.70
Treatment mean	25.24
Controls	
Absolute control	25.03
Standard practice	21.73
Control mean	23.38
SE : M	1.548
L	2.190
LM	3.097
CD : M	NS
L	NS
LM	NS
Treatments *Vs* controls	NS
Between controls	NS
Between treatments (including controls)	NS

4.4 QUALITY ATTRIBUTES

4.4.1 Cooking properties

Cooking properties of rice were evaluated by determining the optimum cooking time, volume expansion, and elongation ratio.

4.4.1.1 Optimum cooking time

The results on the optimum cooking time as influenced by organic sources, levels of substitution and their interactions are presented in Table10.

The optimum cooking time did not vary significantly between the organic sources, among the levels of substitution and among the different L x M treatment interactions. A simple comparison between the means indicated that L_2 (50 percent substitution with FYM) required a lower cooking time of 23.67 minutes compared to the other levels of substitution. Between the controls the absolute control took longer time (34.33 minutes) to cook properly compared to the standard practice (29 minutes) the market sample took 28 minutes to cook (Table 12).

4.4.1.2 Volume expansion ratio

The results on volume expansion ratio summarized in Table10, also showed that the organic sources, levels of substitution and their interaction failed to have significant impact on this parameter.

Among the different treatment combinations l_1m_2 (25 percent substitution with FYM + neem cake)) followed by l_4m_1 (100 percent substitution with FYM) and l_4m_2 (100 percent substitution with FYM + neem cake) recorded higher volume expansion ratios of 4.27, 4.13 each respectively. The standard practice and the absolute control did not vary significantly. However, the standard practice (4.33) was slightly better than absolute control (3.73). The volume expansion ratios of grains in the treatment combinations and the market sample (4.20) were more or less similar.

Table 10. Effect of organic sources, levels of substitution and their interaction on optimum cooking time, volume expansion ratio and grain elongation ratio

Treatments	Optimum cooking time (min.)	Volume expansion ratio	Grain elongation ratio.
Organic sources			
M_1	27.00	3.85	1.59
M_2	27.08	4.00	1.58
Levels of substitution			
L_1	31.00	4.00	1.56
L_2	23.67	4.03	1.65
L_3	26.50	3.53	1.60
L_4	27.00	4.13	1.54
Interaction effects			
l_1m_1	30.00	3.73	1.54
l_1m_2	22.33	4.27	1.63
l_2m_1	30.00	4.00	1.64
l_2m_2	25.67	4.07	1.56
l_3m_1	32.00	3.53	1.57
l_3m_2	25.00	3.53	1.68
l_4m_1	23.00	4.13	1.56
l_4m_2	28.33	4.13	1.53
Treatment mean	27.04	3.92	1.58
Controls			
Absolute control	34.33	3.73	1.57
Standard practice	29.00	4.33	1.50
Control mean	31.66	4.03	1.53
SE : M	1.583	0.184	0.033
L	2.239	0.260	0.047
LM	3.166	0.367	0.067
CD : M	NS	NS	NS
L	NS	NS	NS
LM	NS	NS	NS
Treatments *Vs* controls	NS	NS	NS
Between controls	NS	NS	NS
Between treatments (including controls)	NS	NS	NS

4.4.1.3 Grain elongation ratio

The perusal of the data presented in Table10, revealed that organic sources, levels of substitution and their interaction had no significant influence on elongation ratio.

Among the different treatment combinations, though not significant, l_3m_2 (75 percent substitution with FYM + neem cake) followed by l_2m_1 (50 percent substitution with FYM) resulted in higher grain elongation ratios of 1.68 and 1.64 respectively.

No significant difference could be observed when the treatments were compared against the controls. The elongation ratio of grains was not significantly different between the absolute control (1.57) and the standard practice (1.50).

A wide variation could not be observed in the elongation ratio, between the market sample (1.61) and the treatment combinations.

4.4.2 Chemical properties

The chemical properties, which govern the nutritional quality of the grains, were assessed in terms of the crude protein, total starch, amylose and amylopectin contents.

4.4.2.1 Crude protein content

The results on the crude protein content are presented in Table 11.

The perusal of the data revealed that organic sources significantly influenced the crude protein content of the grains. The substitution of chemical fertilizers with FYM (M_1) was found to yield significantly higher crude protein in grain as compared to substitution with FYM + neem cake (M_2). While M_1 recorded 5.80 percent, M_2 faired with 5.47 percent of crude protein.

Table 11. Effect of organic sources, levels of substitution and their interaction on crude protein, total starch, amylose and amylopectin content of the grain

Treatments	Crude protein (%)	Total starch (%)	Amylose (%)	Amylopectin (%)
Organic sources				
M_1	5.80	63.41	24.86	38.56
M_2	5.47	63.01	23.55	39.47
Levels of substitution				
L_1	5.60	65.38	24.37	41.02
L_2	5.56	49.45	23.22	26.23
L_3	5.49	72.87	24.78	48.10
L_4	5.89	65.13	24.45	40.07
Interaction effects				
l_1m_1	5.53	65.57	25.93	39.63
l_1m_2	5.77	47.17	24.13	23.03
l_2m_1	5.70	78.33	24.47	53.87
l_2m_2	6.20	62.57	24.90	37.70
l_3m_1	5.66	65.20	22.80	42.40
l_3m_2	5.35	51.73	22.30	29.43
l_4m_1	5.29	67.40	25.10	42.33
l_4m_2	5.58	67.70	24.00	43.70
Treatment mean	5.63	63.20	24.20	39.01
Controls				
Absolute control	4.23	62.50	29.53	32.96
Standard practice	5.61	79.03	29.73	49.30
Control mean	4.92	70.76	29.63	41.33
SE : M	0.063	2.160	0.490	2.157
L	0.089	3.055	0.693	3.050
LM	0.126	4.320	0.981	4.314
CD : M	0.187	NS	NS	NS
L	0.264	9.077	NS	9.064
LM	0.374	NS	NS	NS
Treatments *Vs* Controls	S	S	S	NS
Between controls	S	S	NS	S
Between treatments (including controls)	0.385	12.838	2.915	12.819

The crude protein content was observed to differ significantly among the various levels of substitution. Hundred percent substitution of SDF with organics (L_4) was significantly superior (5.89 %) when compared to other three levels, which were at par.

The crude protein content was observed to vary significantly among the different treatment combinations, with l_2m_2 (50 percent substitution with FYM + neem cake) recording the highest protein content of (6.20 %).

Comparison of the treatment combinations against the controls revealed a significant superiority for the treatments. Between the controls, the standard practice was significantly superior (5.61 %). The analysis made between the treatment combinations including controls also showed that, the treatment combination, where in 50 percent of SDF was substituted with FYM + neem cake (l_2m_2) was superior.

The market sample had 5.61 percent crude protein. Thus the treatment combinations were as good as the market sample, with respect to the protein content of the grains.

4.4.2.2 Total starch content

The effect of organic sources on the total starch content of the grains (Table 11) was insignificant. The different levels of substitution had a significant impact on the starch content. Among the levels of substitution, 75 percent substitution (L_3) recorded the highest starch content (72.87 %). Further, L_3 was found to be at par with 25 percent substitution (L_1) and 100 percent substitution (L_4) levels.

The L x M interaction was not significant. Between the controls, the standard practice (79.03 %) had 16.53 percent more starch than absolute control (62.50 %)

The comparison made between the treatments including the controls also proved to be significant with standard practice, l_2m_1 (78.33 %), l_4m_1 and l_4m_2 at par.

The mean starch content of market sample (68.39 %) when compared with the treatment combinations did not show apparent difference.

4.4.2.3 Amylose content

The results on the amylose content presented in Table 11, revealed that neither the organic sources, levels of substitution, nor their interaction had any significant effect on the amylose content of the grains.

Among the different L x M interaction effects, l_1m_1 (25 percent substitution with FYM) recorded 25.93 percent amylose followed by l_4m_1 (100 percent substitution with FYM) and l_2m_2 (50 percent substitution with FYM + neem cake).

The comparison made between the treatments against controls proved to be significant. No significant difference was observed with respect to amylose content between the absolute control and standard practice. The amylose content of the absolute control and the standard practice were significantly higher, even in a between treatments (including controls) comparison.

The market sample had an amylose content of 23.76 percent (Table 12).

4.4.2.4 Amylopectin content

The perusal of the data presented in Table 11 indicated a non-significant influence for the organic sources on the amylopectin content of the rice. The levels of substitution were observed to have a significant influence on this nutritional parameter of rice. The treatment L_3 (75 percent substitution with organics) recorded significantly higher amylopectin content (48.10 %) and was at par with L_1 (25 percent substitution with organics) and L_4 (100 percent substitution with organics).

Table 12. Cooking properties and chemical properties of market sample

Cooking property / chemical property	Value
Optimum cooking time (min.)	28.00
Volume expansion ratio	4.20
Grain elongation ratio	1.61
Crude protein content (%)	5.61
Total starch content (%)	68.39
Amylose content (%)	23.76
Amylopectin content (%)	44.63

Table 13. Mean rankings for appearance, colour, flavour, doneness and taste

Treatment	Rank means				
	Appearance	Colour	Flavour	Doneness	Taste
l_1m_1	62.08	61.71	64.63	64.25	64.08
l_1m_2	70.08	74.33	69.25	73.21	70.54
l_2m_1	60.04	46.88	55.58	61.96	58.29
l_2m_2	83.75	85.42	84.42	74.92	75.38
l_3m_1	56.87	63.14	54.71	60.88	56.63
l_3m_2	87.38	86.21	82.58	79.13	83.00
l_4m_1	62.92	63.04	65.50	65.75	68.33
l_4m_2	63.50	63.33	68.92	67.25	68.88
Absolute control	41.08	45.67	40.25	53.96	42.71
Standard practice	80.21	78.29	76.42	90.25	73.67
Market sample	63.5	63.58	69.25	69.96	70.00

The L x M interaction and the effect of the treatments as against the controls were not significant. Between the controls the standard practice recorded significantly higher amylopectin content (49.30 %) when compared to the absolute control (32.96 %). When the treatment combinations were compared including controls, the treatments l_2m_1 (50 percent substitution with FYM+ neem cake) l_4m_1 (100 percent substitution with FYM) l_3m_1 (75 percent substitution with FYM) l_4m_2 (100 percent substitution with FYM + neem cake) and standard practice were at par.

The market sample analysed to contain 44.63 percent amylopectin (Table 12).

4.4.3 Organoleptic qualities

The quality attributes selected in this study were appearance, colour, flavour, doneness and taste. The mean rankings of the scores are presented in Table 13.

The highest rank for appearance (87.38) was obtained with the treatment combination, l_3m_2 (75 percent substitution with FYM+neem cake) followed by l_2m_2 (50 percent substitution with organics) and the standard practice. The market sample ranked fourth with a mean rank of 63.50. The appearance of the absolute control was poor (41.08).

The comparison made between the treatment combinations, controls and market sample revealed that, the grains produced by l_3m_2 (75 percent substitution with FYM+ neem cake) followed by l_2m_2 (50 percent substitution with FYM+ neem cake) and the standard practice acquired the first three ranks for colour, with mean rank values of 86.21, 85.42 and 78.29 respectively. Market sample was assessed to a mean rank value of 63.58 and ranked only fifth.

The flavour was ranked to be the best (84.42) with the treatment combination, l_2m_2 (50 percent substitution with FYM + neem cake), followed by l_3m_2 (75 percent substitution with FYM + neem cake) with a mean ranking of 82.58. The standard practice, with a mean ranking of 76.42 was the third best. The market sample and l_1m_2 (25 percent substitution with FYM + neem cake) were similar in flavour ranking (69.25).

The standard practice had the highest ranking for doneness (90.25) followed by l_3m_2 (75 percent substitution with FYM + neem cake) and l_2m_2 (50 percent substitution with FYM + neem cake) with mean rankings of 79.13 and 74.92 respectively.

The mean ranking given by the panel of judges, judged l_3m_2 (75 percent substitution with FYM + neem cake) to have the best taste (83.00). The treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) ranked second (75.38) followed by the standard practice, which got a ranking of 73.67.

The absolute control was observed to possess a very poor ranking with respect to all the above quality attributes. In general, the treatment combinations, l_3m_2, l_2m_2 and standard practice were judged to be better than the market sample.

4.5 SEED QUALITY

The effect of substitution of chemical fertilizers with organics on the seed quality was studied in terms of germination percentage and seedling vigour.

4. 5.1 Germination percentage

The results on the effect of treatments on the germination percentage are presented in Table.14.

The germination percentage was observed to remain unaffected by the organic sources, the different levels of substitution and their interaction. Irrespective of treatments, more than 90 percent germination was noted.

4. 5.2 Seedling vigour index

The data on seedling vigour (Table13) also revealed a similar trend as that of germination. When the treatments were compared against the controls, the treatment combinations were significantly superior to the controls. Between the controls, the standard practice, recorded significantly a higher vigour index (84.80) compared to absolute control (80.32).

Table 14. Effect of organic sources, levels of substitution and their interaction on germination percentage and seedling vigour index

Treatments	Germination percentage	Seedling vigour index
Organic sources		
M_1	95.33	114.99
M_2	95.00	102.36
Levels of substitution		
L_1	94.00	107.12
L_2	96.67	108.24
L_3	95.33	106.41
L_4	94.67	112.95
Interaction effects		
l_1m_1	92.00	108.73
l_1m_2	97.33	111.11
l_2m_1	96.00	114.67
l_2m_2	96.00	125.45
l_3m_1	96.00	105.50
l_3m_2	96.00	105.36
l_4m_1	94.67	98.16
l_4m_2	93.33	100.44
Treatment mean	95.16	108.60
Controls		
Absolute control	92.00	80.32
Standard practice	92.00	84.80
Control mean	92.00	82.56
SE : M	1.202	4.704
L	1.701	6.660
LM	2.405	9.419
CD : M	NS	NS
L	NS	NS
LM	NS	NS
Treatments *Vs* Controls	NS	S
Between controls	NS	S
Between treatments (including controls)	NS	NS

4.6 NUTRIENT UPTAKE

4. 6.1 Nitrogen uptake

The results summarized in Table 15 revealed that the organic sources alone had significant influence on nitrogen uptake. FYM (M_1) resulted in significantly higher nitrogen uptake (44.14 kg ha^{-1}) when compared to the combined application of FYM + neem cake (39.92 kg ha^{-1}).

The treatment combinations were significantly superior to the controls. The standard practice recorded significantly higher uptake values for nitrogen (48.42 kg ha^{-1}) compared to the absolute control (18.04 kg ha^{-1}). The nitrogen uptake analyzed, between the treatment combinations including controls, revealed that the treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) recorded the highest nitrogen uptake (51.28 kg ha^{-1}) and was on a par with l_2m_1 (50 percent substitution with FYM) l_4m_2 (100 percent substitution with FYM + neem cake) and the standard practice.

4. 6.2 Phosphorus uptake

From the data on phosphorus uptake in Table 15, it could be seen that, while the effect of the organic sources on phosphorus uptake was not significant the effect of levels of substitution and L x M interactions were significant.

The highest substitution level (L_4) resulted in maximum phosphorus uptake (19.76 kg ha^{-1}) all the other levels were at par.

Among the different treatment combinations l_2m_2 (50 percent substitution with FYM + neem cake) was superior with a phosphorus uptake of 21.16 kg ha^{-1} and was found to be at par with the standard practice (19.29 kg ha^{-1}).

Table 15. Effect of organic sources, levels of substitution and their interaction on nutrient uptake at harvest

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
Organic sources			
M_1	44.14	16.41	60.06
M_2	39.92	17.17	56.12
Levels of substitution			
L_1	39.38	15.56	52.79
L_2	41.26	15.90	55.48
L_3	40.29	15.93	59.10
L_4	47.21	19.76	64.98
Interaction effects			
l_1m_1	40.94	14.17	55.87
l_1m_2	40.55	14.89	54.24
l_2m_1	43.79	15.40	59.04
l_2m_2	51.28	21.16	71.08
l_3m_1	37.81	16.94	49.72
l_3m_2	41.96	16.91	56.72
l_4m_1	36.79	16.46	59.16
l_4m_2	43.13	18.35	58.88
Treatment mean	42.03	16.78	58.08
Controls			
Absolute control	18.04	6.88	25.73
Standard practice	48.42	19.29	70.77
Control mean	33.23	13.08	48.25
SE : M	1.416	0.391	1.744
L	2.003	0.553	2.466
LM	2.833	0.782	3.488
CD : M	4.208	NS	7.329
L	NS	1.643	NS
LM	NS	2.324	NS
Treatments *Vs* Controls	S	S	S
Between controls	S	S	S
Between treatments (including controls)	8.418	2.428	10.365

4.6.3 Potassium uptake

The perusal of the data in Table 15 revealed that trend between the two organic sources, FYM (M_1) resulted in a higher potassium uptake (60.06 kg ha^{-1}) and was significantly superior to FYM + neem cake (M_2).

The effect of the levels of substitution LxM interaction was not significant. The K uptake in the standard practice (70.77 kg ha^{-1}) was significantly higher than that of absolute control (25.73 kg ha^{-1}).

The potassium uptake in the standard practice and in the treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) was found to be at par, when the treatment combinations and the controls were compared together.

4.7 NITROGEN USE EFFICIENCY

The NUE of the different treatments were analysed in terms of agronomic efficiency, physiological efficiency, agro physiological efficiency, apparent recovery efficiency and utilization efficiency.

4.7.1 Agronomic efficiency

The results presented in Table16a indicated a significant influence for the different levels of substitution on the agronomic efficiency. L_4 (100 percent substitution with organics) recorded the highest agronomic efficiency of 16.24 kg grain per kg of nitrogen applied. The other levels were at par.

The effect of organic sources and L x M were non-significant. Significance was observed when the treatment combinations were compared including the control. The treatment combination l_2m_2 (50 percent substitution with FYM + neem cake) emerged out to be agronomically most efficient (18.30 kg kg^{-1}) and was on a par with the standard practice (16.14 kg kg^{-1}).

Table 16a. Effect of organic sources, levels of substitution and their interaction on agronomic efficiency and physiological efficiency

Treatments	Agronomic efficiency (kg grain kg $^{-1}$ N added)	Physiological efficiency (kg grain + straw kg $^{-1}$ N uptake)
Organic sources		
M_1	14.81	84.79
M_2	13.59	86.59
Levels of substitution		
L_1	13.00	86.53
L_2	14.50	88.49
L_3	13.06	84.04
L_4	16.24	83.54
Interaction effects		
l_1m_1	13.78	94.54
l_1m_2	13.89	83.00
l_2m_1	13.26	83.27
l_2m_2	18.30	78.00
l_3m_1	12.22	78.51
l_3m_2	15.11	93.97
l_4m_1	12.85	84.81
l_4m_2	14.18	89.08
Treatment mean	14.19	85.64
Controls		
Standard practice	16.14	84.99
SE : M	0.529	2.987
L	0.749	4.225
LM	1.059	5.975
CD : M	NS	NS
L	2.24	NS
LM	NS	NS
Treatments *Vs* Control	NS	NS
Between treatments (including control)	3.176	NS

4.7.2 Physiological efficiency

The treatments and their interaction failed to have a significant impact on the physiological efficiency. Even the comparison between the treatments and the controls proved non-significant.

4.7.3 Agro physiological efficiency

The agro physiological efficiency also exhibited a trend similar to the physiological efficiency.

4.7.4 Apparent recovery efficiency

The results on apparent recovery efficiency summarized in Table 16b showed that both the organic sources and levels of substitution had significant effect. However, their interaction was found to be not significant. Between the organic sources, the apparent recovery efficiency was the highest (28.97 %) with FYM (M_1) as compared to FYM + neem cake (23.82 %). Among the different levels of substitutions L_4 (100 percent substitution with organics) was significantly superior (32.37 %) and the other three levels were at par.

The apparent recovery efficiency of standard practice (33.72 %) was significantly superior to the treatment combinations. The comparison made between the treatments including the control revealed significance. Substituting 50 percent of the SDF with FYM + neem cake (l_2m_2) resulted in the highest recovery efficiency (36.89 percent) and was at par with the standard practice and l_2m_1 (50 percent substitution with FYM).

4.7.5 Utilization efficiency

The organic sources, levels of substitution and their interaction had no significant effect on the utilization efficiency. The comparison made as treatments *versus* control and between treatments including controls also proved to be non-significant.

Table 16b. Effect of organic sources, levels of substitution and their interaction on agro physiological efficiency, apparent recovery efficiency and utilization efficiency

Treatments	Agro physiological efficiency (kg grain kg $^{-1}$N uptake)	Apparent recovery efficiency (%)	Utilization efficiency (kg grain + straw kg $^{-1}$ N added)
Organic sources			
M_1	52.94	28.97	25.01
M_2	58.04	23.82	20.96
Levels of substitution			
L_1	57.45	23.68	20.90
L_2	57.86	25.76	23.33
L_3	56.49	23.77	20.61
L_4	50.25	32.37	27.10
Interaction effects			
l_1m_1	57.91	25.42	24.70
l_1m_2	57.03	24.98	21.68
l_2m_1	47.18	28.58	24.75
l_2m_2	49.62	36.89	28.86
l_3m_1	57.00	21.94	17.05
l_3m_2	58.68	26.55	24.98
l_4m_1	65.79	18.96	16.47
l_4m_2	50.88	27.85	25.34
Treatment mean	55.51	26.39	22.98
Controls			
Standard practice	48.07	33.72	28.97
SE : M	3.193	1.423	1.829
L	4.516	2.012	2.586
LM	6.387	2.846	3.658
CD : M	NS	4.266	NS
L	NS	6.033	NS
LM	NS	NS	NS
Treatments *Vs* control	NS	S	NS
Between treatments (including control)	NS	8.533	NS

4.8 SOIL FERTILITY STATUS AFTER THE EXPERIMENT

The fertility status of soil after the experiment was studied in terms of the organic carbon, available nitrogen, available phosphorus, and available potassium status.

4. 8.1 Organic carbon

The results on the organic carbon status of the soil after the experiment (Table 17) revealed a non-significant effect for organic sources, levels of substitution and their interaction.

All the comparisons made like the effect of treatments *versus* controls, between controls and between the treatments including the controls proved to be non-significant.

4. 8.2 Available nitrogen

The results pertaining to the available nitrogen status of the soil after the experiment are presented in Table 17.

The organic sources, levels of substitution and their interaction failed to influence the available nitrogen status of the soil. Though not significant, among the different treatment combinations, l_3m_1 (75 percent substitution with FYM) resulted in more available nitrogen in the soil.

Significance was observed when the treatment combinations were compared against the controls. Between the controls the standard practice resulted in more available nitrogen (229.97 kg ha^{-1}) in the soil in contrast to the absolute control (163.06 kg ha^{-1}). The effect of treatments including the controls was significant. Except absolute control all the treatment combinations including the standard practice were at par.

Table 17. Effect of organic sources, levels of substitution and their interaction on organic carbon, available nitrogen, available phosphorus and available potassium status of the soil

Treatments	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Organic sources				
M_1	1.24	231.02	51.88	91.84
M_2	1.16	229.97	63.38	111.17
Levels of substitution				
L_1	1.05	229.97	56.60	113.58
L_2	1.23	221.61	55.42	94.08
L_3	1.24	236.26	65.74	95.32
L_4	1.27	234.15	52.77	103.04
Interaction effects				
l_1m_1	0.86	213.25	46.57	98.56
l_1m_2	1.48	234.15	54.24	80.64
l_2m_1	1.32	234.18	61.91	89.60
l_2m_2	1.31	242.52	44.80	98.56
l_3m_1	1.24	246.70	66.62	128.60
l_3m_2	1.06	209.07	56.60	107.52
l_4m_1	1.17	238.33	69.57	101.04
l_4m_2	1.15	225.79	60.73	107.52
Treatment mean	1.19	230.49	57.62	101.50
Controls				
Absolute control	1.62	163.06	58.36	85.12
Standard practice	1.48	229.97	52.47	118.31
Control mean	1.55	196.51	55.41	101.71
SE : M	0.143	7.367	6.913	4.985
L	0.203	10.418	9.777	7.050
LM	0.287	14.734	13.827	9.971
CD : M	NS	NS	NS	14.813
L	NS	NS	NS	NS
LM	NS	NS	NS	NS
Treatments *Vs* Controls	NS	S	NS	NS
Between controls	NS	S	S	S
Between treatments (including controls)	NS	43.779	NS	NS

4.8.3 Available phosphorus

The results summarized in Table 17 revealed a non-significant effect for the treatment as well as their combinations on the available phosphorous status of the soil. However, substituting 75 percent SDF with FYM (l_3m_1) was found to record more available phosphorus in the soil after the experiment. The effect of the treatment combinations compared against the controls was also insignificant. Between the controls the absolute control recorded a higher available phosphorous content (58.36 kg ha^{-1}) in the soil compared to the standard practice (52.47 kg ha^{-1}). The comparison made between the treatments including controls gave a non-significant result.

4.8.4 Available potassium

The organic sources had significant effect on the available potassium content of the soil. The combined application of FYM and neem cake resulted in a higher available potassium status (111.17 kg ha^{-1}) in comparison to the application of FYM alone (91.84 kg ha^{-1}). The levels of substitution and L x M interaction had no significant impact on the availability of this dynamic nutrient in the soil. However, l_3m_1 (75 percent substitution with FYM) maintained relatively higher available potassium in the soil. The standard practice was significantly superior in maintaining a higher available potassium status (118.31 kg ha^{-1}) in the soil when compared to the absolute control (85.12 kg ha^{-1}).

4.9 ECONOMICS OF CULTIVATION

The per hectare cost of cultivation for basmati rice worked out to Rs.35,000 under the standard practice. The cost of cultivation for the other treatment combinations varied according to the treatments *per se*.

The data summarized in Table18 showed that the use of FYM alone for substituting chemical fertilizers (M_1) was more remunerative than the combined application of FYM and neem cake (M_2), in terms of net income and BCR.

Table 18. Effect of organic sources, levels of substitution and their interaction on the net income and benefit cost ratio

Treatments	Net income	BCR
Organic sources		
M_1	27332.43	1.69
M_2	18531.32	1.43
Levels of substitution		
L_1	23974.48	1.63
L_2	21813.98	1.50
L_3	23339.93	1.60
L_4	22639.10	1.49
Interaction effects		
l_1m_1	27804.03	1.74
l_1m_2	24101.03	1.60
l_2m_1	25658.17	1.68
l_2m_2	31846.50	1.75
l_3m_1	20144.93	1.52
l_3m_2	19526.93	1.40
l_4m_1	21021.70	1.53
l_4m_2	13431.70	1.26
Treatment mean	22941.88	1.55
Controls		
Absolute control	-6344.96	0.81
Standard practice	35256.67	1.98
Control mean	14455.85	1.39
SE : M	1603.872	0.0401
L	2268.218	0.0567
LM	3207.745	0.0802
CD : M	4765.526	0.1192
L	NS	NS
LM	NS	NS
Treatments *Vs* Controls	S	S
Between controls	S	S
Between treatments (including controls)	9351.052	0.238

The different levels of substitutions had no significant effect. The L x M interaction was also not significant. The treatment combinations were significantly superior to the controls. Between the controls, the absolute control resulted in a loss and recorded a benefit cost ratio of less than 1 (0.810). In the comparison made between the treatment combinations including the controls, it was observed that the standard practice, l_1m_1 (25 percent substitution with FYM) and l_2m_2 (50 percent substitution with FYM + neem cake) were at par. While the standard practice recorded, a BCR of 1.98, the treatment combination $l_1m_1$and l_2m_2 yielded a BCR of 1.74 and 1.75 respectively.

The results showed that the basmati rice responded well to integrated nutrient management. The study also aimed at checking out the feasibility of adopting 100 percent organic nutrition in basmati rice. The results revealed that L_4 (100 percent substitution with organics) recorded better growth attributes, yield and yield attributes, seedling vigour, nitrogen use efficiency, nutrient uptake, crude protein content and volume expansion.

Discussion

5. DISCUSSION

The results of the study conducted to evaluate the efficiency of integrated nutrient management on the production potential and quality of basmati rice and its comparison with the standard practice, are discussed in this chapter.

5.1 GROWTH CHARACTERS

An appraisal of the results on plant height indicated a positive influence of the different levels of substitution at the maximum tillering stage. The entire quantity of fertilizers, substituted with organics was observed to be the best. Several workers reported the positive influence of substituting at least a part of the chemical fertilizers with organics (Johnkutty and Anilakumaran, 1991; Padmaja et al., 1993; Balasubramaniyan, 2004) on the plant height of rice. FYM produced better growth in terms of taller plants and more dry matter accumulation (Singh et al., 2002). The higher plant height obtained by substitution of chemical fertilizers with organics had been attributed to the rapid meristematic activity triggered by a better availability of plant nutrients, especially nitrogen (Crowther, 1935). The absolute control was significantly inferior to the standard practice. The role of balanced application of fertilizers in improving the growth of plants has been well documented.

The tiller number per square metre at the panicle initiation and flowering stages was significantly superior with 100 percent substitution of chemical fertilizers with organics (L_4) Sharma (1994) observed that application of FYM alone or in combination with chemical fertilizers resulted in the production of more tillers in rice.

As in the case of plant height and tiller count, the LAI at the harvest stage was found to be higher with substitution of SDF with organics. The interaction between different levels of substitution and organic manures was significant at flowering and harvest stages. Fifty percent substitution with FYM + neem cake (l_2m_2) proved superior. Irrespective of the treatments, the LAI was maximum at the flowering stage and thereafter it declined (Table 4). This might be due to the reduction in the tiller number and size of the leaves during the later stages of growth (Sindhu, 2002). One of the major benefits of applying organics is that they improve nutrient availability to crops. According to Russel (1973) as the nutrient availability especially nitrogen increases, the extra protein produced allows the plant leaves to grow larger. Usman et al. (2003) reported that the application of organics in combination with chemical fertilizers produced the maximum LAI in basmati rice varieties.

The results on the percent biomass partitioning (Fig.3) indicated a non-significant effect of treatments on the root weight. On the other hand the effects were significant with respect to shoot weight and panicle weight. While the treatment combination, l_1m_1 (25 percent substitution with FYM) produced a higher percent shoot biomass, the treatment combination, l_2m_2 (50 percent substitution with FYM + neem cake) resulted in a better partitioning of the total biomass to the panicle. Studies conducted by Trubat et al. (2006) indicated that under conditions of limited nutrient supply the carbohydrate utilisation gets more localised towards the root portion. The absolute control had more root biomass compared to all the other treatment combinations. This might be due to the effect of deficient nutrient supply as reported by Trubat et al. (2006) who observed that the deficiency of major nutrients did not effect the below ground biomass accumulation or the root morphology. They also found that root length, root surface area, and the specific root weight were higher in the nutrient deficient plants. Whereas the application of chemical fertilizers in conjunction with organics might have improved the availability of nutrients to the plants and thus resulted in a better partitioning efficiency to the aerial portions.

5.2 YIELD ATTRIBUTES

The productive tiller count significantly improved with the substitution of chemical fertilizers with organics (Fig.4). Hundred percent substitution and 50 percent substitution were effective in increasing the productive tiller count. Integrated use of organic and inorganic fertilizers improved the number of productive tillers produced by rice as reported by Kumawat and Jat (2005). The beneficial effect of organic manure on the yield attributes like the number of productive tillers could be attributed to the supply of plant nutrients in an available form through the proper decomposition

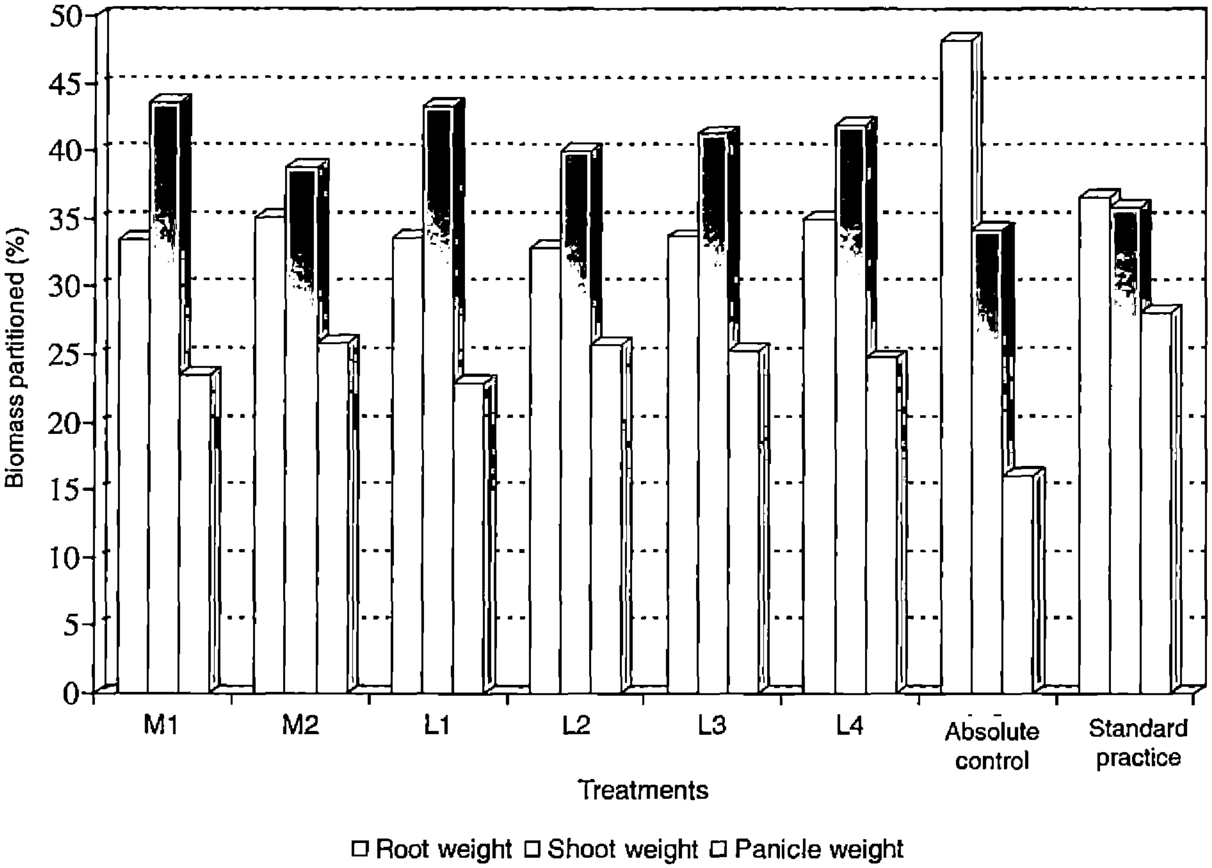


Fig. 3. Effect of organic sources and levels of substitution on the biomass partitioning (%)

and mineralization of organic manure and also on the solubilising effects of organic manure on the fixed forms of nutrients (Sinha et al.,1981). Chaudhary and Thakuria (1996) observed more number of productive tillers under integrated nutrient management due to the greater survival of tillers with organic manures owing to continuous and controlled supply of nutrients throughout the crop growth period.
The different treatment combinations did not influence panicle weight significantly.

Among the different levels of substitution 100 percent and 50 percent substitution levels produced more number of spikelets per panicle. Among the different treatment combinations, 50 percent substitution with a combination of FYM + neem cake was found to be superior. Puste et al. (1996) found that substitution of 25 percent of chemical fertilizers with organics produced significantly higher number of spikelets per panicle. The higher number of spikelets at higher levels of substitution can be attributed to a better supply of nutrients, minimizing the loss of nitrogen and potassium, which are highly mobile. The favourable effect of nitrogen and potassium in increasing the number of spikelets per panicle were previously reported by Khanda and Dixit (1996).

The combined application of FYM and neem cake (M_2) resulted in significantly lower sterility percentage as compared to FYM alone (M_1). The levels of substitution and interaction effect were not significant. Organic manures, in general have been reported to maintain a better nutrient status in the soil. This in turn might have improved the photosynthetic efficiency of the plant and thereby increased the number of filled grains as observed by Nehra et al. (2001). The favorable influence of integrated nutrient management noticed in the present study can also be attributed to the increased availability of potassium following organic matter addition as reported by Ganal and Singh (1990). Bridgit and Potty (2002b) opined that organic manures acted as facilitators for efficient translocation of carbohydrates to the grains and thereby reduced the sterility percentage in rice.

Thousand grain weight did not vary significantly among the different treatments. This yield attribute is a stable varietal character because the grain size is rigidly controlled by hull. Hence the grains cannot grow to a size greater than that

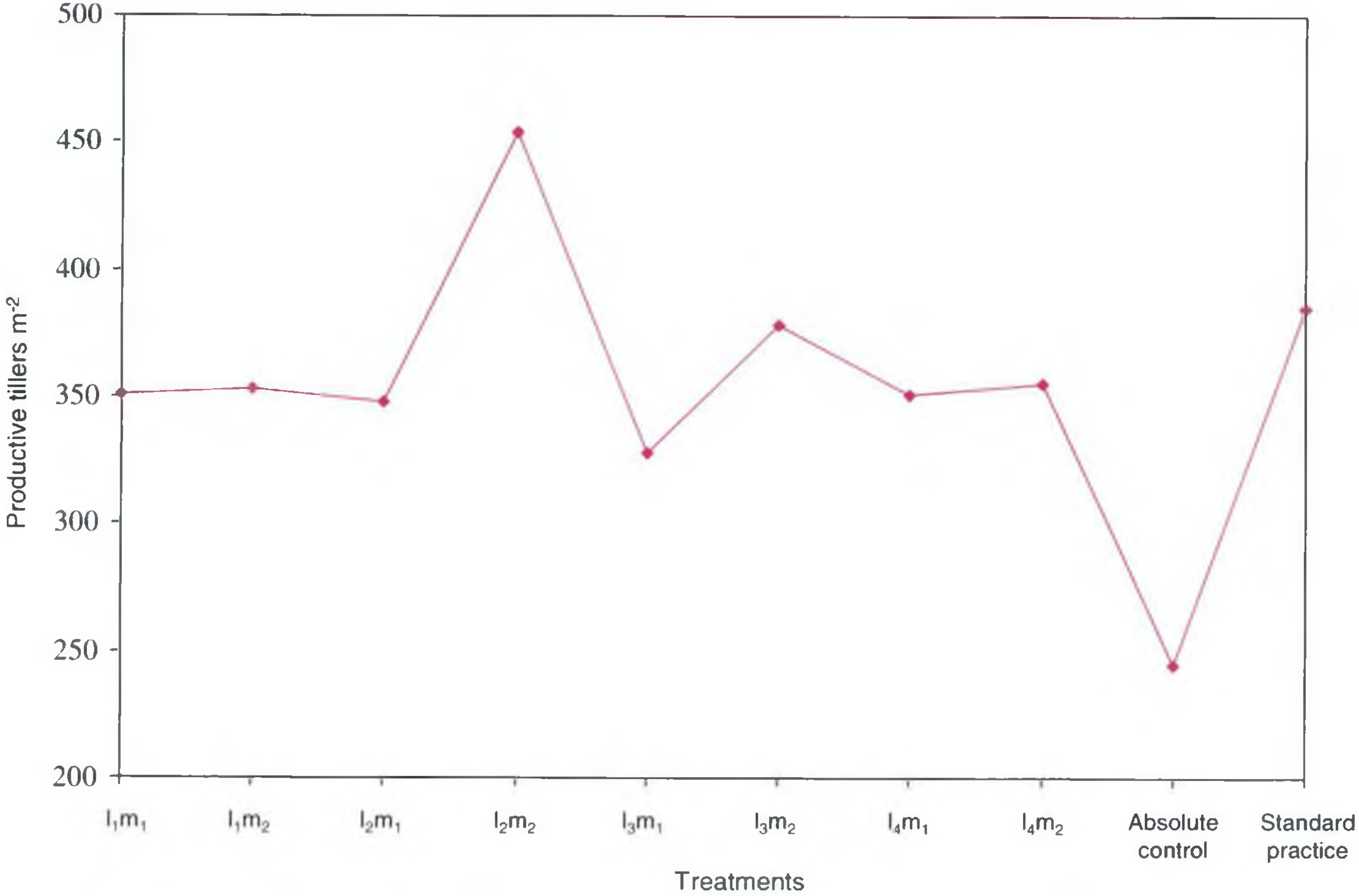


Fig. 4. **Interaction effect of organic sources and levels of substitution including controls on the productive tiller count at harvest**

Plate 3. Main field at panicle emergence

Plate 4. General view of the experiment

permitted by the hull despite the favourable weather conditions and nutrient supply (Yoshida, 1981).

5.3 YIELD

5.3.1 Grain yield

The grain yield (Fig.5) differed significantly among the levels of substitution. Hundred percent substitution (L_4) and 50 percent substitution were at par. Significant variation was observed between the treatment combinations and controls, between the controls and between the treatments including the controls. However, the effect of organic sources on grain yield was not significant.

Among the different treatment combinations including the controls, 50 percent substitution of SDF with FYM + neem cake (l_2m_2) proved to be superior and was on a par with standard practice.

The superiority revealed by L_4 and L_2 in terms of the number of tillers, LAI and productive tillers might have contributed to a higher grain yield. The beneficial effect of substituting chemical fertilizers with organics, could be attributed to the fact that after proper decomposition and mineralisation the organic manures, might have supplied available nutrients directly to the plant as reported by Sinha et al. (1981). Organic manures might have also increased the adsorptive power of the soil for cations and anions, particularly phosphates and nitrates and released them slowly for the benefit of the crop during the entire crop growth period leading to higher yield as reported by Singh et al. (1981). Sindhu (2002) also found that 50 percent substitution of chemical fertilizers with organics could be recommended for maximizing the yield of basmati in the wetlands. Higher grain yields were reported by Singh et al. (2003) in basmati with 75 percent of the recommended dose of fertilizers applied as FYM. Flaig (1975) reported that some of the low molecular constituents of the organic manures had a favourable influence on plant metabolism. Further lignin degradation products such as phenolic compounds,

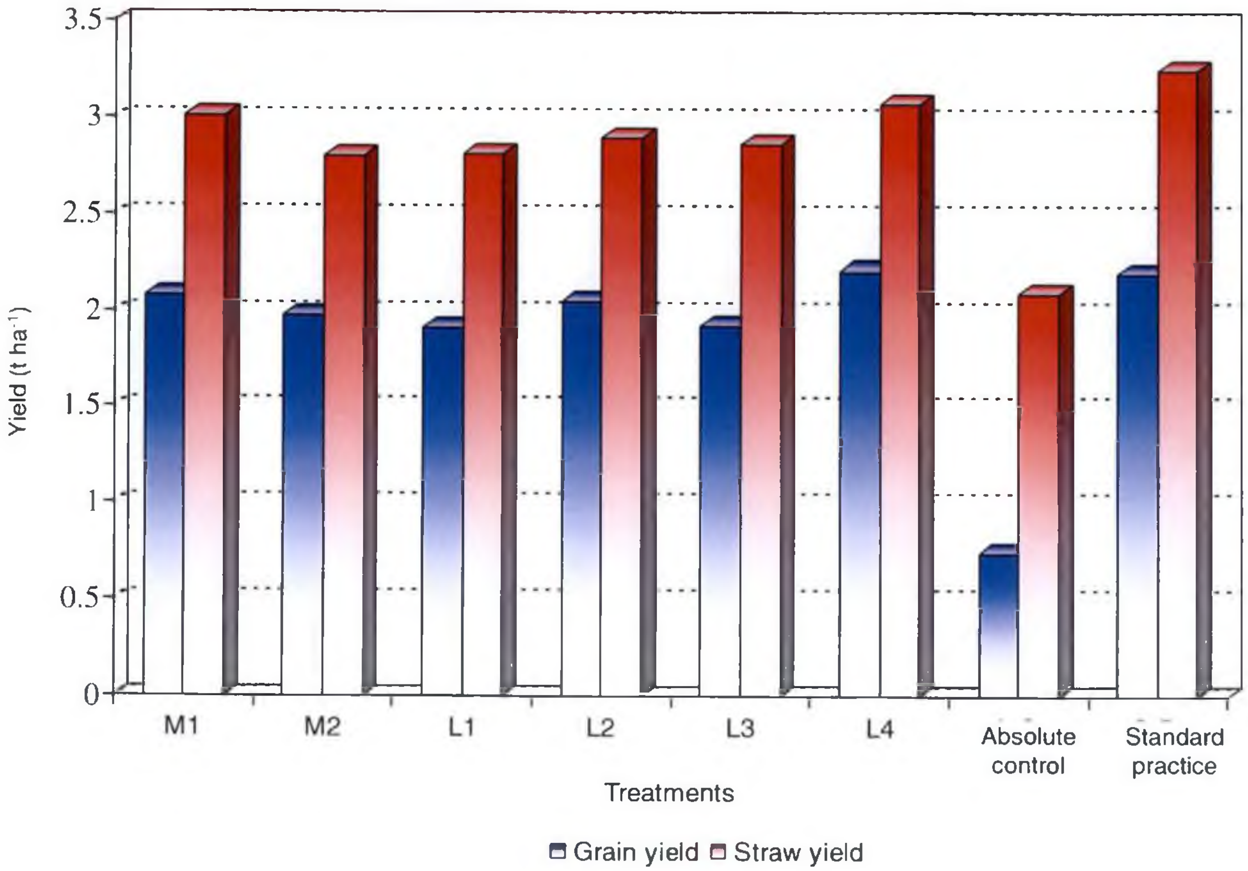


Fig. 5. Effect of organic sources and levels of substitution on yield of rice (t ha^{-1})

at lower concentration, acted as phytohormones and exerted a favorable effect on the yield of rice.

The combination of neem cake and FYM was better in improving the grain yield. Application of neem cake as fertilizer and pesticide is a traditional practice. Apart from the major nutrients neem cake also contains calcium, magnesium and sulphur compounds which favours the crop growth and yield. Further neem cake, which has been shown to inhibit nitrification, might have resulted in a desirable slow release of nitrogen to the plants. Thus it might have helped in spreading the effect of fertilizer over a longer period of time by reducing losses through denitrification and leaching. Similar observations were made by Singh et al. (2001a) and Balasubramaniyan (2004). Singh et al. (2006a) also observed the favourable effect of substituting 50 percent recommended nitrogen with neem cake in increasing the grain yield of rice.

5.3.2 Straw yield

The straw yield did not vary significantly among the different treatments (Fig.5). Between the controls, the standard practice recorded more straw yield than the absolute control. The standard practice, where in NPK was applied at ratio of 2:1:1.5 as chemical fertilizers along with FYM should have supplied the plants with more or less the required quantity of nutrients and resulted in a higher straw yield. The absolute control might have suffered from nutrient deficiency as evidenced by the significantly lower tiller count and LAI.

5.3.3 Harvest index

The organic sources, levels of substitution and their interaction failed to have any impact on harvest index (Fig.6). However, significance was observed in comparison made between the treatment combinations including controls. A harvest index of 0.4 to 0.5 is believed to be ideal for high yielding varieties to achieve potential production (IRRI, 1994). The integration of organics with inorganics resulted in more or less an ideal harvest index. The absolute control was significantly inferior in terms of the harvest index.

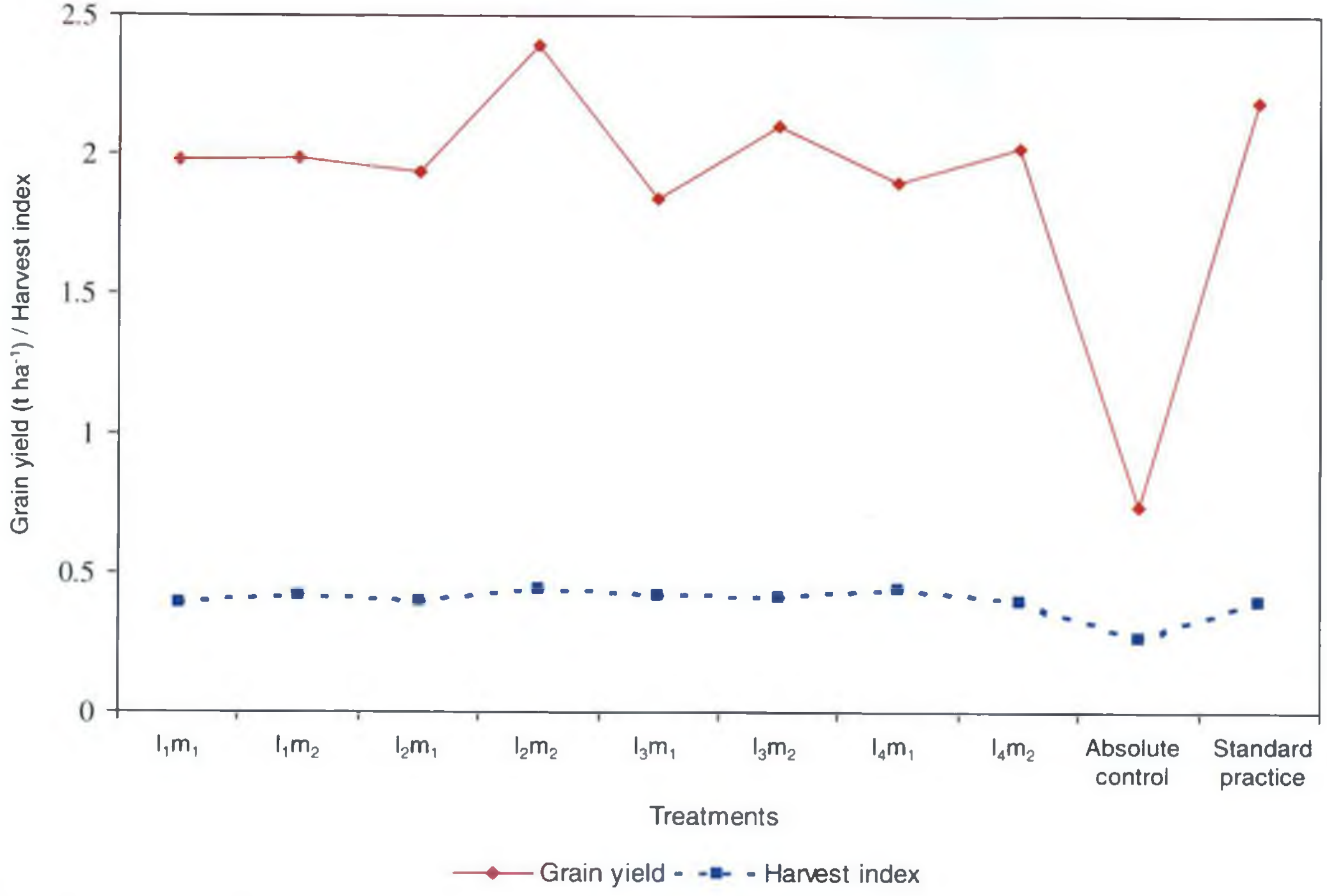


Fig. 6. **Interaction effect of organic sources and levels of substitution including controls on the grain yield and harvest index**

5. 4 BACTERIAL LEAF BLIGHT INCIDENCE

The incidence of Bacterial leaf blight disease was more or less uniform regardless of the treatments tested. Devadath (1992) reported BLB as one of the most devastating disease affecting aromatic rices. Pusa Basmati-1 has been reported to be highly susceptible to this disease. Pillai and Ajithkumar (2006) reported that a combination of rainy weather, dull windy days and temperature of $22^{o} - 26^{o}C$ favours the incidence of BLB. Thus the susceptibility of the test variety, clubbed together with weather conducive (Fig.1) for disease development and spread, may be the factors responsible for the uniform incidence of the disease.

5.5 QUALITY ATTRIBUTES

5.5.1 Cooking properties

The cooking properties were assessed in terms of the optimum cooking time, elongation ratio and volume expansion ratio. The results are presented graphically in Fig.7.

The treatments, their interactions and the controls, did not have any significant impact on the cooking properties. However a generalised trend could be observed among the different levels of substitution. Substituting 50 percent of chemical fertilizers with organics were observed to have a lower cooking time, higher elongation ratio and volume expansion ratio. The grains obtained from the absolute control took more time to cook. The poor cooking properties of basmati rice grown under nutrient deficient conditions have been previously reported by Azeez and Shafi, 1966). Adhikari et al. (2005) and Tripathi et al. (2007) also observed a non-significant effect for organic fertilization on the grain quality of basmati rice.

Among the different treatment combinations l_1m_2 had the lowest cooking time and the highest volume expansion ratio. The elongation ratio was higher in l_3m_2. These treatment combinations were better than market sample.

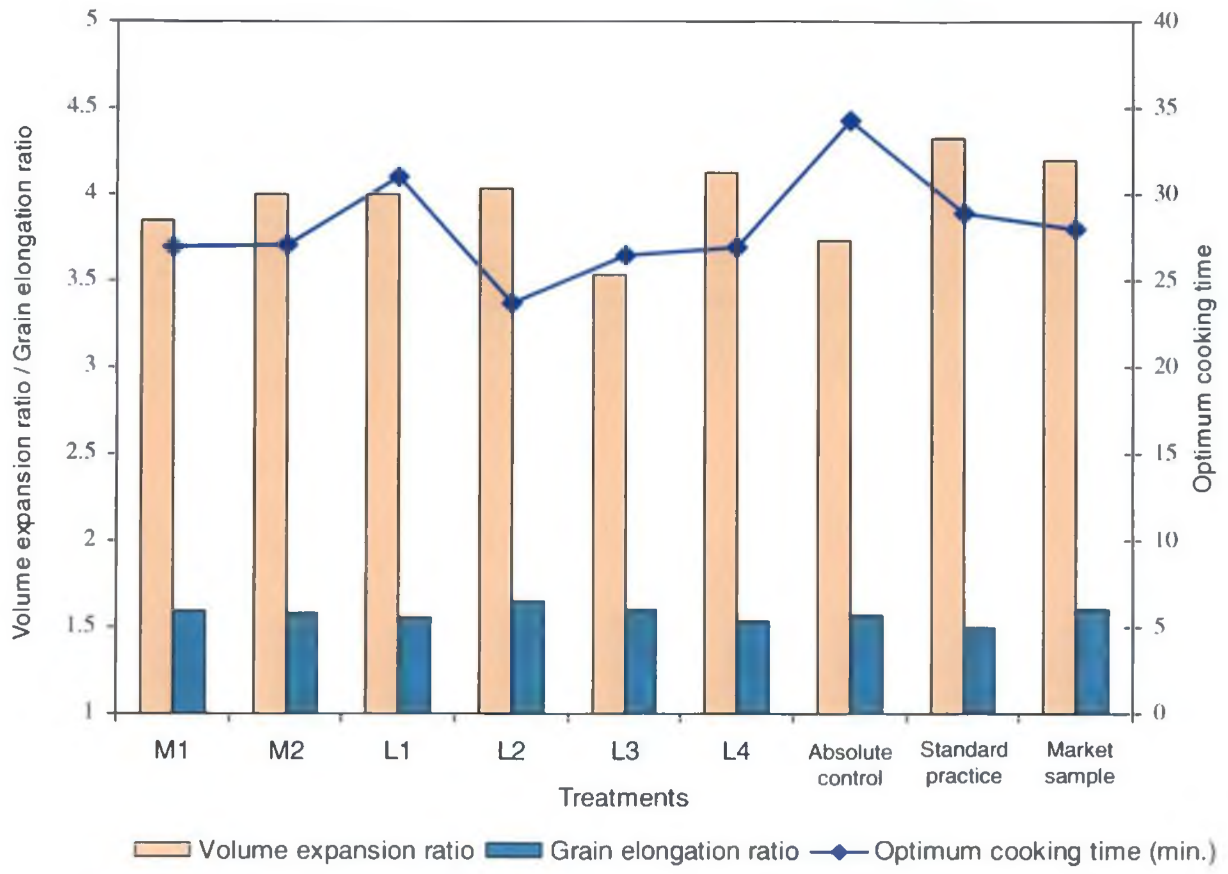


Fig. 7. Effect of organic sources and levels of substitution on the cooking properties of rice

It was observed that, though not significant, substituting at least a part of the chemical fertilizers with organics could marginally improve the cooking qualities of rice. Similar trends were reported by Adhikari et al. (2005).

5. 5.2 Chemical properties

The chemical properties determine the nutritional quality of rice. The nutritional quality of rice was evaluated by determining the crude protein, total starch, amylose and the amylopectin contents.

The treatments and their interactions had a significant influence on crude protein content. FYM (M_1) and 100 percent substitution with organics (L_4) resulted in higher protein content (Fig.8). The higher nitrogen uptake recorded by this treatment may have contributed to the higher protein content as explained by Tisdale et al. (1995). Similar results were reported by Adhikari et al. (2005). Among the different treatment combinations l_2m_2 (50 percent substitution with FYM + neem cake) was found to be superior. This can also be attributed to the higher nitrogen uptake recorded by this treatment combination.

The market sample recorded protein content, which was more or less similar to that of the treatments.

Substituting 75 percent of chemical fertilizers with organics (L_3) gave the highest starch content and was at par with L_1 and L_4. Starch is the major constituent in cereal grains and is the nutritional reservoir. The market sample and the treatments did not show apparent difference in the starch content.

Starch is a mixture of amylose and amylopectin. Amylose content, the major determinate of cooking and eating characteristics did not vary significantly among the different treatments (Fig.8). However, when the treatment combinations were compared taking into account the controls also, the control treatments had significantly higher content of amylose. Rice with 20-25 percentage of amylose were rated as intermediate (Chikkalingaiah et al., 1997) and reported to possess good cooking quality.

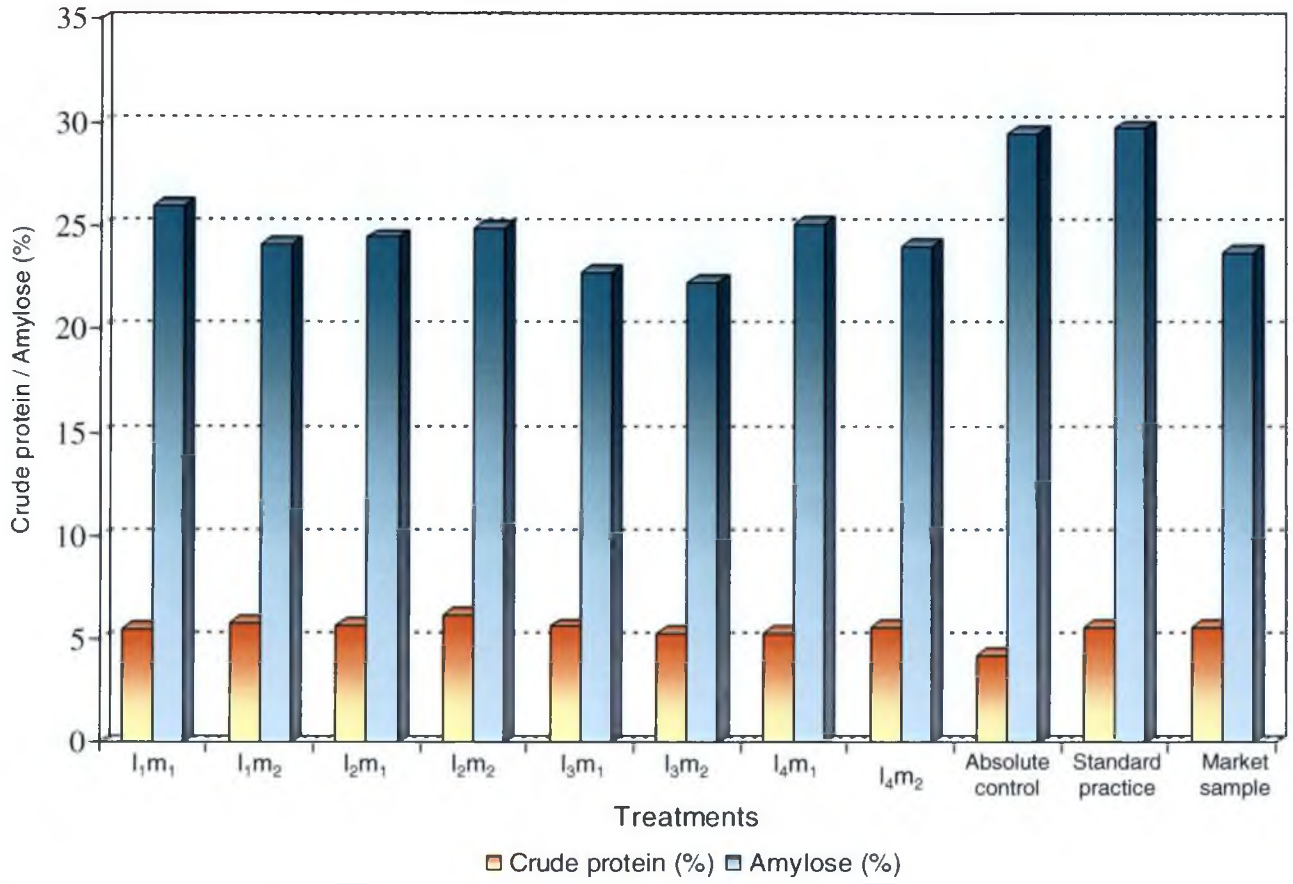


Fig. 8. **Interaction effect of organic sources and levels of substitution including controls on the crude protein and amylose content of rice**

The high amylose content recorded by the controls (29.63 %) is an indicator of poor consumer preference, because high amylose content result in hard cooked rice as reported by Dipti et al. (2002). The mean amylose content of the treatment combinations tested was 24.20 percent. This is a clear indication of the fact that INM can produce grains with desirable amylose content.

The market sample had an amylose content of 23.76 percent and remained within desirable limits. The amylopectin content was calculated in relation to the amylose content.

5. 5.3 Organoleptic qualities

Quality is considered as the relative excellence of a food based on the sensory estimates of colour, texture, and flavour. In the present study the quality attributes such as appearance, colour, flavour, doneness and taste were studied. The results of the organoleptic test are graphically presented in Fig. 9.

Appearance is an important quality trait because rice is mostly consumed in the whole grain form. Substituting 75 percent of the chemical fertilizers with FYM and neem cake ranked first in terms of appearance, colour, and taste. However, flavour was best at 50 percent substitution with FYM and neem cake.

Doneness was superior in the standard practice (90.25) which was followed by 50 percent substitution with FYM + neem cake (l_2m_2).

5.6 SEED QUALITY

The germination percentage and the seedling vigour were not influenced significantly by the various treatment combinations. When the treatment combinations were compared against the controls, the treatment combinations wherein inorganics were applied in conjunction with organic manures, proved to be superior. Between the controls, the standard practice was better. The beneficial effect of integrated nutrient management on seed quality might be due to the accumulation of some enzymes or

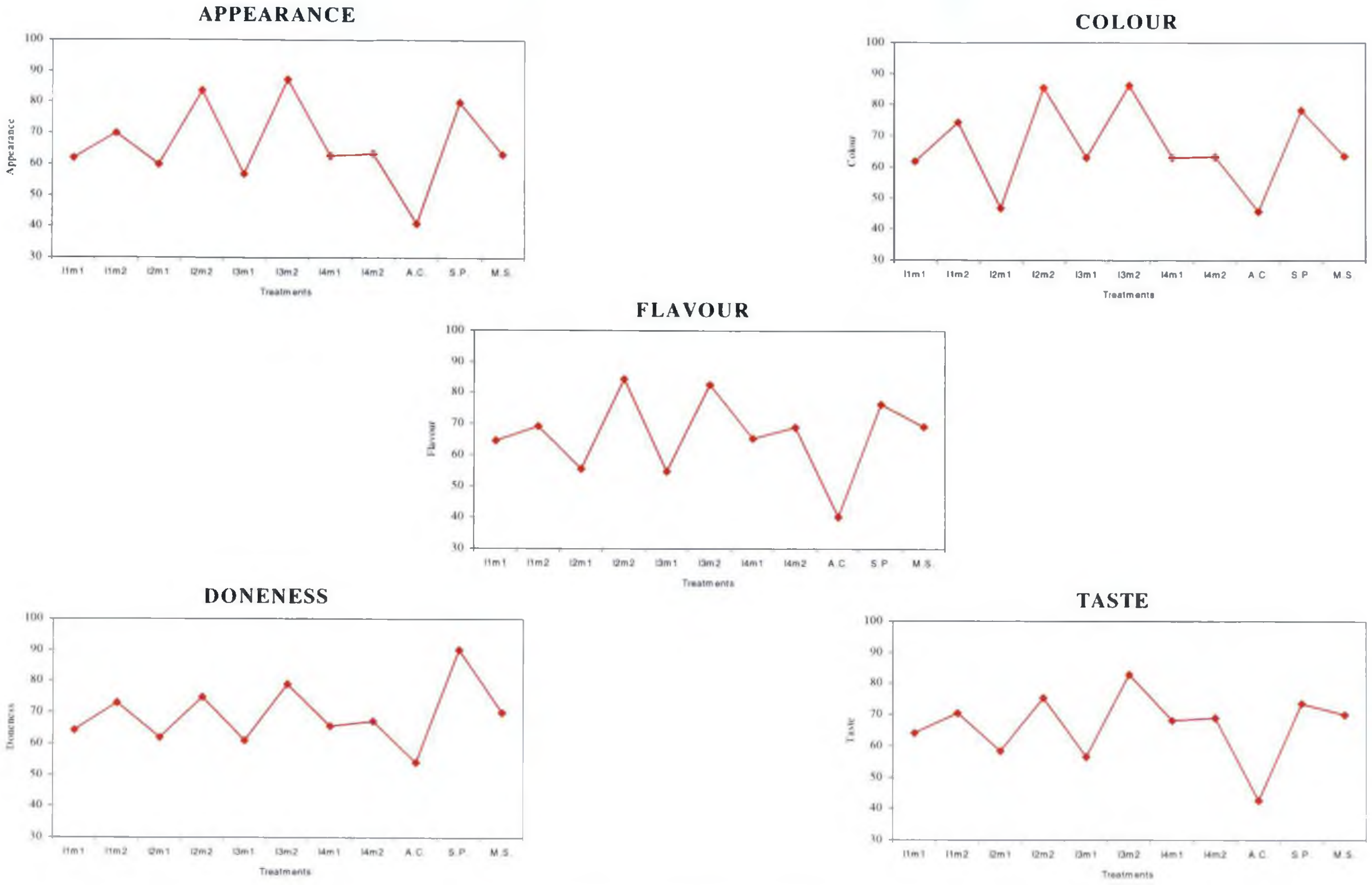


Fig. 9. Mean ranking in organoleptic test

growth promoting substances in the seeds in addition to proteins as suggested by Khamkar (1993).

5.7 NUTRIENT UPTAKE AT HARVEST

The nitrogen uptake (Fig.10) was found to vary significantly between the two organic sources, with FYM (M_1) being superior. The absolute control was very poor in terms of nitrogen uptake. Among the different treatments combinations including controls, l_2m_2 (50 percent substitution with FYM + neem cake) recorded the highest uptake value. FYM might have supplied major and minor nutrients along with organic acids and provided good physical condition for plant growth. This in turn might have increased the uptake of nitrogen. Similar results were reported by Charjan and Gaikwad (2005). The favourable influence of neem cake in combination with inorganics and other organic sources was reported previously by Balasubramaniyan (2004) in a study conducted on fine grain rice. Among the different treatments combinations, l_2m_2 was significantly superior. When the controls were also taken into account, l_2m_2 was at par with the standard practice.

The levels of substitution had a favorable influence on the phosphorus uptake (Fig.10). The L x M interaction was also significant. Hundred percent substitution of SDF with organics (L_4) resulted in the highest phosphorus uptake. Addition of organics might have improved the phosphorus availability and subsequently the uptake. The integration of organic matter in plant nutrition was reported to increase the phosphorus supply to plants through direct enrichment, by enhancing the solublization of native phosphorus, by accelerating the mineralization of added phosphorus and by reducing the P fixation (Johnkutty and Anilakumaran, 1991).

The potassium uptake (Fig.10) varied significantly between the two organic sources. FYM ensured a better uptake of potassium. Among the treatments combinations including controls, l_2m_2 had a higher K uptake, which was at par with the standard practice. The favourable effect of integrated nutrient management on nutrient uptake were previously reported by Das et al. (2003) and Singh (2006). Application of FYM, alone or in combination within chemical fertilizers might have

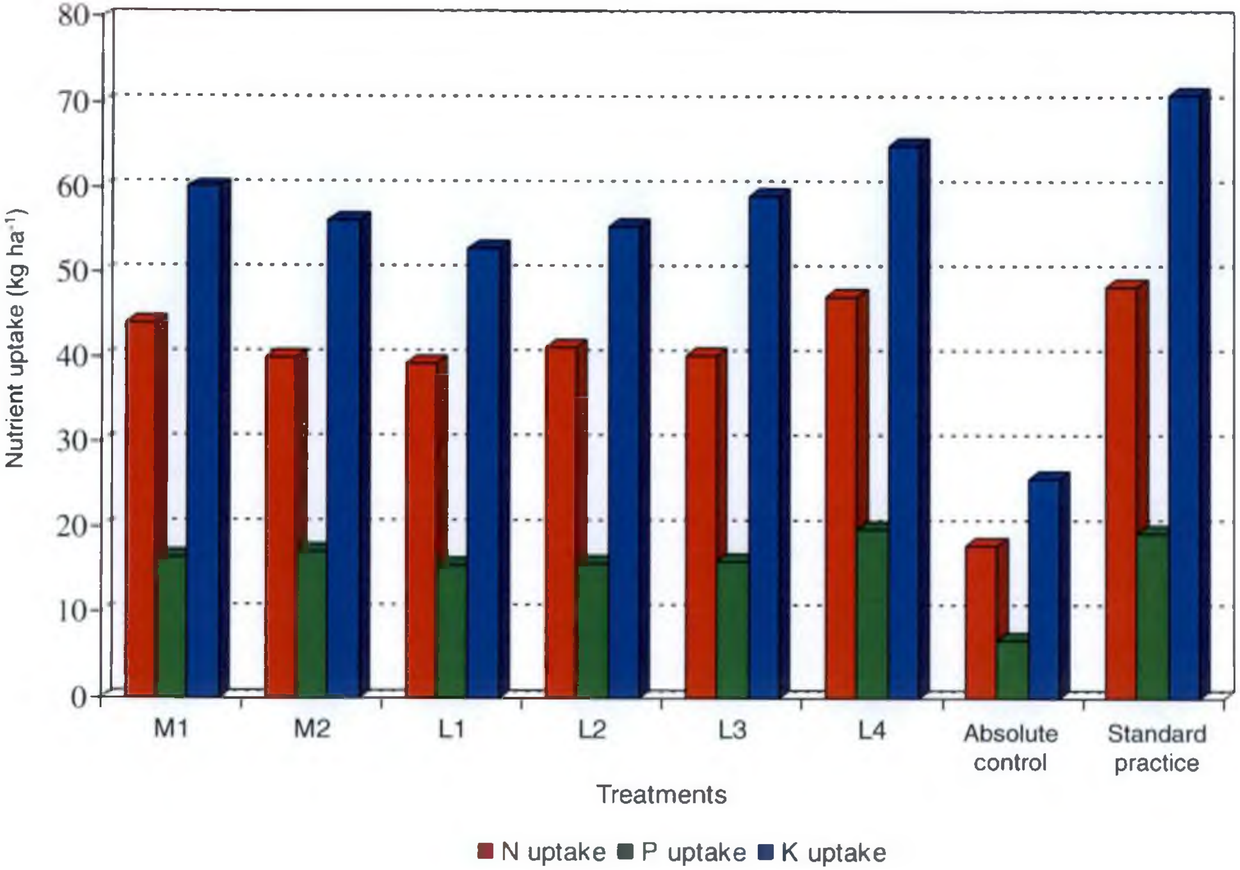


Fig. 10. Effect of organic sources and levels of substitution on NPK uptake (kg ha^{-1})

improved the availability of K in the soil. This might have improved the K uptake of plants as reported by Charjan and Gaikwad (2005).

In general, nutrient uptake values were related to the crop yield levels. As the dry matter accumulation increased, nutrient uptake was also observed to increase. This is in accordance with the findings of Fageria and Baligar (2005) who have stated that nutrient accumulation pattern in plants followed dry matter accumulation.

5. 8 NITROGEN USE EFFICIENCY

Among the different indicators used to assess the NUE, the agronomic efficiency and the apparent recovery efficiency were found to be influenced significantly by the treatments. The physiological efficiency, agro physiological efficiency and utilization efficiency remained unaffected.

The treatments comprising 100 percent substitution (L_4) and 50 percent substitution (L_2) were agronomically more efficient (Fig.11). Agronomic efficiency reflects, the production achieved per kg of nutrient applied. Application of organic manures either alone or in combination with chemical fertilizers yielded better agronomic efficiency in rice (Chakraborty et al., 2001).

Comparing the treatments including the controls the treatment combination, l_2m_2 was found to exhibit higher agronomic efficiency and was on a par with the standard practice. Murwira and Kirchmann (1993) reported that nutrient use efficiencies increased with the complementary applications of organic manures and chemical fertilizers. The beneficial effect of including neem cake as reported by Porwal et al. (1994) and Chaudhary et al. (2006) might be due to its effect as a nitrification inhibitor and thereby improving and prolonging the continuous availability of nitrogen to the crop.

The organic sources and the levels of substitution had significant impact on the apparent recovery efficiency of nitrogen, with FYM and 100 percent substitution exhibiting superiority (Fig.11). When the treatment combinations including the

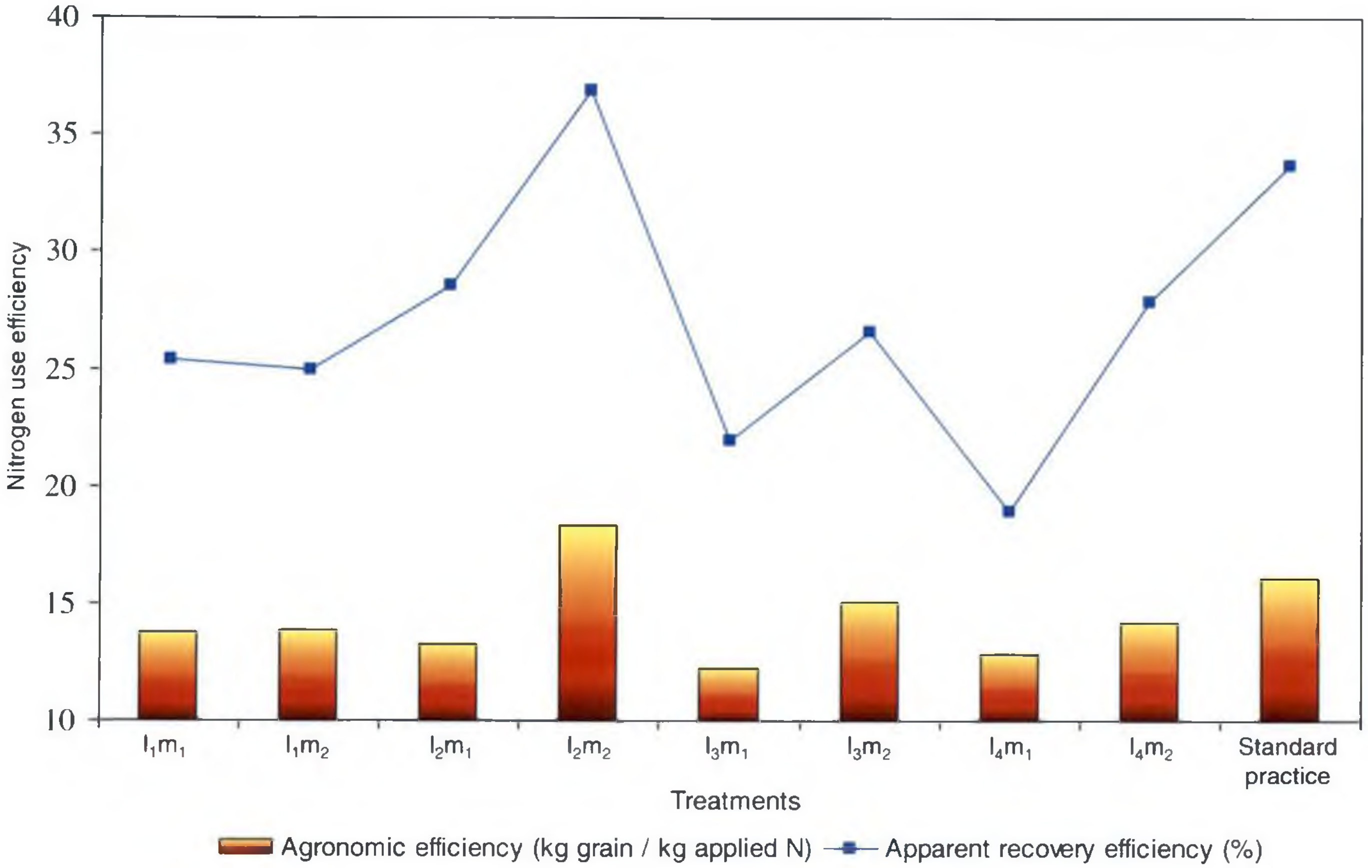


Fig. 11. **Interaction effect of organic sources and levels of substitution including controls on the nitrogen use efficiency**

controls were compared, l_2m_2 was found to be the best and was at par with the standard practice. Integrated approaches of organic and inorganic nutrient management have shown increased efficiency of applied fertilizer in rice (Buresh and De Datta ,1991). This has been attributed to the continuous supply of nitrogen in the presence of organic manures and tying up of inorganic nitrogen preventing its loss through denitrification, volatilization or leaching. Khan et al. (2006) reported a higher recovery efficiency of applied nitrogen in the presence of organic manures and have attributed it to the minimal loss of nitrogen in case of organic sources. In the present study the presence of neem cake might have also helped in reducing the loss of nitrogen as suggested by Chaudhary et al. (2006).

The effect of organics in improving the NUE has been summarized by Bondietti et al. (1972). Accordingly, the amino compounds such as proteins, peptides, aminoacids and amino sugars formed during the decomposition of organic matter is partially stable against microbial degradation and thus, serve as a source of slow release nitrogenous material for plant nutrition. Further, the quinones, degradation products of humic acid have nitrification inhibition property. Thus, organic manure application enables slow release of nitrogen for the rice crop and thereby improve the NUE.

5.9 SOIL FERTILITY STATUS AFTER THE EXPERIMENT

The organic carbon content of the soil remained unaffected by the different treatment combinations.

The treatments and their interactions fail to have any significant effect on available nitrogen status of the soil. However, the comparison made among the treatment combinations including controls proved to be significant. The absolute control recorded a low available nitrogen status of soil. Similar increase in the available nitrogen content of the soil due to the application of organics were reported by Sharma et al. (1987), Roul and Mahapatra (2006) and Singh (2006).

Significant difference was not observed in the available phosphorus status of the soil, among the treatments and controls. Between the two controls, the absolute

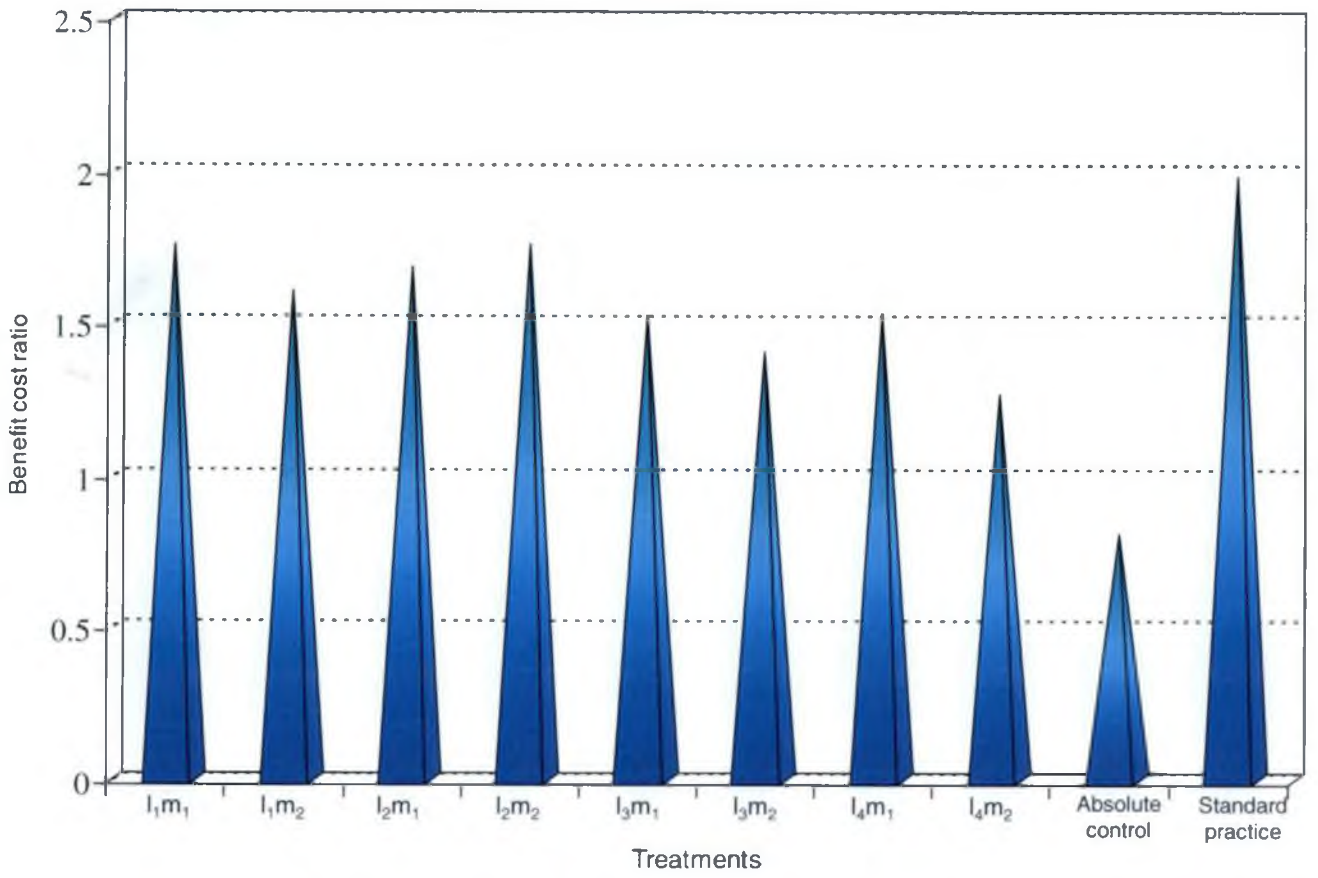


Fig. 12. **Interaction effect of organic sources and levels of substitution including controls on the benefit cost ratio**

control, maintained a higher available phosphorus status in the soil. This may be due to the poor uptake values recorded by this treatment.

The available potassium status of the soil was significantly higher, when chemical fertilizers were substituted with a combination of FYM + neem cake as compared to the application of FYM alone. Prakash et al. (2003) observed that application of organic manures including oilcakes, in basmati rice cultivation, improved the available nutrient status of the soil.

5.10 ECONOMICS OF CULTIVATION

The use of FYM (M_1) alone for substituting with the chemical fertilizers was higher in terms of net income, and BCR. The different levels of substitution and their interaction had no significant effect. Similar results were reported by Sudha (1999). Integration of neem cake along with FYM (M_2) had favourable effects on crop growth and yield. But, application of neem cake increased the cost of cultivation considerably. Based on the nitrogen content and price of FYM and neem cake, it was found that, while application of 1kg of nitrogen as FYM required Rs. 110, an amount of Rs. 350 was required to supply the same quantity of nitrogen as neem cake.

The absolute control showed a loss with a benefit cost ratio of less than 1 (Fig.12). Yadav et al. (1998) reported on an average 57 percent yield reduction in rice under unfertilized plots. The standard practice gave high BCR of 1.98. Though the interactive effect was not significant, among the treatment combinations, l_2m_2 (50 percent substitution with FYM + neem cake) recorded the highest BCR, which was on a par with l_1m_1 (25 percent substitution with FYM). Several workers have established the remunerative effect of integrated nutrient management on the economics of cultivation of rice. Barik et al. (2006) observed higher net returns and BCR when 50 percent of the recommended dose of fertilizers was substituted with FYM. Singh et al. (2006b) also reported that even though the cost of cultivation was marginally higher under integrated nutrient management, it resulted in higher net income and BCR.

Summary

6. SUMMARY

A study entitled 'Integrated nutrient management for Basmati rice (*Oryza sativa* L.) production' was taken up at the Cropping Systems Research Centre, Karmana, Thiruvananthapuram, Kerala, from September 2006 to January 2007, with the objective of assessing the agronomic and economic feasibility of adopting integrated nutrient management in basmati rice.

The experiment was laid out in a (4 x 2) + 2 Randomised Block Design with three replications. The treatments comprised two organic sources (M_1- FYM, M_2- FYM + neem cake), four levels of inorganic substitution with organics (L_1- 25 percent substitution, L_2- 50 percent substitution, L_3 - 75 percent substitution, L_4 -100 percent substitution) compared against two controls (absolute control, standard practice). There were a total of ten treatment combinations including the two controls. The test variety was Pusa Basmati-1. The salient findings of the study are summarized below.

Substituting the entire quantity of chemical fertilizers with organics recorded an appreciable increase in plant height at the maximum tillering stage. The effect of organic sources was not significant. Among the treatment combinations, the plants in l_2m_2 (substituting 50 percent of SDF with FYM + neem cake) were significantly taller at maximum tillering stage.

The tiller count was significantly influenced by the different levels of substitution, at the panicle initiation and flowering stages, with 100 percent substitution with organics proving to be the best. It was at par with 50 percent substitution. These treatments were equally effective as the standard practice. The interactive effect of the organic sources over the levels of substitution was not significant. Substituting 50 percent of SDF with FYM + neem cake recorded the maximum tiller count at panicle initiation, flowering and harvest.

Among the levels of substitution, 100 percent and 50 percent substitution levels were equally effective in increasing the LAI, recorded at harvest. Both at flowering and harvest stages, substituting 50 percent SDF with FYM and neem cake was observed to be as efficient as the standard practice in optimizing the LAI.

Compared to the percentage of biomass accounting for the root weight, the biomass partitioned towards the shoot and panicles varied significantly between the organic sources and levels of substitution. Substitution of inorganics with FYM (M_1) and 25 percent substitution (L_1) recorded higher shoot biomass. Application of FYM + neem cake (M_2) and 50 percent substitution with organics (L_2) resulted in higher panicle biomass. The L x M interaction was not significant with respect to biomass partitioning.

Maximum number of productive tillers was recorded with 100 percent substitution of SDF, both at the flowering and harvest stages. At harvest, 50 percent substitution was at par with 100 percent substitution. The L x M interaction was significant at harvest. The treatment combination, wherein 50 percent of SDF was substituted with FYM + neem cake (l_2m_2) proved superior.

Neither the treatments nor their interactions could significantly influence the panicle weight and thousand grain weight. Substituting SDF with organics significantly increased the number of spikelets per panicle, with equal effectiveness at 100 percent and 50 percent substitution levels. The L x M interaction was significant. Fifty percent substitution with FYM + neem cake (l_2m_2) recorded maximum number of spikelets per panicle.

The sterility percentage was less when FYM was applied in combination with neem cake. The L x M interaction was not significant. The absolute control recorded the highest sterile grain percentage.

The substitution levels, 100 percent and 50 percent, were equally effective in increasing the grain yield, with 100 percent substitution recording the highest grain yield. The effect of organic sources and its interaction with the levels of substitution was not significant. The treatment combinations when compared after taking into account the controls also, revealed that substituting 50 percent of the SDF with FYM + neem cake (l_2m_2) gave a higher yield which was at par with the standard practice.

The variation observed in the straw yield was not significant with respect to the organic sources, levels of substitution and their interaction. The standard practice recorded a higher straw yield than the absolute control.

Neither the treatments nor their interaction had any significant influence on the harvest index. The comparison between treatment combinations including controls proved significant, with 50 percent substitution of SDF with FYM + neem cake and and 100 percent substitution with FYM recording the highest harvest index of 0.44 .

The incidence of bacterial leaf blight disease was more or less uniform, in all the treatment combinations including controls.

The cooking properties, assessed in terms of the optimum cooking time, volume expansion ratio and grain elongation ratio were unaffected by the treatments and their interaction. However; the general trend noticed was a lower cooking time and a higher elongation ratio at 50 percent substitution of SDF with organics. The absolute control took longer to cook and had lower volume expansion ratio. There was no apparent difference in the cooking properties of the market sample and treatments. Thus integrated nutrient management proved its efficiency in producing quality grains.

Among the chemical properties, the crude protein content was significantly higher with FYM (M_1) and 100 percent substitution with organics (L_4). The other levels of substitution were at par. Substituting 50 percent of SDF with FYM + neem cake yielded the highest crude protein content. The total starch content was highest at 75 percent substitution (L_3) and was at par with 25 percent and 100 percent substitution levels. While the treatments and the treatment combinations recorded intermediate amylose content, the controls (absolute control, standard practice) recorded higher amylose content, which was undesirable. The variation in the amylopectin content of the grains was relative to the total starch and amylose contents. The treatments and their interactions as compared to the market sample did not show any marked difference.

In the organoleptic test, the appearance, colour, flavour, doneness and taste of the grains were ranked. Substituting 75 percent of SDF with FYM and neem cake (l_3m_2) followed by 50 percent substitution with FYM + neem cake (l_2m_2) was ranked to be the best in appearance, colour and taste. Fifty percent substitution with FYM + neem cake (l_2m_2) resulted in the best flavour .The grains from the standard practice ranked first with regard to doneness, followed by l_3m_2 and l_2m_2. The market sample ranked fifth in terms of appearance, colour, doneness and taste and fourth in terms of flavour. This showed that integrated nutrient management was effective in improving the grain quality parameters, which have a direct bearing on the consumer preference and acceptability.

The germination percentage did not vary significantly among the different treatments. The treatment means, when compared against the control means showed a significant difference in the seedling vigour. The seedlings that emerged out of the seeds from the treatment combinations were more vigorous with a vigour index of 108.60 compared to the controls, which had a vigour index of 82.56. The seeds from the standard practice produced seedlings that were more vigorous than those from the absolute control.

Nitrogen and potassium uptake revealed similar trends. FYM recorded significantly higher uptake values for nitrogen and potassium. The effect of levels of substitution and L x M interaction was not significant. The levels of substitution significantly influenced the phosphorus uptake. Phosphorus uptake was the highest at 100 percent substitution with organics (L_4). Between the treatment combinations including controls, 50 percent substitution with FYM + neem cake (l_2m_2) resulted in better nutrient uptake and was at par with the standard practice.

Substituting the entire SDF with organics resulted in the highest nitrogen use efficiency, in terms of the agronomic efficiency and was at par with the 50 percent substitution level. Both the organic sources and the levels of substitution had significant impact on the apparent recovery efficiency of nitrogen. FYM (M_1) and 100 percent substitution with organics (L_4) recorded the highest ARE. Between the treatments including controls, AE and ARE were the highest at 50 percent substitution with FYM + neem cake (l_2m_2), which was at par with the standard practice. The treatments failed to have any impact on physiological efficiency, agro physiological efficiency and utilization efficiency of nitrogen.

The organic carbon did not vary significantly among the different treatments. The available nitrogen and phosphorus content of the soil remained unaffected by the different treatments and their interactions. Among the treatment combinations including controls, all the treatment combinations and the standard practice were significantly superior to the absolute control, in terms of available nitrogen. The combined application of FYM and neem cake resulted in more of available potassium in the soil, compared to the application of FYM alone. The effects of levels of substitution and L x M interaction were not significant with regard to the available potassium status of soil.

While the different levels of substitution could not bring significant variation in the net income and BCR, substitution of chemical fertilizers with FYM (M_1) proved to be more remunerative than a combination of FYM + neem cake (M_2). The comparison made between treatments including controls, showed that the BCR recorded by the standard practice (1.98), 25 percent substitution with FYM 1.74 (l_1m_1) and 50 percent substitution with FYM + neem cake (1.75) were at par.

The present investigation indicated a positive response of basmati rice to integrated nutrient management and organic nutrition. It could be observed that substituting 50 percent of the SDF with a combination of FYM + neem cake was beneficial in improving the grain yield, nutrient uptake, nitrogen use efficiency, crude protein content and recorded relatively better organoleptic ranking and BCR. This treatment combination was mostly at par with the standard practice. The study also showed that 100 percent organic nutrition was also possible in basmati rice without much yield reduction.

Future line of work

1. The same study needs to be repeated for conformity of results.

2. Studies are needed to assess the long term impact of INM on the production potential and quality of basmati rice.

3. Attempts can be made to evolve site specific nutrient management strategies for basmati rice.

4. Keeping in view the premium price for organically produced basmati, efforts are to be taken to develop location specific organic production packages for basmati.

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* Originals not seen

Appendix

APPENDIX – I

Weather parameters during the cropping period (September, 2006 to January, 2007)

Standard week	Maximum temperature (°C)	Minimum temperature (°C)	Mean relative humidity (%)	Rainfall (mm)	Evaporation (mm day^{-1})
38	29.7	22.8	88.5	167.0	2.4
39	30.3	23.0	85.8	105.4	4.2
40	30.4	23.1	88.3	39.9	4.6
41	30.5	23.0	87.2	86.1	3.3
42	30.4	22.7	87.8	176.9	3.2
43	29.6	22.8	89.0	194.3	3.0
44	29.4	22.3	88.9	110.8	2.9
45	30.0	23.4	87.9	46.6	2.7
46	29.9	23.1	89.2	54.3	2.9
47	31.3	22.3	84.5	82.7	2.4
48	31.8	23.1	84.4	23.6	3.4
49	30.8	21.8	81.1	0.0	3.1
50	31.6	22.4	85.4	6.0	3.1
51	31.4	22.6	81.9	0.0	3.4
52	32.2	21.6	82.1	0.0	3.8
01	31.3	19.9	77.2	0.0	4.2
02	31.9	22.1	78.0	0.0	4.4
03	32.2	21.7	77.2	0.0	4.2
04	31.2	21.2	79.3	0.6	4.3
05	31.9	22.0	79.0	0.0	4.4

INTEGRATED NUTRIENT MANAGEMENT FOR BASMATI RICE (*Oryza sativa* L.) PRODUCTION

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ABSTRACT

A study entitled "Integrated nutrient management for basmati rice (*Oryza sativa* L.) production" was undertaken at the Cropping Systems Research Centre, Karmana, Thiruvananthapuram, Kerala, from September 2006 to January 2007, with the main objective of evaluating the relative efficiency of different integrated nutrient management practices on the yield and quality of basmati rice.

The experiment was laid out in (4 x 2) + 2 Randomized Block Design with three replications. The treatments comprised two organic sources (M_1- FYM, M_2- FYM + neem cake) and four levels of inorganic substitution with organics (L_1- 25 percent substitution, L_2- 50 percent substitution, L_3 - 75 percent substitution, L_4 -100 percent substitution.) compared against two controls (absolute control, standard practice). The test variety was Pusa Basmati-1.

The response of the growth characters (plant height, tiller count and LAI) was more pronounced with respect to the levels of substitution than the organic sources. Substituting the entire quantity of the standard dose of fertilizers (SDF) and 50 percent substitution of SDF with organics were more or less equally effective in boosting the vegetative growth of basmati rice.

Between the two organic sources tried, the application of FYM and among the levels of substitution, 25 percent substitution recorded higher shoot biomass. The combined application of FYM + neem cake (M_2) and 50 percent substitution of SDF with organics (L_2) resulted in higher panicle biomass.

The higher number of productive tillers, spikelets per panicle and a lower sterility percentage supported by substituting 50 percent of SDF with FYM + neem cake, reflected upon the grain yield also. This treatment combination was at par with the standard practice.

Though the cooking properties were not influenced by INM, in general, the optimum cooking time was lower and the volume expansion and grain elongation ratios were higher at 50 percent substitution of SDF with organics. Integration of chemical fertilizers and organics maintained a higher crude protein and intermediate amylose content. The organoleptic test rankings were higher for 75 percent and 50 percent substitution with FYM + neem cake. Integrated nutrient management was observed to produce grains, which were as good as or even better than the market sample, with the respect to grain quality attributes studied.

Application of FYM to the substitute chemical fertilizers resulted in higher uptake of nitrogen and potassium. The phosphorus uptake was maximum with 100 percent organic nutrition.

The agronomic efficiency and apparent recovery efficiency of basmati rice improved significantly when 50 percent of the chemical fertilizers were applied as FYM + neem cake. This treatment was at par with the standard practice.

The organic carbon, available nitrogen and available phosphorus status of the soil remained unaffected after the experiment. Application of FYM in conjunction with neem cake as a substitute for chemical fertilizers, improved the available potassium status of the soil.

Considering organic sources tested, application of FYM was more remunerative than the combined application of FYM + neem cake. The effect of substitution on net income and BCR was not significant. Between the various treatment combinations including controls, the standard practice, 25 percent substitution of chemical fertilizers with FYM and 50 percent substitution fertilizers with FYM + neem cake were at par.

The study indicated that the response of basmati rice to INM was at par with the standard practice. However, considering the multifaceted benefits of organics, on crop yield, quality and soil health, integrated nutrient management needs to be emphasized. Thus it could be concluded that, the treatment combination where in 50 percent of the standard dose of fertilizers was substituted with a combination of FYM and neem cake, was a better option than the application of chemical fertilizers alone for achieving higher yields and quality in basmati rice.

Substituting the entire dose of chemical fertilizers with organics (L_4) was found to improve the growth, yield, nitrogen use efficiency and nutrient uptake in basmati rice. The volume expansion and crude protein content were better at 100 percent organic nutrition. Thus the present study also revealed the possibility of adopting organic nutrition in basmati rice without any appreciable reduction in yield and quality.