NUTRIENT MANAGEMENT FOR YIELD IMPROVEMENT OF TRANSPLANTED RICE (*Oryza sativa* L.) IN THE SOUTHERN REGION OF KERALA

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled **"Nutrient management for yield improvement of transplanted rice (*Oryza sativa* L.) in the southern region of Kerala"** 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 to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Sudha

VELLAYANI SUDHA.B

10-12-1999.

...........to my parents

CERTIFICATE

Certified that this thesis entitled "**Nutrient management for yield improvement of transplanted rice (*Oryza sativa* L.) in the southern region of Kerala**" is a record of research work done independently by Ms.Sudha.B 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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EXTERNAL EXAMINER

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ABBREVIATIONS USED IN THIS THESIS

@ .... at the rate of

cm .... centimetre

cv .... cultivar

^{0}C .... degree celsius

DAT .... days after transplanting

FYM .... farmyard manure

Fig. .... figure

g .... gram

ha .... hectare

HI .... harvest index

INM .... integrated nutrient management

kg .... kilogram

kg ha^{-1} .... kilogram per hectare

LAI .... leaf area index

m .... metre

m^2 .... square metre.

mg g^{-1} .... milligram per gram

NPK .... nitrogen:phosphorus:potassium

ppm .... parts per million

PPR .... package of practices reccomendation

S .... sulphur

t .... tonnes

Introduction

INTRODUCTION

The rice crop in India, accounts for about 22 per cent of the total cropped area under cereals and about 31 per cent of the total area under food grains. Rice forms roughly 46 per cent of the total output of cereals and 41 per cent of India's output of grains. It is grown in an area of about 43 million ha and is the staple food of more than 50 per cent of the population. With the current grain production of about 198 million tonnes India will have to add about 35 million tonnes by 2002, to meet the food needs of the large expanding population. Out of this 35 million tonnes, 20-25 million ton enhancement is expected from rice and wheat. According to Pillai (1996), to sustain the present level of self sufficiency, about 3.3 million tonnes of rice has to be added annually which is equivalent to about 3 to 3.5 percent of annual growth.

With the introduction of high yielding varieties, India has been witnessing a progressive growth in rice production. The production of milled rice during 1997-98 was 82.3 million tonnes and with the present growth rate it could be safely assured that the projected target of 95-100 million tonnes of rice by 2000 AD would be achieved. While the projected target of rice is necessary for the food security, there are serious doubts as to its social and economic sustainability. The shrinking crop area, fast degenerating natural source base, decrease in use of on farm inputs, inadequate infra structure facilities, irrigation water use, post harvest technology, marketing awareness etc and dwindling input-output ratio renders rice farming less remunerative. According to Singh (1999) the output of rice in India is not showing any signs of growth in recent years with production stagnating at around 82 million tonnes. At present, India is one of the largest exporters of rice in the world but if nothing is done to improve the yield, by 2005 the country may turn into an importer of rice.

In Kerala, out of the total gross cropped area of 30.42 lakh ha, only 22 per cent is under food crops (Anon, 1997). Kerala which is chronically short in food grain production, is confronted with a serious problem of retaining even this small area. Despite Governmental support for rice production, the mid seventies onwards witnessed a change in cropping patterns. Conversion of prime paddy fields for urban, industrial and other non-agricultural use was rampant. A large chunk of paddy fields gave way for cultivation of cash crops like coconut, arecanut, banana, tapioca and even plantation crops like rubber without any regard to the parameters for sustainable cultivation of these crops. The total rice area witnessed a sharp fall from 8.74 lakh ha in 1972-73 to 4.31 lakh ha in 1996-97 (Anon, 1997).

Though the average yield of rice in Kerala is slightly better than the National average, the yield of high yielding varieties is lower at 3028 kg ha^{-1} against 3465 kg ha^{-1} at the National level and very much lower than their potential productivity of 5 to 6 t ha^{-1}. This low productivity of HYVs amply justifies the poor coverage of HYVs in the state at 36 per cent inspite of the efforts made during the last three decades. The low realised yields and poor adoption of the recommended HYVs necessitate identification of technologies for maximising the productivity of HYVs in the cultivator's field. It is observed that the HYVs grown at present are responding to higher levels of NPK than what is recommended (Channabasavanna *et al.*, 1996). Sanker *et al.* (1988) reported the optimal fertilizer requirement of N, P_2O_5 and K_2O doses for varying soil test values of N, P and K to achieve maximum yield or maximum profit per ha.

Apart from the three major nutrients, the secondary nutrient sulphur too is gaining international importance as a result of more frequent occurrence of sulphur deficiencies. Sulphur is found to be absorbed by rice crop in amounts equal to P and is considered essential for the attainment of 90 per cent optimum yield of rice. It is thus being identified as the fourth major nutrient in agriculture. Tandon (1991) reported that sulphur deficient soils are found in all the districts of Kerala which ranged from 20 per cent in Thiruvananthapuram to 55 per cent in Palakkad. Increased use of high analysis fertilizers containing little or no sulphur, multiple cropping and high yielding varieties which remove greater amount of sulphur from the soil, use of crop residues for feed and fuel, declining reserves of soil sulphur and decreased use of sulphur containing pesticides have contributed to the growing need for application of sulphur as a nutrient, which hitherto was not a concern in fertilization.

Higher nutrient levels alone deteriorate soil health and therefore an integration of organic manures and inorganic nutrients is the best solution for yield improvement. The use of organic manures which supplement the chemical fertilizers is a solution for the energy crisis resulting from the degenerating resource base and also for the increasing fertilizer prices which often prevent farmers from using the recommended and balanced proportion of nutrients. Thus a combined use of organic fertilizers is a workable way to save the cost of production. The organic manures like FYM, vermicompost etc in combination with inorganic nutrients help in maintaining the soil fertility and rhizosphere environment by improving the physico-chemical properties of paddy soils without hindering the production of succeeding crop (Tiwari and Tripathi, 1998).

The southern region of Kerala comprises of districts of Thiruvananthapuram, Kollam, Pathanamthitta and Kottayam, where rice is the only cereal crop grown. In Kollam and Thiruvananthapuram, the productivity of rice is less than state average and the fertilizer consumption is low (Anon, 1997). Sulphur deficiency is high in the rice soils of Kollam (80 per cent) and Thiruvananthapuram (64 per cent), as reported by Nair (1995).

As an attempt to standardise the technique of integrated nutrient management for improving the yield of high yielding rice varieties in Kerala, the present investigation was undertaken with the following objectives.

1) To find out the efficacy of organic manures in conjunction with varying levels of NPK nutrients and sulphur in improving rice yields.

2) To work out the economics of cultivation.

Review of Literature

REVIEW OF LITERATURE

An investigation was carried out at Cropping Systems Research Centre (CSRC), Karamana to find out the efficacy of organic manures in conjunction with varying levels of NPK nutrients and sulphur on yield improvement of transplanted rice.

Higher rice yields are reported to be achieved by the combined application of higher doses of organic manures and inorganic nutrients. There are also reports of increased rice yields by the application of sulphur, an important plant nutrient which is becoming deficient in most soils due to intensive cultivation, leaching losses, less organic matter addition and continuous use of sulphur free fertilizers. The present study was thus based on an integrated nutrient supply which is important to sustain higher levels of soil fertility and crop productivity. A brief review on the response of rice towards high yield, by varying the fertilizer dose and organic manure supply as well as sulphur application is presented in this chapter.

2.1 Effect of organic manures on soil productivity and rice yield

2.1.1 Organic manure on soil productivity

Application of organic manures improves the physical, chemical and biological properties of soil.

2.1.1.1 Physical properties

The soil physical properties including bulk density, resistance to penetration, infiltration rate etc. were improved by FYM application (Ganal and Singh, 1990). Application of FYM and crop residues significantly lowered the bulk density of the soil and penetrometer resistance and increased the cumulative infiltration and water holding capacity of soil(Sharma and Sharma, 1994).

Earthworms participate in soil forming process by acting as agents of physical decomposition, promoting humus formation and improving soil structure(Bhawalkar and Bhawalkar, 1993). Kale (1994) reported that the body exudates of earthworms improve the water holding capacity of soils. Singh and Rai (1998) reported that the earthworms made use in vermicompost are effective in aerating soil and improving drainage.

2.1.1.2 Chemical properties

Varghese (1990) reported that application of 80 kg N as FYM increased the pH of soil. According to Rai *et al.*(1990), it is possible to increase the organic C, available K and Ca contents in soil by FYM application. Soil chemical properties including soil pH and CEC were improved by FYM(Ganal and Singh, 1990). Dhargawe *et al.*(1991) reported increased availability of P by the addition of 10 to 20 t FYM ha^{-1}. The application of organic manures increased the soil organic carbon and available N, P and K contents (Sharma and Sharma, 1994).

Bhawalkar (1992) reported that vermicompost application resulted in 37 per cent more N, 66 per cent more P_2O_5, 10 per cent more K_2O, 50 per cent less electrical conductivity and 46 per cent less chlorides than inorganic fertilization, while studying the effect of vermicompost on sugar cane yields. Rahudkar (1993) reviewed the research work on vermicompost and concluded that it contained more amount of essential plant nutrients than FYM and on application to soil, increased the nutrient availability to crop. Raut and Malewar(1995) reported the richness of vermicompost in N, P, K, Ca, Mg and micro nutrient content over farm yard manure. Vasanthi *et al.* (1995) reported that in rice-rice system, application of vermicompost at 5 t ha^{-1} in both the seasons increased the organic carbon content and the available N status of soil by 87.7 and 42.9 per cent respectively. George(1996) reported higher available N, P and K in soil with vermicompost application.

2.1.1.3 Biological properties

Ponomareva(1962) observed that earthworm casts contained large number of micro organisms. There was an increase in actinomycetes and bacteria after the passing of soil through the earthworm intestine. Toyota and Kimura (1992) observed that the number of antagonistic microorganisms among total microorganisms were higher in FYM amended soil than in chemical fertilizer amended soil. Gunathilagaraj and Ravignanam (1996) reported that vermicompost applied to soil harboured rich amount of microbes that degrade and mobilize the nutrients to available form.

2.1.2 Organic manures on growth characters

2.1.2.1 Height of plants

Sharma(1994) opined that plants with FYM application were taller than those grown without FYM. Incorporation of soybean residue increased plant height in the rice variety CR-1009 (Arulmurugan *et al.* 1995).

Significant increase in the plant height of rice variety Pavizham has been reported with FYM @ 10 t ha^{-1} (Babu, 1996). Increased plant heights with vermicompost @ 2.5 t ha^{-1} was reported by Janaki and Hari (1997).

2.1.2.2 Tiller number

Shuxin *et al.* (1991) reported a 10 percent increase in effective tillering in rice due to vermicompost application. According to Sharma (1994) FYM application produced more tillers in rice than in conditions without FYM. Babu (1996) reported that addition of organic manure as 10 t ha^{-1} of FYM had pronounced effect on tiller production in medium duration rice. Janaki and Hari (1997) reported higher production of tillers in rice with 2.5 t ha^{-1} of vermicompost.

Subbiah *et al.* (1983) opined that incorporation of organic residues @ 10 t ha^{-1} had no influence in increasing tiller number $metre^{-2}$ in rice.

2.1.2.3 Leaf area index

Babu (1996) reported that the LAI of medium duration rice variety Pavizham was significantly increased by organic manure addition as 10 t ha^{-1} of FYM.

2.1.2.4 Dry matter production

Incorporation of organic residues @ 10 t ha^{-1} could influence the dry matter production at maturity stage (Subbiah *et al.* 1983). Sharma (1994) opined that rice plants produced more dry matter when grown with FYM application. Krishnamoorthy *et al.* (1994) found that organic manures increased the dry matter production of rice at tillering and flowering stages. Enhanced dry matter accumulation in rice with organic manure addition has been reported by Babu (1996).

2.1.2.5 Chlorophyll content

Rai *et al.* (1990) observed higher chlorophyll content in rice with organic manuring. Organic manuring resulted in a marginal increase in the chlorophyll content of medium duration rice variety Pavizham (Babu, 1996).

2.1.3 Organic manures on yield attributes

2.1.3.1 Panicle number $metre^{-2}$

Farmyard manure as a source of organic manure was effective in increasing the number of panicles m^{-2} in rice (Zia *et al.*, 1992). Sharma and Sharma (1994) reported that incorporation of FYM could increase the number of panicles m^{-2} in rice. Rathore et al. (1995) observed an increase in the panicle number m^{-2} in rice with FYM application than in an unfertilized control. The performance of organic manure applied plots were better than untreated and complete inorganic fertilizers in producing higher number of panicles in rice variety Kanchana (Deepa, 1998).

Senapathi *et al.* (1985) reported increased panicle number m^{-2} in rice with the application of vermicompost. In a study Janaki and Hari (1997) noticed that the panicles $plant^{-1}$ increased twice due to vermicompost application @ 2.5 t ha^{-1}.

Application of organic manures could not significantly influence the panicle number in the medium duration rice variety Pavizham (Babu, 1996).

2.1.3.2 Number of grains $panicle^{-1}$

Sharma and Sharma (1994) reported that FYM addition could significantly increase the grain number $panicle^{-1}$ in rice. Rathore *et al.* (1995) observed significantly higher grain number $panicle^{-1}$ in rice with FYM addition.

Senapathi *et al.* (1985) recorded higher number of grains $panicle^{-1}$ in rice with vermicompost addition. A two time increase in the grain number $panicle^{-1}$ in rice was observed with application of vermicompost @ 2.5 t ha^{-1} by Janaki and Hari (1997).

2.1.3.3 Chaff percentage

Prakash *et al.* (1990) observed considerable reduction in chaff percentage in rice due to organic matter addition. Sharma and Sharma (1994) and Babu (1996) reported that incorporation of FYM could significantly reduce the chaff percentage in rice.

2.1.3.4 Thousand grain weight

Rathore *et al.* (1995) observed significant increase in thousand grain weight of rice with FYM application. According to Deepa (1998) organic manuring in rice field could increase thousand grain weight.

2.1.4 Organic manures on rice yield

2.1.4.1 Grain yield

Chettri and Rai (1988) observed 20 per cent increase in grain yield of rice with FYM @ 7 t ha^{-1}, than in conditions without FYM addition. Zia *et al.* (1992) reported increased grain yields of rice with organic manuring through FYM. Sharma and Sharma (1994) also obtained significantly higher grain yields of rice through FYM incorporation. While studying the effects of FYM application on yield and soil fertility in a rice - wheat rotation, Brar and Dhillon (1994) observed that grain yield of rice reached upto 6.7 t ha^{-1} using 40 t ha^{-1} as against 4.1 t ha^{-1} in control plot. Sharma(1994) observed 26 per cent increase in yield of rice with the application of 10t ha^{-1} of FYM. Rathore *et al.*(1995) reported significantly higher grain yields of rice with FYM addition.

Senapathi *et al.*(1985) recorded 95 per cent increase in grain yield of paddy as a result of vermicompost application. Janaki and Hari (1997) reported that rice gave almost double yield over control when supplemented with 2.5 t ha^{-1} vermicompost.

2.1.4.2 Straw yield

Sharma and Sharma (1994) reported significant increase in the straw yield of rice with FYM incorporation. Babu(1996) could observe significant increase in the straw yield of rice var.Pavizham with FYM addition @ 10 t ha^{-1} . According to Deepa(1998) the straw yield of rice was found better in plots which received organic manure, when compared to treatments which received 100 per cent recommended NPK through chemical fertilizers.

2.1.4.3 Harvest index

Application of organic manure @ 10 t ha^{-1} FYM could not influence the harvest index of rice (Babu 1996).

2.1.5 Uptake of nutrients

In a rice - wheat system, incorporation of FYM increased the NPK uptake both with and without N fertilization in paddy. Varma and Dixit, (1989). Sharma and Mittra (1991) revealed that application of organic materials including FYM could increase NPK uptake in rice.

Uptake of N, P and K by rice was not influenced by the application organic manure even at the rate of 10 t ha^{-1} FYM (Babu, 1996).

2.1.6 Nutrient content in plant

The content of P and K in rice grain didn't differ significantly with or without organic manure addition (Babu, 1996). He also reported that the straw N concentration decreased significantly with 10 t ha^{-1} of FYM application.

2.1.7 Benefit : Cost ratio

Hussain *et al.* (1991) reported highest input cost for the application of 10 t ha^{-1} FYM alone than an integrated approach in rice cultivation.

Higher net return in terms of Rs ha^{-1} was obtained with FYM addition @ 7.5 t ha^{-1} in rice(Singh *et al.* 1998). However the treatment was found on par with FYM @5 t ha^{-1}.

2.1.8 Nutrient substitution by organic manure

Kulkarni *et al.* (1983) reported that application of 12 t of FYM along with 90 kg N ha^{-1} gave comparable yields in rice as that with 120 kg N alone. The results of experiments conducted in rice - wheat crop sequence revealed the possibility of saving N and P by 20 and 40 kg respectively by applying FYM to paddy crop. (Kaushik *et al* . 1984).

Yield of rice obtained with FYM and lower rates of NPK were comparable with NPK @ 120:60:40 kg ha^{-1} (Kavimandan *et al.*1987). According to Khan *et al.* (1988), application of 30 kg N ha^{-1} in the form of FYM at puddling and 30 kg N ha^{-1} as urea at planting gave maximum grain yield of rice; compared to that of 60 kg N ha^{-1} as urea. Verma and Bhagat (1991) suggested incorporation of FYM for saving 50 per cent of inorganic fertilizers in paddy crop.

At Maruteru (A.P) and CSRC, Karamana under rice - rice cropping system, it was found that 50 per cent N substitution through FYM in Kharif followed by application of 100 per cent NPK in Rabi produced significantly higher grain yield than applying 100 per cent chemical fertilizer during both seasons (PDCSR, 1992).

Mathew *et al.* (1993) could obtain a saving in the mineral fertilizer requirement of rice to the extent of $\frac{1}{3}$ dose of N and K_2O and $\frac{2}{3}$ dose of P_2O_5 from a recommended fertilizer dose of 70:35:35 kg NPK ha^{-1}, when FYM was regularly applied in all seasons @ 5t ha^{-1}.

Tiwari and Tripathi(1998) suggested that organic manures could be substituted upto 50 per cent of nutrients along with improvement of physico - chemical properties in paddy soils without hindering the production of succeeding crop. Hegde[1998] reported that in humid ecosystems, all organic sources including FYM were able to substitute 25-50 per cent N needs of rice with significant yield advantage in some cases.

Thakur *et al.* (1999) reported that 25 per cent of applied nitrogen could be saved and chemical fertilizer use can be reduced upto 50 per cent in rice by using a combination of organic and inorganic nutrient sources.

Kale and Bano (1983) suggested the possibility of replacing chemical fertilizers with vermicompost in paddy variety IR-20. Perrura and Cruz (1992) opined that vermicompost was not a substitute for fertilizer, but advantageous to use in combination.

2.2 Effect of higher NPK levels on growth and yield of rice

Sanker *et al.* (1988) reported the optimal fertilizer requirement of N, P_2O_5 and K_2O doses for varying soil test values of N,P and K to achieve maximum yield or maximum profit ha^{-1}.

2.2.1 Effect on rice growth

2.2.1.1 Plant height

Sheela (1993) reported increased height of rice plants when the nutrients were supplied in excess than that of the normal rate. Channabasavanna *et al.* (1996) reported that increase in fertilizer levels from 100:50:50 to 150:75:75

kg NPK ha^{-1} and further to 200:100:100kg ha^{-1} significantly increased the plant height . Significant increase in the plant height of rice was noted with higher NPK level of 120:60:60 over 90:45;45 kg NPK ha^{-1}, at maximum tillering and harvest stages (Babu,1996).

2.2.1.2 Tiller count

Sheela (1993) reported an enhanced growth of rice in terms of tiller number with excess nutrient supply over normal rate. Enhancement of nutrient supply from moderate levels of 90:45:45 to higher levels of 120:60:60 kg NPK ha^{-1} did not yield any advantage on tiller production in rice (Babu, 1996).

2.2.1.3 Leaf area index

Panda and Rao (1991) reported increase in LAI of rice with increase in N rates upto 120 kg ha^{-1}. A significant increase in the LAI of medium duration rice was reported by Babu(1996) with higher NPK levels of 120:60:60 kg ha^{-1} over normal rates of 90:45:45 kg ha^{-1}.

2.2.1.4 Chlorophyll content

Rai *et al.* (1990) observed that increased doses of chemical fertilizers resulted in enhanced production of chlorophyll for performing more photosynthesis. Singh *et al.* (1992) observed a significant increase in the chlorophyll content of rice with N application upto 150 kg ha^{-1}. Higher NPK levels of 120:60:60 kg ha^{-1} could significantly increase the chlorophyll content in rice leaves (Babu,1996).

2.2.1.5 Dry matter production

Significant increase in dry matter accumulation of rice with increase in nitrogen levels from 0 to150 kg ha^{-1} has been reported by Nagre and Mahajan (1981) and Hari *et al.* (1997).

Subbian *et al.* (1989) observed that application of phosphorus at higher rate of 90 kg P_2O_5 ha^{-1} could significantly improve the dry matter accumulation in rice. Rani *et al.* (1997) reported increased dry matter accumulation in rice with increased NPK rates upto 120 : 80 : 40 kg ha^{-1}.

Enhancement of nutrients from normal to higher levels did not influence the dry matter production at 45 DAS in rice (Babu, 1996).

2.2.2 Effect on yield attributes

2.2.2.1 Panicle number $metre^{-2}$

According to Mohapatra *et al.* (1990), the number of panicles m^{-2} could be significantly increased with an enhanced NPK of 80:40:40 kg ha^{-1} than that with 60:30:30kg NPK ha^{-1}. Higher panicle number m^{-2} could be obtained with NPK rate of 100:50:50 over 80:40:40:kg NPK ha^{-1} (Kanungo and Roul,1994). Channabasavanna *et al.* (1996) observed significant increase in panicle number m^{-2} with an enhanced NPK rate of 150:75:75kg ha^{-1} over the normal rate of 100:50;50 kg NPK ha^{-1}.

The highest NPK rate of 100:50:50 kg ha^{-1} in rice could result in significantly higher number of panicles m^{-2} over lower rate of NPK(Turkede *et al.*, 1996). Acccording to Dhiman *et al.*(1997) 150 per cent of the recommended dose of fertilizers could produce significantly higher number of panicles m^{-2} over the recommended dose(120 kg N +60 kg P_2O_5+25 kg $ZnSO_4$), in both the crops in a rice - wheat cropping system.

Babu(1996) reported that with enhanced rate of 120:60:60 kg ha^{-1}, a decreasing number of panicle m^{-2} was observed than that with normal rate of 90:45:45 kg NPK ha^{-1}.

2.2.2.2 Number of grains panicle^{-1}

Significant increase in the grain number panicle^{-1} in rice has been reported by Channabasavanna *et al.* (1996) with higher NPK rates of 200:100:100 and 150:75:75 kg ha^{-1} over that of 100:50:50 kg ha^{-1}

According to Turkhede *et al.* (1996) higher NPK rates of 100:50:50 kg ha^{-1} produced significantly higher number of grains panicle^{-1} in rice over lower rates of NPK. Significantly higher number of grains panicle^{-1} has been reported by Dhiman *et al.* (1997) with 150 per cent of the recommended dose of fertilizers than the recommended dose of 120:60 N and P. According to Singh *et al.*(1998), an increase of 25 per cent over the recommended fertilizer dose of 100:50:50 kg NPK ha^{-1} could bring about a significant increase in both total and filled grain number panicle^{-1}.

According to Kanungo and Roul (1994), with higher NPK rates of 100:50:50 kg ha^{-1}, a reduction in the filled grain number panicle^{-1} was noticed in rice, than with NPK rates of 60:40:40 kg ha^{-1}. Babu (1996) observed that the effect of higher levels of NPK fertilizers on grain number panicle^{-1} was insignificant. Only a marginal increase in grain number was noted with higher rates of NPK.

2.2.2.3 Chaff per centage

According to Babu(1996) there was reduction in chaff per centage of rice, though not significant with higher NPK rate 120:60:60 kg ha^{-1} over the normal rate of 90:45:45 kg ha^{-1}. Asif *et al.* (1997) reported that the rate of occurrence of abortive, opaque and chalky kernels was significantly decreased, whereas the rate of occurrence of normal kernels significantly increased with the optimum fertilizer rate of 130:67:67 kg ha^{-1}.

In another experiment, with rice var.Basmathi-385, Asif *et al.* (1999) recorded lesser number of chaffy grains with NPK rate of 130:67:67 than that with 180:90:90 kg ha^{-1}.

2.2.2.4 Thousand grain weight

Significant increase in the thousand grain weight of rice with increased NPK rate of 200:100:100 kg ha^{-1} was observed by Channabasavanna *et al.* (1996).

Even though not significant, an increasing trend in 1000 grain weight with increased NPK rates has been reported in rice by several workers (Kanungo and Roul, 1994; Turkhede *et al.*, 1996).

Increased dose of chemical fertilizers decreased thousand grain weight in rice (Chandra, 1990 and Babu, 1996). Singh *et al.*(1998) reported a reduction in the 1000 grain weight of rice with 25 per cent increase in the recommended dose of 100:50:50 kg NPK ha^{-1}.

2.2.3 Effect on rice yield

2.2.3.1 Grain yield

While investigating the efficiency of NK combination on nutrient uptake and productivity of IR-50 rice with varying population, Balasubramaniyan and Palaniappan (1992) observed highest grain yield with 150 kg N and 50 kg K_2O ha^{-1}. Among the two NPK rates of 100:50:50 and 150:75:75 kg ha^{-1}, the latter increased the yield of IR-64 rice significantly.(Channabasavanna and Setty,1994). Patnaik and Sathe (1993) reported highest grain yields for rice cv Tellahamsa in a pot culture on red sandy loam soil with 150:100:60 kg NPK ha^{-1} along with 60 kg S ha^{-1} as gypsum.In a study on the response of rice cv. Jagannath to varying levels of NPK, Mishra *et al.*(1993) observed that NPK level of 120:60:60 kg ha^{-1} recorded the highest grain yield of 5.95 t ha^{-1}. Kanungo and Roul (1994) reported that higher grain yield of rice was obtained with an NPK level of 100:50:50 kg ha^{-1}.

Molla *et al.* (1996) studied the influence of different levels of fertilizer management on yield and yield contributing factors in boro rice and reported that most of the modern varieties responded positively upto the highest level of 80 : 60 : 60 kg ha^{-1} of NPK..Channabasavanna *et al.* (1996) studied the response of paddy to fertilizer levels under deep black soils of Thungabhadra project area and reported that increasing fertilizer dose from 100:50:50 to 200:100:100 kg NPK ha^{-1} increased the yield of paddy significantly.

Dhiman *et al.* (1997) obtained higher grain yields of rice with 150 per cent recommended dose of fertilizers than that with 100 per cent recommended dose of 120 kg N and 60 kg $ZnSO_4$ ha^{-1}. In an experiment conducted at Uttar Pradesh, grain yields upto 5.53 t ha^{-1} was obtained with 125 per cent increase in fertilizer dose of 100 : 50 : 50 kg ha^{-1} (Singh *et al.*, 1998). Asif *et al.* (1999) obtained highest grain yields of rice cv. Basmati-385 with an NPK rate of 130:67:67 kg ha^{-1}. Saxena *et al.* (1999) studied the effect of varying NPK levels on ripening ratio in low land rice var, DR-92 and reported the superiority of the NPK level 100:80:60 kg ha^{-1} over control and 60 : 60 : 40 kg NPK ha^{-1}.

Enhanced NPK rates of 120:60:60 kg ha^{-1} produced lower but statically similar yields to the normal rate of 90:45:45 kg NPK ha^{-1} in medium duration rice (Babu 1996).

2.2.3.2 Straw yield

Kanungo and Roul (1994) observed higher straw yields of rice with NPK rate of 100:50:50 kg ha^{-1} over that of 60 : 30 : 30 and 80 : 40 : 40 kg ha^{-1}. According to Turkhede *et al.* (1996) higher straw yields of rice were obtained with NPK applied @ 100:50:50 kg ha^{-1} over lower NPK rates. Babu (1996) could obtain significantly higher straw yields of rice with an enhanced NPK rate of 120 : 60 : 60 kg ha^{-1}. Singh *et al.* (1998) also reported a similar significant effect of 125 per cent of the recommended dose of 100 : 50 : 50 kg NPK ha^{-1}, in increasing the straw yield of rice.

2.2.3.3 Harvest index

Chavan *et al.*(1989) observed low grain : straw ratio with increase in nitrogen application rates. Dhyani and Mishra (1994) reported slight reduction in harvest index with N levels above 60 kg ha^{-1}. According to Hari *et al.* (1997), harvest index of rice decreased progressively with increased N application.

Significant reduction in harvest index has been reported in rice with enhanced fertilizer application of 120 : 60 : 60 kg ha^{-1} (Babu, 1996).

2.2.4 Effect on Nutrient uptake

Munda (1989) observed higher N and P uptake by rice with increase in N levels. Pandey *et al.* (1991) reported significantly higher N,P and K uptake by rice grain and straw with 90 kg N ha^{-1} over 60 and 30 kg N ha^{-1}. Sarmah and Baroova (1994) observed significantly higher N uptake by the highest level of 90 kg N ha^{-1}.

Subbiah *et al.* (1989) observed increase in NPK uptake with increased rates of phosphorus application in rice . In field experiments Aulakh *et al.* (1990) observed that at low levels of P and S, there was synergistic effect on uptake of both, whereas at high levels, antagonistic effect of P x S was noticed. In a pot experiment on sandy loam soil of pH 5.4, Sarkunan *et al.* (1998) observed significantly higher P and S uptake by rice grain with increase in P levels upto 50 mg kg^{-1} soil.

K uptake values revealed a positive upward trend with the increased K application of 100 kg ha^{-1} (Ammal and Muthiah, 1995).

Naphade *et al.* (1995) found that the NPK uptake in sorghum-wheat cropping system was higher with 150 per cent of the recommended NPK rate of 100 : 50 : 40 kg ha^{-1} for sorghum and 120 : 60 : 60 kg ha^{-1} for wheat. The increase in NPK application from zero to a higher level of 120 : 60 : 60 kg ha^{-1} significantly increased the uptake of NPK in rice grain and straw (Babu, 1996). Mishra and Sharma (1997) observed significant increase in the NPK uptake of rice with NPK addition @ 120 : 50 : 40 kg ha^{-1} than that with 60:25:20 kg ha^{-1} NPK.

2.2.5 Effect on nutrient content in plant

Babu (1996) observed significant increase in the N content in grain and straw of rice with an enhancement of NPK rate upto 120 : 60 : 60 kg ha^{-1}. The P concentration in grain was unaffected, but that in straw increased though not significantly. There was significant increase in the K concentration of straw with fertilizer rates upto 120 : 60 : 60 kg ha^{-1}. The concentration of K in grain also showed an increasing trend with high NPK levels, though the effect wasn't statistically significant.

2.2.6 Effect on Soil Productivity

In a pot culture study at Coimbatore, Ammal and Muthaih (1995) observed the highest available N,P and K in soil by the highest K level of 100 kg ha^{-1}. There was significant increase in the available N, P and K status of soil with NPK @ 120 : 50 : 40 kg ha^{-1} over that with 60:25:20 kg ha^{-1} (Mishra and Sharma, 1997).

2.2.7 Effect on benefit : cost ratio

Kanungo and Roul (1994) could obtain the highest benefit : cost ratio of 1.49 with NPK @ 100 : 50 : 50, over 1.39 obtained with 80:40:40 kg NPK ha^{-1} in rice. According to Channabasavanna *et al.* (1996), NPK @ 200 : 100 : 100 kg ha^{-1} recorded the highest net returns in terms of Rs ha^{-1}, followed by 150 : 75 : 75 and 100 : 50 : 50 kg NPK.

Mishra and Sharma (1997) noticed a slight decline in benefit : cost ratio with increase in fertilizer dose from 60:25:20 kg NPK ha^{-1} to 120:50:40: kg NPK ha^{-1}. Similarly Singh *et al.* (1998) could observe a reduction in net returns (Rs ha^{-1}) in a rice system with 25 per cent increase in NPK rates over the recommended dose of 100:50:50 kg ha^{-1}.

2.3 Effect of sulphur on rice nutrition

2.3.1 Effect on growth characters

2.3.1.1 Plant height

In soil containing 33ppm S, Karim and Khan (1958) observed increase in height of rice plants with sulphur applications upto 28 kg ha^{-1}. Several scientists have reported that rice plants become shorter under S deficiency (Howard and Ensminger, 1962; Suzuki, 1978; Blair *et al.*, 1978).

Muraleedharan and Jose (1993) observed that in rice var.Jyothi, applications of 10 kg S ha^{-1} increased the plant height. Nair (1995) reported the progressive and significant increase in height of rice var.Jyothi upto 30 kg S ha^{-1} in Kerala.

2.3.1.2 Tiller Number

Deficiency of sulphur reduces the number of tillers in rice. (Suzuki, 1978; Blair *et al.*, 1978). Blair *et al.*(1979) found that tiller number at active tillering, maximum tillering and maturity stages significantly and progressively increased upto 80 kg S ha^{-1}. Ahmed *et al.*(1988) observed significant increase in tiller production of rice with sulphur levels upto 30 kg S ha^{-1} and a reduction in the same with higher sulphur rates of 60 kg ha^{-1}.

Significantly higher tiller number in rice has been reported with 10 kg S ha^{-1} (Muraleedharan and Jose, 1993). According to Nair (1995), the number of rice tillers per hill at maturity significantly increased due to sulphur application upto 30 kg ha^{-1}.

2.3.1.3 Leaf Area Index

Karim and Khan (1958) observed increase in LAI of rice with S addition @ 28 kg ha^{-1}. Howard and Ensminger (1962) reported reduction in LAI of rice under S deficiency. George (1989) found higher LAI of rice with sulphur application. Nair (1995) could observe progressive and significant increase in LAI of rice upto 30 kg S ha^{-1}.

2.3.1.4 Chlorophyll content

Nanawati *et al.* (1973) observed that chlorophyll content of rice got significantly reduced under conditions of S deficiency. A deficiency of sulphur in rice makes it chlorotic at tillering (Suzuki, 1978).

2.3.1.5 Drymatter production

Suzuki (1978) observed significantly higher dry matter production in rice with sulphur application. Increase in dry matter production at active and maximum tillering and at harvest stages were observed by Blair *et al.* (1979) due to S application. Higher dry matter production has been reported in upland rice by the application of S @ 20ppm (Gupta and Otoole, 1986). Dry matter yield of rice increased by 47.1 per cent with S application when the total sulphur in plant was less than 0.13 per cent (Islam and Buiyan, 1988).

In an experiment conducted at Mannuthy with the rice cv. Jaya, George (1989) observed higher dry matter production with S application. Nair (1995) reported significantly higher dry matter production with higher S levels upto 30 kg ha^{-1}.

2.3.2 Effect on yield attributes

According to Chowdhury and Majumdar (1994) the yield attributes of rice were significantly influenced by S application irrespective of source and dose.

2.3.2.1 Panicle number m^{-2}

There was progressive increase in panicle number of rice with S application upto 20 kg ha^{-1} (Ismunadji *et.al.*, 1987). According to George (1989), S application increased the panicle number $hill^{-1}$ in rice. Sulphur levels made a significant increase in the panicle number $hill^{-1}$ in rice cv. Jyothi (Nair, 1995).

2.3.2.2 Number of grains panicle^{-1}

Hossain *et al.*(1987) reported higher number of grains panicle^{-1} for rice with S application. Sulphur application increased the filled grain number panicle^{-1} in rice (Ahmed *et al.* 1989). George (1989) could observe increase in the number of grains panicle^{-1} of rice with S application.

In Kerala, Muraleedharan and Jose (1993) reported that rice variety Jyothi gave higher grain number panicle^{-1} with S @ 10 kg ha^{-1}, compared to control. According to Nair (1995) there was significant increase in the grain number panicle^{-1} in rice with sulphur application.

2.3.2.3 Chaff percentage

The percentage of filled grains increased progressively with S application upto 20 kg ha^{-1}. (Ismunadji *et al.*, 1987). Ahmed *et al.* (1989) also observed an increase in the percentage of filled grains in rice with S application.

2.3.2.4 Thousand grain weight

There was increase in the weight of 1000 grains in rice with S levels upto 20 kg ha^{-1} (Ismunadji *et al.*, 1987). George (1989) found that S application could increase the thousand grain weight in rice. Muraleedharan and Jose (1993) reported that thousand grain weight in rice variety Jyothi was increased with application of 10 kg ha^{-1} S.

Ahmed *et al.* (1989) reported that effect of sulphur application on thousand grain weight of rice was not significant.

2.3.3 Effect on rice yield

2.3.3.1 Grain yield

Nambiar (1985) reported 27 per cent increase in rice grain yield due to sulphur incorporation over optimum NPK input. Based on studies conducted at Atomic Energy Commission farm, Dhaka with different sources of sulphur, Alam *et al.* (1985) reported that sulphur application improved the yield of rice crop.

Ramanathan and Saravanan (1987) reported that sulphur application increase rice yield by 8 to 15 per cent over the yield by nitrogen fertilizer alone. Addition of 50 kg S ha^{-1} as ammonium phosphate sulphate could increase the grain yield of rice from 2.73 t ha^{-1} to 3.7 t ha^{-1}. Hossain *et al.* (1987) reported increased grain yield of rice upto 8.46 t ha^{-1} with 30 kg S ha^{-1}.

Increase in rice yield by sulphur application has been reported by Mamaril *et al.* (1991). He identified ammonium sulphate as superior to other sulphur sources like gypsum, elemental S etc. Ismunadji (1991), while studying the effect of sources and rates of sulphur on rice yields reported the superiority of ammonium sulphate in improving rice yields. Ammonium sulphate at levels upto 32 kg S ha^{-1} recorded significantly higher yields. Higher rice grain yields were obtained with sulphur addition in the form of ammonium phosphate sulphate @ 37.5 kg S ha^{-1} (Clarson and Ramaswamy, 1992).

Raju *et al.* (1994) observed that in a field experiment during the kharif season of 1991 at Maruteri, AP, rice cv. Chaitanya could produce 28.8 and

26.4 per cent increase in grain yields with the application of 25 and 50 kg S ha^{-1} respectively. Mondal *et al.* (1994) observed increase in rice yield with S bearing fertilizers over S free fertilizers in a field experiment on a sandy clay loam at Kalyani, West Bengal. Haque and Jahiruddin (1994) reported higher crop yields in a continuous rice cropping system on loam soil at Bangladesh with 20 kg ha^{-1} S application.

Zia *et al.* (1995) reported that ammonium sulphate produced better grain yields in rice over urea application. Nair (1995) reported increased grain yield of medium duration rice by the application of 30 kg S ha^{-1}. Sahu *et al.* (1996) observed maximum grain yield in rice with sulphur application @ 30 kg ha^{-1}. In two field experiments one in black soil and other in laterite soil using rice varieties Jajati and Lalit at Orissa, Sahu and Nanda (1997) reported that grain yield increased upto 5.06 t ha^{-1} and 4.26 t ha^{-1} in black and laterite soil respectively with S @ 40 kg ha^{-1} for black soil and 60 kg ha^{-1} for laterite soil. Field trials conducted in the states of Andra Pradesh, Gujarath, Delhi, Punjab, Rajasthan, Orissa, Tamil Nadu, West Bengal and Uttar Pradesh revealed that S application increased paddy yields under normal conditions by 17 per centage (Ram *et al.* 1997; Malik, 1997).

A field experiment conducted in the Kharif seasons of 1996 and 1997 at RARS, Jammu revealed that application of 10, 20, 30 and 40 kg S ha^{-1} resulted in increased yield of rice by 14.2, 24.2, 25.6 and 20.1 per cent respectively over control (Gupta *et al.* 1998). Sakal *et al.* (1999) reported increased grain yields of rice with sulphur addition in a rice-wheat system and identified 40 kg S ha^{-1} as the optimum level of S for rice.

S application using different fertilizer sources could not make any significant increase in grain yield in a field experiment on a silty clay soil of Bihar using the rice cv. Radha (Thakur *et al.* 1997).

2.3.3.2 Straw yield

Addition of 50 kg S ha^{-1} as ammonium phosphate sulphate increased straw yield of rice by 27 per cent (Vijayachandran, 1987). Increased straw yield upto 9.45 t ha^{-1} was reported by Hossain *et al.* (1987) with 30 kg S ha^{-1}. Increasing levels of S resulted in successive increase in straw yield of rice irrespective of the S source and the maximum yield was obtained with the application of sulphur sludge @ 100 kg ha^{-1} (Malarvizhi *et al.* 1990). Straw yield of rice significantly increased with S application irrespective of the sources and dose (Chowdhury and Majumdar, 1994). Nair (1995) reported increased straw yield of medium duration rice by the application of 30 kg S ha^{-1}. Zia *et al.* (1995) identified ammonium sulphate as superior to urea, in increasing straw yields of rice. Increased straw yield of rice with S application has been reported in rice with 40 kg S ha^{-1} as optimum level (Sakal *et al.* 1999).

2.3.3.3 Harvest index

Nair (1995) studied response of rice to S application and reported higher harvest index for control plots, which could be due to the low straw yield. Kushwaha and Prasad (1998) observed significant enhancement in harvest index of wheat with sulphur dose upto 30 kg ha^{-1}.

2.3.4 Uptake of nutrients

Higher uptake of N, P, K and S were recorded when sulphur bearing fertilizers were used for rice nutrition (Mondal, 1994). S uptake both in straw and grains were better with ammonium sulphate than with urea in rice (Zia *et al.* 1995). Higher S levels enhanced uptake of N, K and S in rice. (Nair, 1995). He also noticed that the increase in P uptake with sulphur application was only upto 20 kg ha^{-1} S and higher S levels significantly reduced P uptake.

Sulphur uptake by rice showed an increase at 25mg S kg^{-1}, but decreased significantly at 50mg S kg^{-1} level. Application of P upto 50mg kg^{-1} enhanced S uptake by grain (Sarkunan *et al.* 1998).

Sakal *et al.* (1999) reported that increasing levels of SSP progressively increased the P and S uptake by rice crop. In another experiment to study the effect of S application on the yield and nutrient concentration in a rice-wheat cropping system for three consecutive years, Sakal *et al.* (1999) reported that increasing S levels increased total N uptake progressively; total K uptake upto 40 kg S ha^{-1} and total P uptake upto 20 kg S ha^{-1}.

2.3.5 Effect of sulphur application on plant nutrient content

2.3.5.1 Nitrogen content

The increasing levels of sulphur concomitantly increased N content in rice plant tissue (Tiwari, 1990). Such synergistic relationship between N and S has been reported by several workers (Sachdev and Deb, 1990: Singh *et al.* 1994; Biswas *et al.* 1995; Chaube and Dwivedi, 1995). According to Nair (1995) the N content in grain and straw of rice increased with the application of higher levels of sulphur. Sakal *et al.* (1999) studied the effect of sulphur on plant nutrient concentrations and reported that S application could significantly increase the N concentration in grain and straw of rice and wheat for 3 consecutive years of study.

2.3.5.2 Phosphorus content

In field experiments, Aulak *et al.* (1990) observed a synergistic effect for P and S, when both were at low levels. However at a high level of 52.5 kg P ha^{-1} antagonistic effect between P and S was noticed. The concentration of P in rice increased significantly with increasing S levels upto 60 kg ha^{-1} (Singh *et al.*, 1994).

Sulphur application decreased P content in grain as well as in straw of rice (Tiwari, 1990). Muraleedharan and Jose (1993) recorded antagonism of P in rice variety Jyothi with the application of sulphur. Phosphorus content in grain and straw decreased with S application non-significantly at lower levels of sulphur and significantly at higher levels (Nair, 1995).

2.3.5.3 Potassium content

Application of sulphur was found to increase the concentration of K in rice (Dev and Kumar, 1982; Singh, 1986 and Singh *et al.*, 1990). According to Nair (1995) potassium content in grain and straw of rice increased by sulphur application upto 40 kg ha^{-1}.

2.3.5.4 Sulphur content

Manchanda *et al.* (1987) found that S content in rice increased from 21 per cent to 43 per cent over control, with S application. According to Tiwari (1990), sulphur application increased S content in grain and straw of rice. Singh et al. (1994) observed that the concentration of S in rice increased significantly with increasing levels of S application, the highest with 60 kg S ha^{-1}. Nair (1995) reported that higher levels of sulphur significantly increased sulphur content in grain and straw of rice. Sakal *et al.* (1999) studied the effect of sulphur on plant nutrient contents for three consecutive years in a rice-wheat system and reported that the application of sulphur significantly increased the S concentration in grain and straw of both crops in all the three years.

2.3.6 Sulphur status of soil after experiment

Mondal *et al.* (1994) reported that fertilizer management with SSP or FYM showed higher positive S balance in rice soil. Singh *et al.* (1994) observed that maximum S availability in soil was brought about by 60 kg S ha^{-1}. Higher levels of S application was thus found to be positively correlated with soil available sulphur. While studying the effect of SSP and DAP on rice based cropping system, Sakal *et al.* (1999) reported that continuous application of SSP raised the soil available S status from deficiency to sufficiency level.

2.3.7 Economics

Sahu and Nanda (1997) conducted field experiments to study the response of rice to S application in the black and latirite soil of Bhubaneshwar.

Maximum profit of Rs 2600/- in black soil and Rs 1830/- in laterite soil were obtained at 60 kg S ha^{-1}. It was observed that any level of sulphur application in black soil and 30 kg ha^{-1} in laterite soil would be economical. In another experiment conducted on a clay loam soil at RARS, Jammu, Wali and Gupta (1997) indicated that recommended NPK of 100 : 50 : 25 kg ha^{-1} when supplemented with S@ 50 and 100 kg ha^{-1}, gave higher net returns.

2.4 Integrated nutrient management on growth and yield of rice

2.4.1 Effect on growth characters

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

2.4.2 Effect on yield attributes

Mondal *et al.* (1994) observed an increase in panicle number m^{-2}, grain number $panicle^{-1}$ and thousand grain weight in rice with increased NPK rates along with FYM application. Mathew *et al.* (1994) while conducting an experiment on INM at RARS Pattambi noticed higher panicle number, filled grains panicle^{-1} and thousand grain weight with 10 t ha^{-1} FYM along with chemical fertilizers in rice variety Jyothi. Patra *et al.* (1998) observed that combining 125 per cent NPK with 10 t ha^{-1} FYM gave higher number of panicles m^{-2} and grain number panicle^{-1} in rice. Singh *et al.* (1998) observed increase in grain number panicle^{-1} and thousand grain weight of rice with higher NPK rates along with 7.5 t ha^{-1}FYM.

2.4.3 Effect on yield

2.4.3.1 Grain yield

Anilakumar *et al.* (1993) obtained a grain yield increase of 7.6 per centage in rice by the combined application of FYM and NPK than application of NPK alone. Mathew *et al.* (1994) observed significantly higher grain yields of rice variety Jyothi with the integrated application of 10 t ha^{-1} FYM along with inorganic nutrients. Rajamannar et al.(1995) concluded that combined application of organic manures with the recommended levels of N increased the grain yields of rice over sole application of organic manures or inorganic nitrogen.

Singh *et al.* (1996) reported that substitution of 25 per centage N through FYM particularly at higher N rates increased rice yields. Babu (1996) reported increased grain yields of medium duration rice upto 5.6 t ha^{-1} with the combined application of organic manures and chemical fertilizers. Rani and

Srivastava (1997) observed higher grain yields of rice with the integration of one third or one quarter of N as vermicompost and the rest as NPK. Roy *et al.* (1997) observed higher grain yields of rice with the combined application of NPK @ 90 : 60 : 90 kg ha^{-1} along with 10 t FYM.

In a field experiment conducted on INM in rice at U.P, higher NPK rates along with 7.5 t ha^{-1} FYM produced very high grain yields of rice (Singh *et al.* 1998). Mondal and Chettri (1998) while studying the effect of INM on productivity and fertility building under rice based cropping system noticed significantly higher grain yield upto 5.3 t ha^{-1} in rice with 50 per cent of recommended NPK through chemical fertilizers along with 10 t ha^{-1} FYM. Saxena *et al.* (1999) reported that NPK @ 100 : 80 : 60 kg ha^{-1} along with 10 t ha^{-1} FYM produced significantly higher yield of rice.

2.4.3.2 Straw yield

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

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.

2.4.4 Nutrient uptake

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

2.4.5 Soil properties

The combined use of 12 t of FYM and 80 kg ha^{-1} of nitrogen not only gave comparable rice yield as that with 120 kg N ha^{-1}, but also gave a residual effect equivalent to 30 kg each of N and P in the succeeding wheat crop (Meelu, 1981 ; Meelu *et al.*, 1981). Kurumthottical (1982) revealed that application of phosphatic fertilizers in combination with organics resulted in higher content of available P compared to inorganic fertilizers alone. Application of FYM conjointly with 100 per cent NPK registered the highest total N, P and K contents in soil (Sheeba and Chellamuthu, 1996). Mishra and Sharma (1997) observed appreciable build up of NPK in soil with the integrated application of fertilizers and FYM.

Mondal and Chettri (1998) studied the effect of INM on productivity and fertility building under rice based cropping systems and reported significantly higher balance of NPK nutrients in soil after the experiment with the integrated application of 10 t ha^{-1} FYM along with the recommended fertilizer dose than that with inorganics alone. Deepa (1998) reported higher status of available NPK of soil at harvest with integrated nutrient management, which supplied 50 per cent of the recommended N through FYM and the rest through chemical fertilizers for rice variety Kanchana.

Materials and Methods

MATERIALS AND METHODS

An investigation was carried out at the Cropping Systems Research Centre (CSRC),Karamana to study the efficacy of organic manures in conjunction with varying levels of NPK nutrients and sulphur on yield improvement of transplanted rice in the southern region of Kerala and to work out the economics.

The experiment was conducted during the first crop season from June to October in the year 1998. The details of the materials used and methods adopted for the study are presented below.

3.1 Experimental site

The experiment was conducted at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, a substation under the NARP(Southern region) of the Kerala Agricultural University. It is located at 8.5°N latitude and 76.9°E longitude and at an altitude of 29m above mean sea level.

3.2 Soil

The soil of the experimental site was sandy loam with pH 5.3, low in cation exchange capacity, high in organic carbon, low in available N and medium in available P and K contents. Soil samples were collected from 30 cm depth and a composite sample was used for the detertmination of physico-chemical properties. The important physico-chemical properties studied are given in Table 1.

3.3 Season

The experiment was conducted during the kharif season of 1998 from June to October.

3.4 Weather conditions

Data on weather conditions like temperature, rainfall and relative humidity were obtained from the Indian Meteorological Department observatory, Thiruvananthapuram. Weather conditions were satisfactory for the proper growth and establishment of the crop. The average values of climatic parameters for the cropping period are given in Appendix-1 and graphically represented in Figure 1. Mean maximum and minimum temperature ranged from 27.5°C to 31.29°C and 22.71°C to 24.29°C respectively. The mean relative humidity ranged from 84.29 to 95.5 per cent. The total rain fall received during the cropping period was 1170mm.

3.5 Cropping history of the field

The field was continuously cultivated with rice since 1995, as per the Package of Practices Recommendations of the Kerala Agricultural University.

3.6 Materials

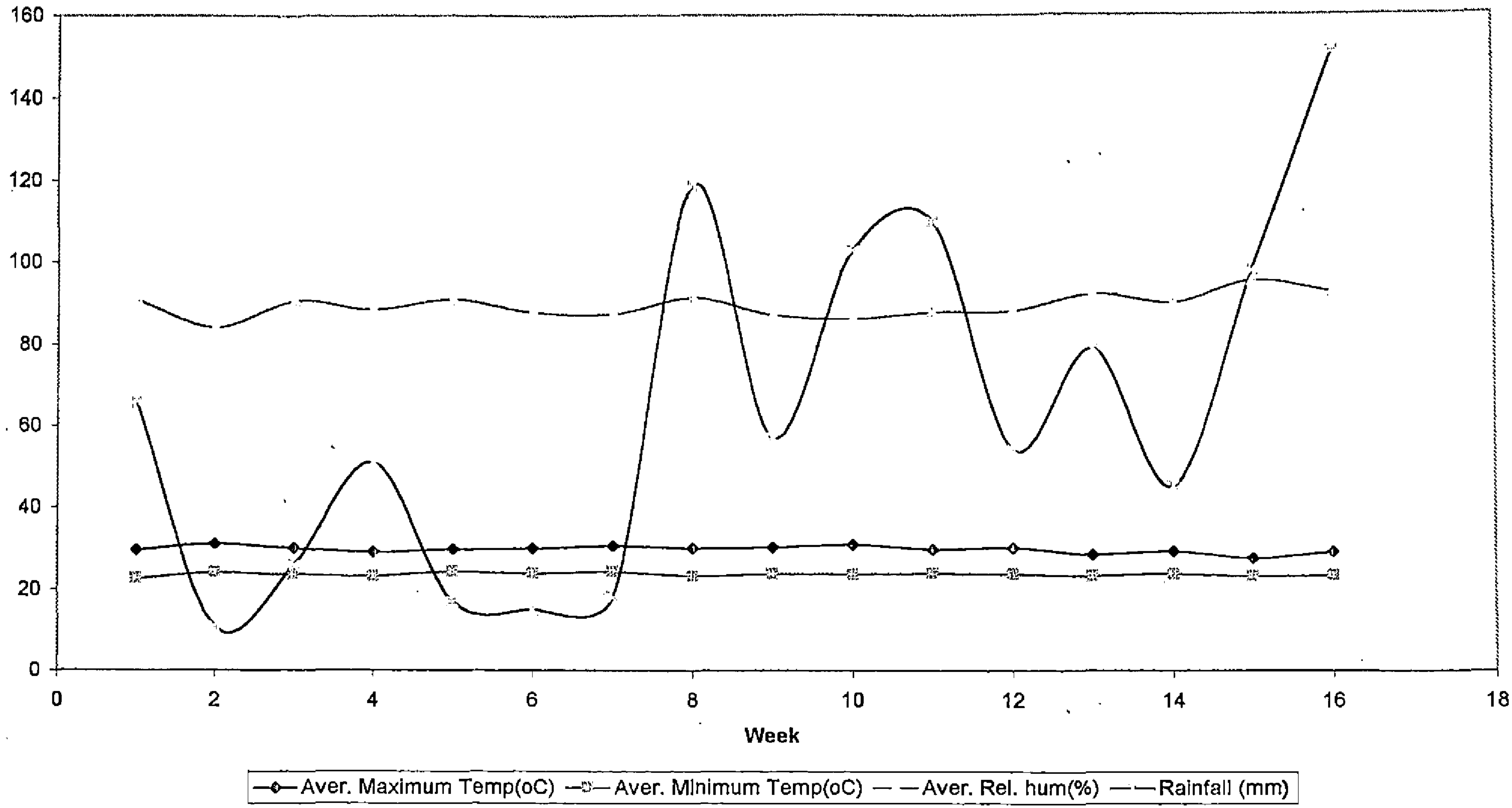
3.6.1 Seeds

The rice variety, selected for the experiment was 'Kanchana' (Ptb-50) released from the RARS, Pattambi-the progeny of a cross between IR-36

Table-1. Physico-chemical properties of soil of the experimental site:

1.	Mechanical composition		
		sand	72 per cent
		silt	7 per cent
		clay	20 per cent
2.	Texture		Sandy loam
3.	pH		5.3
4.	EC(ds m^{-1})		0.016
5.	CEC(Cmol(P+)kg^{-1})		6.84
6.	Organic Carbon (per cent)		1.19
7.	Available N (kg ha^{-1})		244.0
8.	Available P_2O_5 (kg ha^{-1})		26.0
9.	Available K_2O (kg ha^{-1})		162.0
10.	Available S (ppm)		6.2
11.	Bulk density (g cm^{-3})		1.30

Fig.1. Weather data during the cropping period from 23-06-98 to 17-10-98



and Pavizham. Kanchana is a red kerneled variety, having a duration of 110-120 days. It is reported to be resistant to the incidence of rice diseases such as sheath blight, blast, brown spot, tungro virus and to insects like stem borer and gall midge. The seeds are moderately dormant and have an yield potential of 5t ha^{-1}. The seeds for the study were obtained from CSRC, Karamana.

3.6.2 Manures and fertilizers

Dry cowdung(0.35 per cent N, 0.60 per cent P_2O_5, 0.24 per cent K_2O) and vermicompost(1.6 per cent N, 0.76 per cent P_2O_5, and 2.71 per cent K_2O) were used as organic sources. N, P and K were applied as urea (46 per cent N), mussoriephos(20.5 per cent P_2O_5 and 0.1 per cent SO_4-S) and muriate of potash (60 per cent K_2O). Sulphur was supplied through $CaSO_4$ containing 20.5 per cent S.

Full dose of P,K and S and $\frac{2}{3}$ dose of N were applied as basal. The rest $\frac{1}{3}$ N was given as top dressing one week before panicle initiation.

3.7 Methods

3.7.1 Design and layout

The experiment was laid out in 3^3 partially confounded factorial RBD confounding MFS in Rep I and M^2FS in Rep II.

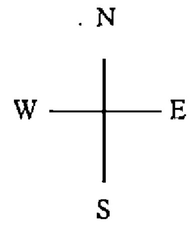
Altogether there were 27 treatment combinations replicated twice. The layout plan of the experiment is given in Figure 2. The details of the layout are given as following.

Design	: 3^3 partially confounded factorial RBD, confounding MFS in Rep I and M^2FS in Rep II
Treatment combinations	: 27
Number of replications	: 2
Number of blocks per replication	: 3
Number of plots per block	: 9

Plot size

Gross	: 4.5 x 4 m^2
Net	: 3.3 x 3.6 m^2
Spacing	: 15 x 10 cm
Variety	: Kanchana (Ptb-50)
Season	: Kharif,1998.

Fig.2 - Layout plan of the experiment



RI			RII		
B1	B2	B3	B1	B2	B3
$M_0F_0S_0$	$M_0F_0S_1$	$M_0F_2S_0$	$M_0F_0S_0$	$M_1F_0S_2$	$M_2F_1S_0$
$M_0F_1S_2$	$M_1F_1S_2$	$M_1F_1S_0$	$M_0F_1S_2$	$M_1F_2S_0$	$M_0F_2S_0$
$M_0F_2S_1$	$M_2F_0S_2$	$M_2F_0S_0$	$M_0F_2S_1$	$M_0F_0S_1$	$M_2F_0S_1$
$M_1F_0S_2$	$M_2F_1S_1$	$M_2F_2S_1$	$M_0F_0S_1$	$M_0F_2S_2$	$M_1F_1S_2$
$M_1F_1S_1$	$M_1F_0S_0$	$M_0F_1S_1$	$M_1F_1S_0$	$M_2F_2S_1$	$M_0F_0S_2$
$M_1F_2S_0$	$M_1F_2S_1$	$M_0F_0S_2$	$M_1F_2S_2$	$M_0F_1S_0$	$M_1F_0S_0$
$M_2F_0S_1$	$M_0F_2S_2$	$M_0F_0S_1$	$M_2F_0S_2$	$M_2F_0S_0$	$M_1F_2S_1$
$M_2F_1S_0$	$M_0F_1S_0$	$M_1F_2S_2$	$M_2F_1S_1$	$M_1F_1S_1$	$M_0F_1S_1$
$M_2F_2S_2$	$M_2F_2S_0$	$M_2F_1S_2$	$M_2F_1S_0$	$M_2F_1S_2$	$M_2F_2S_2$

Manures[M]	**NPK Fertilizers [F]**	**Sulphur levels[S]**
M_0 - *FYM@5t ha^{-1}*	F_0- *70:35:35 kg ha^{-1}*	S_0 - *No sulphur*
M_1 - *FYM@10t ha^{-1}*	F_1 - *87.5:43.75:43.75 kg ha^{-1}*	S_1 - *12.5 kg ha^{-1}*
M_2 - *Vermicompost@5t ha^{-1}*	F_2 - *105:52.5:52.5 kg ha^{-1}*	S_2 - *25 kg ha^{-1}*

3.7.2 Treatments

Factors and levels

Organic manure(M)

M_0 - *FYM 5t ha^{-1}*

M_1 - *FYM 10t ha^{-1}*

M_2 - *Vermicompost 5t ha^{-1}*

Nutrient levels(F)

F_0 - *70:35:35 kg ha^{-1}* (Package of Practices Recommendation)

F_1 - *87.5:43.75:43.75 kg ha^{-1}* (25 per cent increase over the Package of Practices Recommendation)

F_2 - *105:52.5:52.5 kg ha^{-1}* (50 per cent increase over the Package of Practices Recommendation)

Sulphur levels (S)

S_0 - *No sulphur*

S_1 - *12.5 kg ha^{-1}*

S_2 - *25 kg ha^{-1}*

3.7.3 Treatment combinations

$M_0F_0S_0$ - T_1	$M_1F_0S_0$ - T_{10}	$M_2F_0S_0$ - T_{19}
$M_0F_0S_1$ - T_2	$M_1F_0S_1$ - T_{11}	$M_2F_0S_1$ - T_{20}
$M_0F_0S_2$ - T_3	$M_1F_0S_2$ - T_{12}	$M_2F_0S_2$ - T_{21}
$M_0F_1S_0$ - T_4	$M_1F_1S_0$ - T_{13}	$M_2F_1S_0$ - T_{22}
$M_0F_1S_1$ - T_5	$M_1F_1S_1$ - T_{14}	$M_2F_1S_1$ - T_{23}
$M_0F_1S_2$ - T_6	$M_1F_1S_2$ - T_{15}	$M_2F_1S_2$ - T_{24}
$M_0F_2S_0$ - T_7	$M_1F_2S_0$ - T_{16}	$M_2F_2S_0$ - T_{25}
$M_0F_2S_1$ - T_8	$M_1F_2S_1$ - T_{17}	$M_2F_2S_1$ - T_{26}
$M_0F_2S_2$ - T_9	$M_1F_2S_2$ - T_{18}	$M_2F_2S_2$ - T_{27}

3.7.4 Field culture

The experimental area was ploughed twice, puddled and levelled. Weeds and stubbles were removed. Plots of size 4.5x4 m^2 were laid out with 9 plots in each block and 3 blocks per replication. After clearing and thickening of the bunds, the plots were dug again and levelled perfectly.

3.7.5 Application of manures and fertilizers

FYM and vermicompost were incorporated at the time of first ploughing. Urea, mussoriephos and muriate of potash were applied to each plot as per the treatments after levelling the field.

3.7.6 Seeds and sowing

Pre germinated seeds at the rate of 80 kg ha^{-1} were broadcast on the nursery area on 23rd June 1998. After 21 days (July 15), healthy seedlings were pulled out from the nursery and transplanted in the main plots at a spacing of 15x10cm with two seedlings per hill.

3.7.7 Maintenance of the crop

Transplanting was done with a thin film of water in the field. Subsequently the water level was raised to about 5cm. Two handweedings were done at 20 and 45 days after transplanting. Dimecron was sprayed twice as a prophylatic measure against leaf stem borer in the vegetative stage of crop and one spraying with Metacid after flowering against rice bug. Attack of rats was a common menace of the locality and they were controlled by the use of Roban. No disease attack was noticed in magnitudes requiring chemical control.

3.7.8 Plant sampling

Samples were collected from the area left for sampling. Twelve hills were selected diagonally from the net plot area to record biometric observations. Four rows from all sides were left as border rows and the net plot area was 3.3 x 3.6 m^2.

3.7.9 Harvest

The crop was harvested at full maturity, ie., 116 days after sowing (October 16, 1998). The border and sampling rows were harvested separately. Net plot area of individual plots were harvested and the weight of grain and straw was recorded.

3.7.10 Observations

3.7.11 Growth characters of rice

3.7.11.1 Height of plants

Height of plants (in cm) was recorded on 20,40,60 DAT and at harvest. Twelve plants were selected diagonally from the sampling area for measuring the height. Height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest earhead whichever was taller.

3.7.11.2 Number of tillers per unit area

Total number of tillers per unit area was recorded at 20, 40, 60 DAT and at harvest. Twelve hills were selected diagonally from the sampling area and tiller produced in each hill was counted and expressed as number of tillers per unit area.

3.7.11.3 Leaf area index

Leaf area index at 20, 40, 60 DAT and at harvest was recorded, using the formula suggested by Gomez(1972).

3.7.11.4 Dry matter production

Dry matter production at 20, 40, 60, DAT and at harvest was recorded. The sample plants were dried at 70°C for 48 hours and weighed and expressed as t ha^{-1}.

3.7.11.5 Chlorophyll content

The 'a', 'b' and total chlorophyll content of the leaves collected from the destructive sampling area at 20, 40 and 60 DAT were estimated using the method suggested by Arnon(1949).

3.7.12 Yield and yield attributes

3.7.12.1 Number of panicles metre^{-1}

The number of panicles from twelve hills selected diagonally from the sampling area were counted before harvest. The mean panicle number per hill was then expressed as number of panicles m^{-2}.

3.7.12.2 Number of grains panicle^{-1}

The number of grains in ten panicles collected randomly from the sampling area in each plot were counted and the mean value was expressed as number of grains panicle^{-1}.

3.7.12.3 Chaff per centage

The chaff per centage was worked out by using the formula

$$\text{Chaff per centage} = \frac{\text{Number of unfilled grains} \times 100}{\text{Total number of grains}}$$

3.7.12.4 Thousand grain weight

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

3.7.13 Yield of rice

3.7.13.1. Grain yield

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

3.7.13.2 Straw yield

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

3.7.13.3 Harvest index

Harvest index was calculated using the formula,

$$\text{Harvest Index, HI} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.8 Uptake of nutrients

The total uptake of nitrogen, phosphorus, potassium and sulphur by plants at harvest were calculated by multiplying the content of these nutrients in the plant sample with the respective dry weight and expressed as kg ha^{-1}.

3.9 Chemical analysis

3.9.1 Soil analysis

Composite soil samples collected before and after the experimentation were analysed to determine the available nitrogen, available phosphorus, available potassium and available sulphur.

3.9.2 Plant analysis

Plant samples at the harvest stage were analysed for nitrogen, phosphorus, potassium and sulphur after drying to constant weight in an electric hot air oven at 70°C for 48 hours. The samples were then ground and passed through a 0.5 mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in an electronic balance, subjected to acid digestion and the nutrient contents were determined and expressed on dry weight basis.

3.9.2.1 Total nitrogen content

Total nitrogen content was estimated by the modified microkjeldahl method as suggested by Jackson(1973).

3.9.2.2 Total phosphorus content

Total phosphorous content was estimated by the Vanado-molybdo phosphoric yellow colour method(Jackson,1973) and read in a Klett Summerson photo electric colorimeter.

3.9.2.3 Total potassium content

The total potassium content was estimated by flame photometric method by aspirating the digested plant sample into Aimil compressor-diaphram type flame photometer(Jackson, 1973).

3.9.2.4 Total sulphur content

The total sulphur content in the plant sample was determined by diacid digestion followed by estimation of S turbidimetrically (Chesnin and Yien, 1950).

3.10 Scoring for pest and diseases

The pest and disease count was not significant to be scored.

3.11 Benefit : Cost ratio

The economics of cultivation for the field experiments was worked out considering the total cost of cultivation and the prevailing market price of the produce.

Benefit : Cost ratio = gross income/total expenditure

3.12 Statistical analysis

The data generated were subjected to analysis of variance (Panse and Sukhatme, 1985). When ever the results were significant, the critical difference was worked out at five or one per cent probability.

Results

RESULTS

The results of the field experiment entitled "Nutrient management for yield improvement of transplanted rice (*Oryza sativa* L.) in the southern region of Kerala" is presented in this chapter. The experiment was conducted during the kharif season from June to October, 1998 at CSRC, Karamana to study the efficacy of organic manures in conjunction with varying levels of fertilizers and sulphur on the yield of transplanted rice.

4.1 Growth characters

The main as well as interaction effects of various treatments on different growth characters is presented here.

4.1.1 Plant height

4.1.1.1 Effect of M,F and S (Table 2)

Plant height at 20,40,60 DAT and at harvest was recorded. Though an increasing trend was noticed, the main effects of M, F or S failed to produce any significant influence on plant height upto 40 DAT. Plant height significantly increased with increased dose of NPK application at 60 DAT and at harvest stage. Maximum plant height of 94.90cm at harvest was recorded at F_2 level, which was significantly superior to F_0, but on par with F_1(93.80cm). Similarly, an increase in sulphur levels also showed an increasing trend in plant height both at

60 DAT and at harvest. S_2 recorded the maximum plant height of 94.96 cm at harvest, but this was found to be on par with S_1(93.66 cm).

4.1.1.2 Interaction effects of M,F and S

The interactions - MF and MS failed to influence the plant height. At harvest stage, the FS interaction was significant. Maximum plant height was recorded by the combination F_1S_2 (97.47cm).

4.1.2 Tiller number

4.1.2.1 Effect of M,F and S (Table 3)

Tiller count unit area^{-1} was found to be significantly influenced by F and S at all stages of growth. Tiller number increased with increased levels of NPK application and the maximum number was recorded with F_2. At harvest, the highest tiller count of 624.84 per unit area was recorded by F_2 level of NPK application which was significantly superior to F_1 and F_0. Sulphur application increased tiller number and maximum counts were obtained with S_2 at all stages of growth. S_2 was significantly superior to S_0 and S_1 at 20 and 40 DAT; but at 60 DAT and at harvest stage, the levels S_1 and S_2 were on par.

4.1.2.2 Interaction effects of M,F and S (Table 4)

Among various interactions, MS and FS failed to influence the tiller count at any stage of growth. MF interaction was significant at all stages. Among MF interactions, the maximum tiller count at 20 and 60 DAT and at harvest was noticed with M_1F_2. Highest tiller count at all levels of M was obtained with F_2 level of NPK application for all the growth stages studied.

Table - 2. Effect of M, F and S on plant height

	Plant height (cm)			
Effect	20 DAT	40 DAT	60 DAT	Harvest
M_0	48.90	74.96	91.68	94.66
M_1	49.52	74.90	90.00	93.35
M_2	48.38	73.50	89.56	92.61
$F_{2, 22}$	1.429	2.048	2.937	2.845
SE	0.675	0.816	0.923	0.870
CD(0.05)	-	-	-	-
F_0	48.56	73.31	88.68	91.93
F_1	48.82	74.73	90.60	93.80
F_2	49.41	75.31	91.96	94.90
$F_{2, 22}$	0.829	3.174	6.377**	5.963**
SE	0.675	0.816	0.923	0.870
CD(0.05)	-	-	1.914	1.803
S_0	48.84	73.94	89.24	92.00
S_1	48.46	74.54	90.12	93.66
S_2	49.50	74.88	91.88	94.96
$F_{2, 22}$	1.224	0.691	4.260*	5.816**
SE	0.675	0.816	0.923	0.870
CD(0.05)	-	-	1.914	1.803

* Significant at 0.05 level
** Significant at 0.01 level

Table - 3. Effect of M, F and S on tiller number

	Tiller number unit area^{-1}			
Effect	20 DAT	40 DAT	60 DAT	Harvest
M_0	864.08	620.05	576.94	569.21
M_1	877.89	665.20	605.64	597.67
M_2	856.60	638.62	580.11	576.12
$F_{2, 22}$	1.044	3.305	1.700	1.598
SE	14.933	17.651	17.062	16.560
CD (0.05)	-	-	-	-
F_0	845.39	593.43	547.17	542.17
F_1	843.38	647.67	583.27	575.98
F_2	909.79	682.77	632.26	624.84
$F_{2, 22}$	12.795**	13.004**	12.53**	12.524**
SE	14.933	17.651	17.062	16.560
CD (0.05)	30.971	36.609	35.386	34.445
S_0	820.45	610.97	556.21	549.22
S_1	867.31	633.34	596.56	591.19
S_2	910.79	679.57	609.92	602.59
$F_{2, 22}$	18.306**	7.857**	5.372*	5.729**
SE	14.933	17.651	17.062	16.560
CD (0.05)	30.971	36.609	35.386	34.445

* Significant at 0.05 level

** Significant at 0.01 level

Table - 4. Interaction effects of M, F and S on tiller number

	Tiller number unit area^{-1}			
Effect	20 DAT	40 DAT	60 DAT	Harvest
M_0F_0	818.29	513.67	492.90	485.82
M_0F_1	882.28	641.32	593.40	586.41
M_0F_2	891.66	705.18	644.54	635.40
M_1F_0	869.32	636.50	572.74	567.81
M_1F_1	826.33	665.20	596.52	587.45
M_1F_2	938.00	693.90	647.67	637.76
M_2F_0	848.56	630.14	575.87	572.90
M_2F_1	821.53	636.50	559.90	554.10
M_2F_2	899.70	649.23	604.56	601.36
$F_{2,22}$	3.083*	4.653**	2.815*	3.023**
SE	25.864	30.573	29.550	28.683
CD(0.05)	53.643	63.409	61.290	59.660
M_0S_0	808.80	550.42	521.71	513.72
M_0S_1	869.44	636.50	593.40	587.87
M_0S_2	913.99	673.24	615.73	606.04
M_1S_0	842.30	661.96	598.20	589.27
M_1S_1	872.68	625.33	590.16	583.90
M_1S_2	918.68	708.30	628.57	619.85
M_2S_0	810.25	620.53	548.73	544.67
M_2S_1	859.83	638.18	606.13	601.82
M_2S_2	899.70	657.16	585.47	581.87
$F_{4,22}$	0.226	2.532	1.515	1.498
SE	25.864	30.573	29.550	28.683
CD(0.05)	-	-	-	-
F_0S_0	791.27	575.87	529.64	523.79
F_0S_1	842.08	615.84	582.23	577.11
F_0S_2	902.83	588.60	529.64	525.63
F_1S_0	821.53	610.95	561.46	551.90
F_1S_1	826.56	627.01	578.99	573.71
F_1S_2	882.06	705.06	609.37	602.35
F_2S_0	848.56	646.10	577.54	571.96
F_2S_1	933.31	657.16	628.46	622.77
F_2S_2	947.49	745.04	690.77	679.79
$F_{4,22}$	1.474	2.374	2.726	2.533
SE	25.864	30.573	29.550	28.683
CD(0.05)	-	-	-	-

* Significant at 0.05 level
** Significant at 0.01 level

4.1.3 Leaf area index

4.1.3.1 Effect of M,F and S (Table 5)

Different levels and sources of organic manure application had no significant effect on LAI at any stage of growth. Enhanced rate of NPK application resulted in increased LAI upto 40 DAT. The maximum LAI of 5.93 was recorded at F_2 level. But this level was on par with F_1 at all stages of growth. Sulphur application showed significant influence on LAI at 60 DAT and at harvest. The maximum LAI of 4.67 at 60 DAT and 4.2 at harvest stage was recorded by S_2 level.

4.1.3.2 Interaction effects of M,F and S (Table 6)

The interaction effects of MF was found significant only at the harvest stage of crop. The combination M_1F_1 was found to be superior(4.13), but was on par with M_0F_1. MS interaction was significant only at 40 DAT. Maximum LAI was noticed with M_2S_0(6.56). However M_2S_0 was found to be on par with M_1S_2. LAI increased significantly due to FS interaction upto 40 DAT. At 20 DAT, LAI was found to be increased with sulphur levels upto S_2. Among FS interactions, F_2S_2 recorded the maximum LAI of 6.16 which was on par with F_2S_0, F_0S_2, F_1S_1, F_1S_0 and F_2S_1 at 40 DAT.

4.1.4 Chlorophyll content

4.1.4.1 Effect of M,F and S (Table 7)

The influence of organic manure application on increasing chlorophyll content was significant at 20 and 60 DAT. At both these stages, higher chlorophyll content was recorded with the highest level of FYM(M_1). Varying levels of NPK application significantly influenced chlorophyll content at all the growth stages studied. Chlorophyll content significantly increased with increased NPK rates and the maximum chlorophyll content at all stages were observed with F_2 level. Sulphur application had significant influence on chlorophyll content only at 60 DAT. Maximum chlorophyll content was noticed with sulphur level of 12.5 kg ha^{-1} and further increase in sulphur levels decreased the chlorophyll content.

4.1.4.2 Interaction effects of M, F and S (Table 8)

MF interaction was found to be significant at 20 and 60 DAT in increasing the chlorophyll content. For all the growth stages studied, increase in fertilizer levels upto F_2 increased the chlorophyll content at all levels of M. M_1F_2 was identified as the superior combination giving maximum chlorophyll content at 20 DAT(1.04 mg g $leaf^{1}$) At 60 DAT, the maximum chlorophyll content of 1.92 mg g $leaf^{1}$ was recorded with M_1F_1 and M_1F_2.

MS interaction was found significant only at 60 DAT. At this stage, M_1S_0 recorded the highest chlorophyll content of 1.86 mg g $leaf^{1}$, but it was found to be on par with M_0S_1. At all levels of S application, significantly higher chlorophyll contents were recorded with the highest level of FYM (M_1).

FS interaction also was found to be significant at 60 DAT. F_2S_0 recorded the maximum chlorophyll content of 1.92 mg g $leaf^{1}$. In general at F_0 and F_1 levels, sulphur application upto S_1 level increased chlorophyll content and further increase in S levels decreased the chlorophyll content.

Table - 5. Effect of M, F and S on LAI

Effect	LAI			
	20 DAT	40 DAT	60 DAT	Harvest
M_0	3.84	5.16	4.38	3.94
M_1	3.93	5.43	4.32	3.98
M_2	3.94	5.66	4.35	3.99
$F_{2, 22}$	0.186	1.027	0.059	0.268
SE	0.183	0.346	0.165	0.078
CD(0.05)	-	-	-	-
F_0	3.51	4.93	4.08	3.80
F_1	4.15	5.38	4.48	4.02
F_2	4.04	5.93	4.50	4.09
$F_{2, 22}$	7.044**	4.182*	4.110*	7.407*
SE	0.183	0.346	0.165	0.078
CD(0.05)	0.380	0.718	0.341	0.162
S_0	3.65	5.47	4.04	3.71
S_1	3.95	5.21	4.35	4.01
S_2	4.09	5.58	4.67	4.20
$F_{2, 22}$	3.022	0.606	7.358**	20.671**
SE	0.183	0.346	0.165	0.078
CD(0.05)	-	-	0.341	0.162

* Significant at 0.05 level
** Significant at 0.01 level

Table - 6. Interaction effects of M, F and S on LAI

	LAI			
Effect	20 DAT	40 DAT	60 DAT	Harvest
M_0F_0	3.28	4.72	3.87	3.55
M_0F_1	4.52	5.07	4.79	4.19
M_0F_2	3.71	5.70	4.48	4.07
M_1F_0	3.75	4.83	4.27	4.01
M_1F_1	3.94	5.45	4.33	3.81
M_1F_2	4.09	6.00	4.37	4.13
M_2F_0	3.50	5.26	4.10	3.85
M_2F_1	3.99	5.62	4.33	4.06
M_2F_2	4.32	6.10	4.64	4.07
$F_{4,22}$	2.424	0.055	1.568	5.018**
SE	0.318	0.599	0.285	0.136
CD (0.05)	-	-	-	0.281
M_0S_0	3.58	4.59	3.95	3.59
M_0S_1	3.92	5.58	4.62	4.01
M_0S_2	4.00	5.33	4.58	4.22
M_1S_0	3.95	5.25	3.92	3.77
M_1S_1	3.76	4.99	4.24	4.01
M_1S_2	4.07	6.04	4.82	4.28
M_2S_0	3.43	6.56	4.25	3.81
M_2S_1	4.18	5.05	4.21	4.13
M_2S_2	4.20	5.36	4.61	4.34
$F_{4,22}$	1.136	3.053*	1.244	1.205
SE	0.318	0.599	0.285	0.136
CD (0.05)	-	1.243	-	-
F_0S_0	3.81	4.60	3.72	3.54
F_0S_1	3.44	4.33	4.01	3.88
F_0S_2	3.27	5.87	4.51	3.99
F_1S_0	3.64	5.70	4.22	3.77
F_1S_1	4.16	5.74	4.66	4.01
F_1S_2	4.66	4.69	4.57	4.28
F_2S_0	3.51	6.10	4.17	3.81
F_2S_1	4.27	5.54	4.39	4.13
F_2S_2	4.35	6.16	4.92	4.34
$F_{4, 22}$	3.969*	2.881*	0.789	0.183
SE	0.318	0.599	0.285	0.136
CD (0.05)	0.659	1.243	-	-

* Significant at 0.05 level
** Significant at 0.01 level

Table - 7. Effect of M, F and S on chlorophyll content

	Chlorophyll content (mg g^{-1} leaf)		
Effect	20 DAT	40 DAT	60 DAT
M_0	0.68	2.15	1.60
M_1	0.90	2.18	1.78
M_2	0.85	2.22	1.57
$F_{2,22}$	70.029**	2.47	19.589**
SE	0.020	0.036	0.037
CD (0.05)	0.041	-	0.078
F_0	0.700	2.080	1.420
F_1	0.82	2.18	1.66
F_2	0.91	2.29	1.88
$F_{2,22}$	57.301**	17.683**	75.173**
SE	0.020	0.036	0.037
CD (0.05)	0.041	0.074	0.078
S_0	0.81	2.15	1.60
S_1	0.83	2.23	1.72
S_2	0.79	2.18	1.63
$F_{2,22}$	1.672	2.610	5.477*
SE	0.020	0.036	0.037
CD (0.05)	-	-	0.078

* Significant at 0.05 level
** Significant at 0.01 level

Table - 8. Interaction effects of M, F and S on chlorophyll content

	Chlorophyll content (mg g^{-1} leaf)		
Effects	20 DAT	40 DAT	60 DAT
M_0F_0	0.59	2.07	1.38
M_0F_1	0.69	2.18	1.57
M_0F_2	0.76	2.19	1.84
M_1F_0	0.69	2.05	1.51
M_1F_1	0.96	2.15	1.92
M_1F_2	1.04	2.33	1.92
M_2F_0	0.82	2.11	1.36
M_2F_1	0.82	2.23	1.48
M_2F_2	0.92	2.34	1.86
$F_{4,22}$	10.340**	1.129	4.969**
SE	0.034	0.062	0.065
CD (0.05)	0.070	-	0.135
M_0S_0	0.66	2.14	1.37
M_0S_1	0.73	2.19	1.85
M_0S_2	0.64	2.12	1.57
M_1S_0	0.94	2.17	1.86
M_1S_1	0.89	2.23	1.76
M_1S_2	0.87	2.12	1.73
M_2S_0	0.84	2.13	1.56
M_2S_1	0.86	2.26	1.54
M_2S_2	0.86	2.29	1.60
$F_{4, 22}$	2.147	1.852	12.219**
SE	0.034	0.062	0.065
CD (0.05)	-	-	0.135
F_0S_0	0.70	2.02	1.22
F_0S_1	0.70	2.19	1.55
F_0S_2	0.70	2.02	1.48
F_1S_0	0.85	2.17	1.65
F_1S_1	0.84	2.20	1.70
F_1S_2	0.77	2.19	1.62
F_2S_0	0.89	2.25	1.92
F_2S_1	0.93	2.29	1.90
F_2S_2	0.90	2.33	1.81
$F_{4,22}$	1.416	1.900	5.832**
SE	0.034	0.062	0.065
CD (0.05)			0.135

* Significant at 0.05 level

** Significant at 0.01 level

4.1.5 Dry matter production

4.1.5.1 Effect of M,F and S (Table 9)

Different levels and sources of organic manures showed significant influence on drymatter production at all the growth stages. In general, increased dry matter production was noticed with higher doses of organic manures. On comparing the effect of vermicompost and FYM, it was seen that vermicompost as a source of organic manure could increase the drymatter production, comparable to higher dose of FYM(10 t ha^{-1}). The effect of F also was significant at all the growth stages studied. Increased NPK rates increased DMP and the maximum dry matter production of 11004.01 kg ha^{-1} was observed for the F_2 level at harvest. Sulphur application also had significant influence on drymatter production at all the growth stages studied. At 20 DAT, S_1 recorded the highest DMP of 1884.19 kg ha^{-1}. But at 40 and 60 DAT and at harvest, the maximum DMP was recorded with S_2. Thus an increase in drymatter production with increasing levels of sulphur was noticed at all stages except 20 DAT.

4.1.5.2 Interaction effects of M,F and S(Table 10)

The interaction of MF had significant influence on drymatter production at 40 and 60 DAT. M_1F_2 recorded the highest DMP of 6244.4 kg ha^{-1} at 40 DAT and 9423.55 kg ha^{-1} at 60 DAT. M_2F_2, M_1F_1 and M_0F_2 were the other superior combinations identified at these two stages. MS interaction failed to influence the DMP significantly at any stage of growth. FS interaction was significant at 60 DAT and at harvest stage of the crop. F_2S_2 recorded the maximum DMP of 10267.75 kg ha^{-1} and 11970.67 kg ha^{-1} respectively at these two stages.

4.2 Yield attributes and yield

The main as well as interaction effects of various treatments on the yield attributes and yield are presented below.

4.3 Yield attributes

4.3.1 Number of panicles m^{-2}

4.3.1.1 Effect of M,F and S (Table 11)

Organic manure application could significantly influence the panicle number m^{-2}. An increasing trend was noticed with high organic manure addition and the maximum number of panicles (534.46 m^{-2}) was recorded with the highest level of FYM(M_1) . M_1 was superior to M_0, but was on par with M_2. This showed that 10t FYM ha^{-1} was on par with 5t ha^{-1} of vermicompost in enhancing the panicle number. Increased level of NPK increased the panicle number m^{-2}. The maximum number of 547.17m^{-2} was recorded with F_2 level, which was significantly superior to F_1 and F_0.

Sulphur application recorded an increase in panicle number m^{-2} with increased levels. S_2 registered the highest number of 538.66 panicles m^{-2}. However S_1 and S_2 were identified to be on par.

4.3.1.2 Interaction effects of M.F and S (Table 12)

Eventhough the MF interaction was not significant, the combination of highest levels of manure and fertilizer(M_1F_2) recorded the

Table 4.9. Effect of M, F and S on dry matter production

Effect	Dry matter production (kg ha^{-1})			
	20 DAT	40 DAT	60 DAT	Harvest
M_0	1534.3	5120.29	8255.52	10031.54
M_1	1965.71	5919.82	8878.24	10577.07
M_2	1897.59	5573.66	8730.47	10577.81
$F_{2,22}$	28.781**	9.034**	5.350*	3.648*
SE	61.74	188.108	198.325	232.677
CD(0.05)	126.799	391.265	412.515	483.969
F_0	1530.58	5130.34	7882.92	9764.28
F_1	1862.97	5478.37	8739.78	10418.13
F_2	2004.04	6005.06	9241.53	11004.01
$F_{2,22}$	31.619**	10.899**	23.859**	14.126**
SE	61.74	188.108	198.325	232.677
CD(0.05)	126.799	391.265	412.515	483.969
S_0	1664.95	5199.57	8037.02	9744.03
S_1	1884.19	5633.96	8768.07	10692.83
S_2	1848.46	5780.24	9059.15	10749.56
$F_{2,22}$	7.403**	5.126*	14.018**	11.719**
SE	61.74	188.108	198.325	232.677
CD(0.05)	126.799	391.265	412.515	483.969

* Significant at 0.05 level
** Significant at 0.01 level

Table - 10. Interaction effects of M, F and S on dry matter production

	Dry matter production (kg ha^{-1})			
Effect	20 DAT	40 DAT	60 DAT	Harvest
M_0F_0	1318.78	4162.93	7061.80	8973.98
M_0F_1	1538.77	5289.65	8750.20	10424.08
M_0F_2	1745.35	5908.28	8954.55	10696.55
M_1F_0	1656.02	5441.52	8110.35	10062.28
M_1F_1	2017.82	6073.55	9100.83	10727.82
M_1F_2	2223.28	6244.40	9423.55	10941.10
M_2F_0	1616.93	5786.57	8476.62	10256.58
M_2F_1	2032.33	5071.90	8368.30	10102.48
M_2F_2	2043.50	5862.50	9346.50	11374.37
$F_{4,22}$	0.876	5.342**	3.532**	2.421
SE	105.588	325.810	343.509	403.010
CD(0.05)	-	677.69	714.498	-
M_0S_0	1380.20	4820.65	7553.13	9382.23
M_0S_1	1677.23	5253.92	8563.72	10438.6
M_0S_2	1545.47	5286.3	8649.7	10273.78
M_1S_0	1834.68	5636.93	8483.32	10201.87
M_1S_1	2011.12	5881.48	9062.87	10769.13
M_1S_2	2051.13	6241.05	9088.55	10760.20
M_2S_0	1779.97	5141.13	8074.62	9648.00
M_2S_1	1964.22	5766.47	8677.62	10870.75
M_2S_2	1948.58	5813.37	9439.18	11214.69
$F_{4,22}$	0.389	0.254	1.051	0.915
SE	105.588	325.810	343.509	403.010
CD(0.05)	-	-	-	-
F_0S_0	1361.22	4906.63	7411.32	9196.87
F_0S_1	1634.80	5317.57	8271.15	10452.00
F_0S_2	1595.72	5166.82	7966.30	9643.98
F_1S_0	1807.88	5144.48	8367.18	9999.75
F_1S_1	1940.77	5566.58	8908.77	10620.62
F_1S_2	1840.27	5724.03	8943.38	10634.02
F_2S_0	1825.75	5547.60	8332.57	10035.48
F_2S_1	2077.00	6017.72	9124.28	11005.87
F_2S_2	2109.38	6449.87	10267.75	11970.67
$F_{4,22}$	0.829	0.590	3.447*	3.153*
SE	105.588	325.810	343.509	403.01
CD(0.05)	-	-	714.498	838.259

* Significant at 0.05 level
** Significant at 0.01 level

maximum number of panicles m^{-2}. MS interaction also couldn't influence the panicle number m^{-2}. FS interaction had significant influence on the panicle number m^{-2}. F_2S_2 recorded the maximum panicle number of 606.19 m^{-2}. At F_0 and F_1, S_1 level of S application recorded higher panicle numbers; whereas at F_2, sulphur application at S_2 level proved superior.

4.3.2 Number of grains panicle^{-1}

4.3.2.1 Effect of M, F and S (Table 11)

Organic manure application at different levels and through different sources could not produce any significant effect on either total or filled grains panicle^{-1}. However an increasing trend was noticed in both the cases with higher levels of manures. Varying levels of NPK significantly influenced both total and filled grains panicle^{-1}. Higher NPK rates recorded higher number to total and filled grains panicle^{-1}. However F_1 and F_2 were found on par. Sulphur application at different levels failed to influence the grain number panicle^{-1}. But there was an increasing trend in the number of grains panicle^{-1} with sulphur application and the maximum number of 116.20 was recorded with S_2.

4.3.2.2 Interaction effects of M,F and S (Table 12)

MF interaction couldn't influence the total number of grains panicle^{-1} significantly. But there was significant influence of MF on the number of filled grains panicle^{-1}. Higher rate of NPK application upto 25 per cent above PPR along with the highest rate of organic manure addition(M_1F_1) recorded the highest number of filled grains panicle^{-1}(107.11). This level was comparable with

5t ha^{-1} of vermicompost along with higher levels of fertilizer (M_2F_2) as well as 5t ha^{-1} FYM and F_2(M_0F_2).

MS interaction also couldn't influence the number of grains $panicle^{-1}$ significantly. However, higher grain numbers $panicle^{-1}$ were noticed with M_0S_1.

FS interaction also could not express a significant effect on grain number $panicle^{-1}$. The maximum grain numbers were recorded with F_2S_2(122.61).

4.3.3 Chaff percentage

4.3.3.1 Effect of M,F and S (Table 11)

Organic manure application at different levels and through different sources showed marked influence on chaff per centage. The chaff per centage was significantly minimum (11.14 per cent) at the highest dose of FYM(M_1). This was found to be on par with vermicompost application. NPK levels also had influenced the chaff percentage significantly, where higher levels of NPK increased the chaff per centage. Sulphur addition at varying levels couldn't influence the chaff per centage significantly.

4.3.3.2 Interaction effects of M,F and S (Table 12)

None of the interactions could significantly influence the chaff per centage. But it was noticed that at all levels of M, an increase in NPK level upto F_2 resulted in greater chaff per centage.

4.3.4 Thousand grain weight

4.3.4.1 Effect of M,F and S (Table 11)

The main effects of M,F and S had no significant effect on thousand grain weight.

4.3.4.2 Interaction effects of M,F and S (Table 12)

The various two factor interactions also couldn't influence the thousand grain weight significantly. However among three factor combinations, $M_2F_2S_2$ recorded the highest test weight of 30.71 g (Table 15).

4.4 Yield

4.4.1Grain yield

4.4.1.1 Effect of M,F and S (Table 13)

Though an increasing trend in the grain yield was recorded by enhancing the organic manure dose, the effect was not significant. Vermicompost at lower rates and FYM at higher rates were found equally good for grain production of rice. Increase in NPK rates increased the grain yield. Higher grain yield of 4899.93 kg ha^{-1} was recorded with F_2(4899.93 kh ha^{-1}), which was significantly superior to F_1 and F_0. Sulphur application could significantly influence the grain yield. An increase in rice yield was noticed with increased levels of sulphur. S_2 recorded the higher yield of 4673.12 kg ha^{-1}, comparable to S_1(4600.17kg ha^{-1}).

4.4.1.2 Interaction effects of M,F and S (Table 14)

All the interactions - MF, MS and FS responded positively in

Table - 11. Effect of M, F and S on yield attributing characters

Effects	Number of panicles $metre^{-2}$	Number of grains $panicle^{-1}$ Total	Filled	chaff per cent	1000 grain weight (g)
M_0	500.3	114.20	99.39	13.15	28.65
M_1	534.46	114.61	101.78	11.14	29.28
M_2	523.78	113.54	100.15	11.70	28.97
$F_{2,22}$	4.624*	0.062	0.495	13.898**	1.346
SE	11.5	3.09	2.448	0.394	0.387
CD(0.05)	23.845	-	-	0.817	-
F_0	490.76	108.32	96.20	11.08	28.49
F_1	520.61	115.57	101.69	12.00	29.42
F_2	547.17	118.46	103.42	12.91	28.99
$F_{2,22}$	12.05**	5.72**	4.71*	10.855**	2.944
SE	11.5	3.09	2.448	0.394	0.387
CD(0.05)	23.845	6.427	5.094	0.817	-
S_0	491.26	111.28	97.89	11.89	28.49
S_1	528.62	114.87	101.67	11.67	29.03
S_2	538.66	116.20	101.76	12.42	29.38
$F_{2,22}$	9.443**	1.359	1.619	1.936	2.694
SE	11.5	3.09	2.448	0.394	0.387
CD(0.05)	23.845	-	-	-	-

* Significant at 0.05 level
** Significant at 0.01 level

Table - 12. Interaction effects of M, F and S of yield attributing characters

Effects	Number of panicles meter^{-2}	Number of grains panicle^{-1} Total	Filled	chaff (per cent)	1000 grain weight (g)
M_0F_0	446.55	106.11	92.83	12.47	27.68
M_0F_1	524.73	113.45	98.44	13.14	29.60
M_0F_2	529.62	123.06	106.89	13.84	28.67
M_1F_0	507.29	112.28	100.89	9.97	29.35
M_1F_1	532.99	120.17	107.11	10.85	29.68
M_1F_2	563.12	111.39	97.33	12.60	28.82
M_2F_0	518.45	106.56	94.89	10.80	28.44
M_2F_1	504.12	113.11	99.50	12.00	28.99
M_2F_2	548.76	120.94	106.05	12.30	29.49
$F_{4, 22}$	2.734	2.284	3.503*	0.789	1.624
SE	19.91	5.352	4.241	0.680	0.670
CD(0.05)	-	-	8.822	-	-
M_0S_0	465.58	108.78	93.61	13.80	27.22
M_0S_1	512.07	118.34	104.06	12.68	29.37
M_0S_2	523.24	115.50	100.50	12.97	29.35
M_1S_0	513.67	112.72	100.72	10.56	29.35
M_1S_1	528.20	114.50	101.89	10.96	29.13
M_1S_2	561.52	116.61	102.72	11.90	29.36
M_2S_0	494.52	112.34	99.33	11.32	28.90
M_2S_1	545.60	111.78	99.06	11.37	28.60
M_2S_2	531.21	116.50	102.06	12.41	29.42
$F_{4, 22}$	0.903	0.526	0.957	1.586	2.482
SE	19.91	5.352	4.241	0.680	0.670
CD(0.05)	-	-	-	-	
F_0S_0	472.07	103.11	92.50	10.20	27.23
F_0S_1	513.67	111.56	99.39	10.77	28.69
F_0S_2	486.55	110.28	96.72	12.27	29.54
F_1S_0	505.58	115.78	101.50	12.34	29.06
F_1S_1	533.01	115.22	102.28	11.20	29.75
F_1S_2	523.24	115.72	101.28	12.46	29.46
F_2S_0	496.12	114.95	99.66	13.14	29.18
F_2S_1	539.19	117.83	103.33	13.04	28.66
F_2S_2	606.19	122.61	107.28	12.55	29.14
$F_{4, 22}$	4.648**	0.570	0.675	2.719	2.145
SE	19.91	5.352	4.241	0.680	0.670
CD(0.05)	41.301	-	-	-	-

* Significant at 0.05 level

** Significant at 0.01 level

influencing the grain yield. At all levels of M, an increase in NPK upto F_2 increased grain yields. Highest yield of 4980.36 kg ha^{-1} was observed with M_2F_2. This was however found comparable to M_1F_2. Similar trend was noticed with S levels also. At all levels of M, sulphur application upto the highest dose of S_2 could increase grain yield. M_2S_2 recorded the higher grain yield of 4774.13 kg ha^{-1} which was on par with M_0S_1, M_0S_2, M_1S_0, $M_1S_2$and M_2S_1. Among FS interactions, the highest grain yield of 5450.34 kg ha^{-1} was recorded with F_2S_2. This was significantly superior to all other combinations. At F_0 and F_1 levels, sulphur application upto S_1 increased grain yields. Further increase in sulphur application reduced grain yields.

4.4.2 Straw yield

4.4.2.1 Effect of M,F and S (Table 13)

Different levels and sources of organic manures could not significantly influence the straw yield. However, highest straw yield of 5145.90 kg ha^{-1} was recorded with 5 t ha^{-1} vermicompost. Vermicompost was thus found to produce better straw yields than FYM at higher levels. An increase in NPK levels brought about a significant increase in straw yield. The highest straw yield of 5390.48 kg ha^{-1} was recorded with F_2, which was significantly superior to F_1 and F_0. Sulphur application showed significant influence on straw yield of rice.

Maximum straw yield was recorded with S_1 level (5128.13 kg ha^{-1}). Further increase in sulphur levels reduced straw yield.

4.4.2.2 Interaction effects of M,F and S (Table 14)

None of the interactions were effective in influencing the straw yield significantly.

4.4.3 Harvest index

4.4.3.1 Effect of M,F and S (Table 13)

The main effects of M,F or S couldn't influence the harvest index significantly. Though not significant, the maximum harvest index was recorded for M_0. Increased NPK levels and S levels decreased the harvest index.

4.4.3.2Interaction effects of M,F and S

None of the interactions could significantly influence the harvest index.

4.5 Uptake of nutrients at harvest

4.5.1 Nitrogen uptake

4.5.1.1 Effect of M,F and S (Table 16)

All the main effects were significant in influencing the nitrogen uptake. N uptake increased with increased levels of organic manure application and recorded maximum value at M_1(146.89 kg ha^{-1}). M_1 and M_2 were on par indicating that vermicompost @ 5t ha^{-1} was comparable to higher dose of FYM. Increased NPK rates could increase the N uptake and the maximum N uptake of 161.38 kg ha^{-1} was recorded with F_2. The effect of sulphur levels in influencing

Table - 13. Effect of M, F and S on yield

Effect	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
M_0	4444.91	4785.82	0.480
M_1	4544.98	4988.31	0.478
M_2	4541.71	5145.90	0.470
$F_{2,22}$	0.724	2.676	0.809
SE	94.414	155.593	0.008
CD(0.05)	-	-	-
F_0	4269.08	4652.54	0.479
F_1	4362.61	4877.01	0.472
F_2	4899.93	5390.48	0.478
$F_{2,22}$	25.857**	11.753**	0.332
SE	94.414	155.593	0.008
CD(0.05)	196.382	323.635	-
S_0	4258.32	4670.78	0.477
S_1	4600.17	5128.13	0.474
S_2	4673.12	5121.12	0.478
$F_{2,22}$	10.941**	5.640*	0.154
SE	94.414	155.593	0.008
CD(0.05)	196.382	323.635	-

* Significant at 0.05 level
** Significant at 0.01 level

Table - 14. Interaction effects of M, F and S on yield

Effect	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
M_0F_0	4006.73	4381.31
M_0F_1	4478.12	4900.39
M_0F_2	4849.89	5075.76
M_1F_0	4290.12	4769.92
M_1F_1	4475.31	4942.48
M_1F_2	4869.53	5252.53
M_2F_0	4510.38	4806.40
M_2F_1	4134.40	4788.16
M_2F_2	4980.36	5843.16
$F_{4,22}$	3.645*	1.720
SE	163.53	269.50
CD(0.05)	340.143	-
M_0S_0	4041.81	4527.22
M_0S_1	4643.66	5032.27
M_0S_2	4649.27	4797.98
M_1S_0	4621.21	4670.32
M_1S_1	4417.79	5151.52
M_1S_2	4595.96	5143.10
M_2S_0	4111.95	4814.82
M_2S_1	4739.06	5200.62
M_2S_2	4774.13	5422.28
$F_{4,22}$	4.679**	0.387
SE	163.53	269.50
CD(0.05)	340.143	-
F_0S_0	4069.87	4465.49
F_0S_1	4482.32	4928.45
F_0S_2	4255.05	4563.69
F_1S_0	4280.30	4764.31
F_1S_1	4493.55	4847.08
F_1S_2	4313.97	5019.64
F_2S_0	4424.80	4782.55
F_2S_1	4824.64	5608.87
F_2S_2	5450.34	5780.02
$F_{4,22}$	6.538**	2.121
SE	163.53	269.50
CD(0.05)	340.143	-

* Significant at 0.05 level

** Significant at 0.01 level

Table - 15. Effect of treatment combinations on thousand grain weight and benefit : cost ratio

Effect	Thousand grain weight (g)	B : C ratio
$M_0F_0S_0$	25.78	1.34
$M_0F_0S_1$	29.17	1.59
$M_0F_0S_2$	28.08	1.42
$M_0F_1S_0$	28.11	1.70
$M_0F_1S_1$	30.01	1.80
$M_0F_1S_2$	30.67	1.36
$M_0F_2S_0$	27.77	1.64
$M_0F_2S_1$	28.93	1.61
$M_0F_2S_2$	29.32	1.86
$M_1F_0S_0$	28.79	1.62
$M_1F_0S_1$	28.97	1.40
$M_1F_0S_2$	30.28	1.41
$M_1F_1S_0$	28.82	1.58
$M_1F_1S_1$	29.82	1.45
$M_1F_1S_2$	30.41	1.52
$M_1F_2S_0$	30.45	1.67
$M_1F_2S_1$	28.61	1.71
$M_1F_2S_2$	27.40	1.51
$M_2F_0S_0$	27.11	1.24
$M_2F_0S_1$	27.94	1.37
$M_2F_0S_2$	30.26	1.09
$M_2F_1S_0$	30.26	1.17
$M_2F_1S_1$	29.41	1.13
$M_2F_1S_2$	27.31	1.16
$M_2F_2S_0$	29.32	1.21
$M_2F_2S_1$	28.46	1.39
$M_2F_2S_2$	30.71	1.54
$F_{2, 22}$	5.878**	8.027**
SE	0.818	0.054
CD(0.05)	1.702	0.113

* Significant at 0.05 level

** Significant at 0.01 level

nitrogen uptake also was significant. Increase in sulphur levels upto S_2 recorded higher N uptake of 151.46 kg ha^{-1}.

4.5.1.2 Interaction effects of M,F and S (Table 17)

Among the three interactions, MF and FS were significant. Increase in F levels at all levels of M could increase the uptake of N. Maximum nitrogen uptake of 165.03 kg ha^{-1} was noticed with M_1F_2. This was found comparable to M_0F_2, M_1F_1 and M_2F_2.

At all levels of F, an increase in N uptake was noticed with sulphur application upto S_2. The highest N uptake of 182 kg ha^{-1} was recorded with F_2S_2, which was significantly superior to all other combinations.

4.5.2 Phosphorus uptake

4.5.2.1 Effect of M,F and S (Table 16)

Phosphorus uptake was significantly influenced by all the main effects of M,F and S. An increase in P uptake was recorded with increase in organic manure levels. M_1 recorded the highest P uptake of 21.51 kg ha^{-1} which was significantly superior to vermicompost application (M_2) and M_0. A similar increasing trend in P uptake was noticed with increasing NPK levels. F_2 recorded the highest uptake of 21.74 kg ha^{-1}, which was significantly superior to F_1 and F_0. An increase in sulphur levels could increase the P uptake. The highest P uptake of 22.39 kg ha^{-1} was noticed with S_2 and it was significantly superior to S_1 and S_0.

4.5.2.2 Interaction effects of M,F and S (Table 17)

MS interaction significantly influenced P uptake. Increased P uptake was noticed with sulphur levels upto S_2 at all levels of M. M_1S_2 recorded the highest P uptake(23.11 kg ha^{-1}). This was on par with uptake of P by M_2S_2 (22.54 kg ha^{-1}). Lower rate of vermicompost was thus found comparable to higher rate of FYM in increasing P uptake. The interaction of FS also was significant in influencing P uptake. At all levels of F, higher levels of S increased the P uptake. The highest value for uptake of P was noticed with F_2S_2 (23.99 kg ha^{-1}) and it was significantly superior to all other combinations.

4.5.3 Potassium uptake

4.5.3.1 Effect of M,F and S (Table 16)

K uptake increased with increasing levels of organic manuring. The highest value for K uptake was recorded by M_1(144.99 kg ha^{-1}). Vermicompost @ 5 t ha^{-1} recorded higher uptake over the same rate of FYM, even though the effect was not significant. Increase in NPK levels recorded increase in K uptake upto F_2(149.64 kg ha^{-1}). This level was found to be superior to both F_1 and F_0. With increase in S levels, there was marked increase in K uptake and the highest value of 144.06 kg ha^{-1} was recorded with S_2. This level however was found to be on par with S_1.

4.5.3.2 Interaction effects of M,F and S (Table 17)

There was significant effect of MF interaction on the uptake of K. At all levels of M, increase in NPK levels upto F_2 increased the K uptake. The maximum K uptake of 162.62 kg ha^{-1} was recorded with M_1F_2 and it was superior to all other treatments. The interaction effects of MS and FS were not significant in influencing K uptake.

4.5.4 Sulphur uptake

4.5.4.1 Effect of M,F and S (Table 16)

All the main effects showed marked influence on S uptake. An increase in S uptake was noticed with increase manure dose. M_1 recorded the highest S uptake of 10.65 kg ha^{-1} which was superior to M_0 and M_2. Significantly higher uptake of S was noticed with M_2 (9.66 kg ha^{-1}) than M_0(8.7 kg ha^{-1}). Increase in NPK upto F_1 level recorded significantly higher S uptake (11.24 kg ha^{-1}). Further increase in NPK resulted in a reduction in the uptake of S. S uptake increased with increasing levels of sulphur application and recorded highest value at S_2 level(11.87 kg ha^{-1}) which was significantly superior to S_0 and S_1.

4.5.4.2 Interaction effects of M, F and S (Table 17).

MF interaction significantly influenced sulphur uptake. The highest uptake of 12.77 kg ha^{-1} was recorded by the combination M_1F_1. This was found significantly superior to all other combinations. An increase in S uptake was noticed with NPK levels upto F_1.Though not significant at all levels of M, an increase in the S uptake was noticed with S_2 level of Sulphur. The combination M_2S_0 showed better performance than all other combinations Though FS interaction also was not significant, the combination F_1S_2 recorded higher uptake of 13.3 kg ha^{-1}.

Table - 16. Effect of M, F and S on the uptake of nutrients at harvest

	Nutrient uptake (kg ha^{-1})			
Effect	N	P	K	S
M_0	126.65	19.90	129.55	8.70
M_1	146.89	21.51	144.99	10.65
M_2	141.07	20.78	133.43	9.66
$F_{2,22}$	28.160**	47.966**	19.106**	39.333**
SE	2.769	0.164	2.592	0.219
CD(0.05)	5.759	0.342	5.392	0.456
F_0	112.80	19.71	119.40	8.31
F_1	140.43	20.75	138.92	11.24
F_2	161.38	21.74	149.64	9.46
$F_{2,22}$	154.026**	76.506**	69.582**	90.094**
SE	2.769	0.164	2.592	0.219
CD(0.05)	5.759	0.342	5.392	0.456
S_0	120.84	18.58	124.47	6.94
S_1	142.31	21.22	139.43	10.19
S_2	151.46	22.39	144.06	11.87
$F_{2,22}$	64.092**	280.659**	31.026**	259.610**
SE	2.769	0.164	2.592	0.219
CD(0.05)	5.759	0.342	5.392	0.456

* Significant at 0.05 level
** Significant at 0.01 level

Table - 17. Interaction effects of M, F and S on uptake of nutrients at harvest

Effect	Nutrient uptake (kg ha^{-1}) N	P	K	S
M_0F_0	101.25	18.87	111.60	7.10
M_0F_1	122.26	19.93	139.93	10.10
M_0F_2	156.44	20.90	148.75	8.89
M_1F_0	118.93	20.30	126.26	9.16
M_1F_1	156.71	21.56	146.08	12.77
M_1F_2	165.03	22.67	162.62	10.02
M_2F_0	118.21	19.95	120.33	8.67
M_2F_1	142.30	20.74	130.74	10.85
M_2F_2	162.69	21.66	137.56	9.47
$F_{4,22}$	4.041*	0.732	3.847*	3.504*
SE	4.796	0.285	4.490	0.380
CD(0.05)	9.975	-	9.339	0.790
M_0S_0	106.34	17.57	121.06	5.77
M_0S_1	133.96	20.60	136.84	9.47
M_0S_2	139.66	21.54	142.39	10.85
M_1S_0	135.32	19.83	133.86	8.38
M_1S_1	149.08	21.59	147.14	10.79
M_1S_2	156.27	23.11	153.97	12.77
M_2S_0	120.86	18.35	118.49	6.68
M_2S_1	143.88	21.47	134.30	10.31
M_2S_2	158.46	22.54	135.83	12.00
$F_{4,22}$	2.121	3.674*	0.230	1.971
SE	4.796	0.285	4.490	0.380
CD(0.05)	-	0.592	-	-
F_0S_0	96.90	17.57	109.01	5.91
F_0S_1	118.68	20.55	124.70	8.88
F_0S_2	122.82	21.00	124.48	10.14
F_1S_0	129.27	19.05	128.83	8.41
F_1S_1	142.43	20.99	141.62	11.97
F_1S_2	149.57	22.19	146.30	13.34
F_2S_0	136.35	19.13	135.57	6.51
F_2S_1	165.81	22.11	151.95	9.72
F_2S_2	182.00	23.99	161.40	12.15
$F_{4,22}$	4.078*	7.016**	0.940	2.304
SE	4.796	0.285	4.490	0.380
CD(0.05)	9.975	0.592	-	-

* Significant at 0.05 level

** Significant at 0.01 level

4.6 Nutrient content in plant

4.6.1 Nitrogen content

4.6.1.1 Effect of M, F and S (Table 18)

All the main effects showed significant influence in the nitrogen content in plant.

Nitrogen content in the plant increased with higher level of organic manure and recorded maximum values with M_1(1.38 per cent). Increase in NPK levels also increased the nitrogen content. F_2 recorded significantly higher nitrogen content of 1.46 per cent. Higher levels of S also could increase the nitrogen content in plant markedly. The progressive increase in nitrogen concentration was significant upto S_2(1.40 per cent).

4.6.1.2 Interaction effects of M, F and S (Table 19)

The interaction of MF could influence N content significantly. The highest N content of 1.83 per cent was recorded with M_1F_0 combination, which was significantly superior to all other combinations. At lower levels of organic manure application, an increasing trend in nitrogen concentration was noticed with increase in fertilizer levels upto F_2. MS interaction also recorded increasing trends in nitrògen content at all levels of M, with increasing sulphur levels upto S_2. For FS also, increased nitrogen concentrations were recorded with higher S levels upto S_2 at all levels of F. Though the effect of FS was insignificant, the highest nitrogen concentration of 1.52 per cent was recorded with F_2S_2.

4.6.2 Phosphorus content

4.6.2.1 Effect of M, F and S (Table 18)

Among the main effects, only sulphur levels could influence phosphorus content in plant significantly. The highest phosphorus content (0.204 per cent) was obtained with the highest level of organic manure, even though the effect was not significant. Increased NPK levels were found to reduce phosphorus content. Higher P content of 0.21 per cent was recorded by the S_2 level of sulphur which was significantly superior to both S_1 and S_0.

4.6.2.2 Interaction effects of M, F and S (Table 19)

None of the interactions could significantly influence the phosphorus content in plant.

4.6.3 Potassium content

4.6.3.1 Effect of M, F and S (Table 18)

All the main effects could significantly influence the potassium content in plant.

An increase in organic manure levels recorded significant increase in K content and the maximum value was recorded at M_1(1.37 per cent). Vermicompost application decreased the K content in plant. An increase in NPK levels brought significant increase in the K content and the maximum value was recorded for F_2(1.36 per cent). This level was found significantly superior to both F_1 and F_0. Increased sulphur levels also could increase the K content upto S_2(1.34 per cent). This level was found superior to both S_1 and S_0.

4.6.3.2 Interaction effects of M, F and S (Table 19)

MF interaction could significantly influence the K content of plants at harvest. The highest content of K was noticed with M_1F_2 combination(1.49 per cent) and it was found significantly superior to all other combinations. MS and FS interactions were not significant.

4.6.4 Sulphur content

4.6.4.1 Effect of M, F and S (Table 18)

All the main effects significantly enhanced the sulphur content of the plant at harvest stage. There was an increase in S content with increasing organic manure rates. M_1 recorded the highest content of 0.1 per cent which was significantly superior to M_0 and M_2. The increase in NPK levels upto F_1 recorded highest S content of 0.108 per cent. Further increase in NPK showed a decrease in S content. Progressive increase in sulphur content was noticed with increased sulphur levels. S_2 recorded the maximum sulphur content of 0.111 per cent, which was significantly superior to both S_1 and S_0.

4.6.4.2 Interaction effects of M, F and S (Table 19)

MF interaction could significantly influence the content of sulphur in plant at harvest. M_1F_1 recorded the highest S content of 0.119 per cent which was superior to all other combinations. At all levels of M, NPK application upto F_1 could increase the S content. MS and FS interactions couldn't influence the S content significantly.

Table - 18. Effect of M, F and S on nutrient content in plant

Effect	Nutrient content (per cent)			
	N	P	K	S
M_0	1.25	0.20	1.33	0.086
M_1	1.38	0.204	1.37	0.100
M_2	1.33	0.197	1.23	0.091
$F_{2,22}$	21.292**	1.151	29.248**	45.656**
SE	0.021	0.004	0.019	0.001
CD(0.05)	0.043	-	0.039	0.003
F_0	1.15	0.202	1.23	0.084
F_1	1.35	0.20	1.33	0.108
F_2	1.46	0.198	1.36	0.085
$F_{2,22}$	114.489**	0.612	28.548**	142.236**
SE	0.021	0.004	0.019	0.001
CD(0.05)	0.043	-	0.039	0.003
S_0	1.24	0.191	1.27	0.071
S_1	1.33	0.199	1.31	0.095
S_2	1.40	0.21	1.34	0.111
$F_{2,22}$	29.505**	9.901**	6.933**	329.479**
SE	0.021	0.004	0.019	0.001
CD(0.05)	0.043	0.009	0.039	0.003

* Significant at 0.05 level
** Significant at 0.01 level

Table - 19. Interaction effects of M, F and S on nutrient content in plant

	Nutrient content (per cent)			
Effect	N	P	K	S
M_0F_0	1.12	0.210	1.24	0.078
M_0F_1	1.17	0.193	1.34	0.097
M_0F_2	1.46	0.196	1.39	0.082
M_1F_0	1.83	0.202	1.27	0.091
M_1F_1	1.46	0.202	1.36	0.119
M_1F_2	1.51	0.207	1.49	0.091
M_2F_0	1.16	0.195	1.18	0.084
M_2F_1	1.41	0.206	1.30	0.107
M_2F_2	1.43	0.191	1.22	0.081
$F_{4,22}$	9.486**	2.555	5.861**	3.758*
SE	0.036	0.007	0.032	0.003
CD(0.05)	0.075	-	0.068	0.006
M_0S_0	1.13	0.189	1.28	0.061
M_0S_1	1.28	0.199	1.31	0.090
M_0S_2	1.34	0.211	1.38	0.106
M_1S_0	1.33	0.195	1.31	0.082
M_1S_1	1.38	0.201	1.37	0.100
M_1S_2	1.45	0.216	1.43	0.119
M_2S_0	1.25	0.190	1.23	0.069
M_2S_1	1.33	0.199	1.24	0.096
M_2S_2	1.40	0.203	1.22	0.108
$F_{4,22}$	1.438	0.389	2.346	2.603
SE	0.036	0.007	0.032	0.003
CD(0.05)	-	-	-	-
F_0S_0	1.05	0.192	1.19	0.064
F_0S_1	1.14	0.197	1.21	0.084
F_0S_2	1.26	0.219	1.29	0.105
F_1S_0	1.30	0.192	1.29	0.084
F_1S_1	1.35	0.199	1.34	0.113
F_1S_2	1.40	0.210	1.38	0.126
F_2S_0	1.36	0.191	1.35	0.065
F_2S_1	1.51	0.201	1.38	0.089
F_2S_2	1.52	0.202	1.36	0.102
$F_{4,22}$	2.160	1.086	1.844	1.950
SE	0.036	0.007	0.032	0.003
CD(0.05)	-	-	-	-

* Significant at 0.05 level
** Significant at 0.01 level

4.7 Available nutrient status of soil after the experiment

4.7.1 Nitrogen status

4.7.1.1. Effect of M,F and S (Table 20)

Organic manure addition at all levels could maintain the available nitrogen status of soil well above the original status before the experiment. M_2 recorded the highest nitrogen status of 272.85 kg ha^{-1} which was significantly superior to M_1 and M_0. Increased NPK rates of F_1 and F_2 recorded higher nitrogen status in soil than with F_0. F_2 registered significantly higher soil nitrogen status of 270.22 kg ha^{-1}. Increase in sulphur levels showed a decreasing effect on nitrogen status of the soil after the experiment. The available N status was highest in plots without sulphur (268.02 kg ha^{-1}).

4.7.1.2 Interaction effects of M,F and S (Table 21)

None of the interactions were significant enough to influence the soil available nitrogen status after the experiment.

4.7.2 Phosphorus status

4.7.2.1 Effect of M,F and S (Table 20)

Different levels and sources of organic manure application could increase the available P status of the soil after experimentation. M_1 recorded the highest value of 33.89 kg of P_2O_5 ha^{-1} and it was superior to both M_0 and M_1. Higher rates of NPK application could improve the available P status of soil. F_2 recorded the most superior P status of 32.16 kg ha^{-1} P_2O_5. A significant reduction in the available P status of soil was recorded with S application.

4.7.2.2 Interaction effects of M,F and S (Table 21)

All the three interactions could maintain a higher P status well above the initial P status of the soil. There was significant difference among MF combinations in influencing soil P status. M_1F_2 recorded the highest and superior P status of 37.42 kg ha^{-1}. The lowest P status was recorded in M_0F_0 (27.45 kg P_2O_5 ha^{-1}). There was no significant difference among MS and FS combinations in influencing available P status of the soil.

4.7.3 Potassium status

4.7.3.1 Effect of M,F and S (Table20)

Vermicompost application recorded the most superior K status of soil (218.28 kg K_2O ha^{-1}). M_1 was found superior to M_0. Organic manure applied plots maintained a higher level of K_2O in the soil after the experiment. An increase in the available K status of soil was recorded with NPK at normal and enhanced rates. F_2 recorded the highest K_2O status of 193.56 kg ha^{-1}. Sulphur application could maintain an enhanced soil K status after the experiment. But the highest available K status of 192.93 kg K_2O ha^{-1} was recorded in plots without any S application.

4.7.3.2 Interaction effects of M,F and S (Table 21)

MF combinations showed significant difference with regard to soil available K status. M_2F_2 was the most superior treatment which maintained a K_2O status of 221.30 kg ha^{-1}. All the MF combinations could maintain a high K_2O status than that before the experiment. In MS combinations, the maximum K status of 221.97 kg K_2O ha^{-1} was recorded with M_2S_0. In all the MS combinations, the K status could be maintained well above the initial status. A decreasing trend in available K status was however noticed at all the levels of M, with an increase in S levels upto S_2. No significant difference was noticed among FS combinations in influencing the available K status of soil.

4.7.4 Sulphur status

4.7.4.1 Effect of M,F and S (Table 20)

Organic manure application improved the S status of soil after the experiment. The highest and significantly superior sulphur content was recorded with M_1(13.39 ppm). M_2 was significantly superior to M_0. NPK application improved the S status of the soil well above the initial status. F_0 level recorded the highest S status of 10.69 ppm which was significantly superior to F_1 and F_2. The available S status of soil got reduced below the initial status without S addition. But with S_1 and S_2, the soil available S status was considerably raised. S_2 recorded the highest S status of 14.34 ppm.

4.7.4.2 Interaction effects of M,F and S (Table 21)

All MF combinations maintained the S status well above the initial status. No significant differences were identified between different MF combinations in influencing soil S status. Significant differences were however identified in MS combinations. M_0S_0 and M_2S_0 reduced the sulphur status, while all other MS combinations enhanced S status with the maximum being in M_1S_2 (17.83 ppm). No significant differences among FS combinations were identified

Table - 20. Effect of M, F and S on available nutrient status of soil after the experiment

Effect	Nutrient status			
	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})	S(ppm)
M_0	249.02	28.08	164.49	8.19
M_1	266.64	33.89	189.04	13.39
M_2	272.85	30.18	218.28	8.74
$F_{2,22}$	70.688**	70.710**	5203.461**	247.82**
SE	2.073	0.493	0.526	0.256
CD(0.05)	4.312	1.026	1.095	0.532
F_0	256.48	29.46	187.52	10.69
F_1	261.82	30.52	190.72	9.92
F_2	270.22	32.16	193.56	9.72
$F_{2,22}$	22.180**	15.07**	65.676**	8.121**
SE	2.073	0.493	0.526	0.256
CD(0.05)	4.312	1.026	1.095	0.532
S_0	268.02	31.98	192.93	5.86
S_1	262.40	30.64	190.23	10.13
S_2	258.09	29.52	188.65	14.34
$F_{2,22}$	11.448**	12.373**	33.635**	548.31**
SE	2.073	0.493	0.526	0.256
CD(0.05)	4.312	1.026	1.095	0.532

* Significant at 0.05 level

** Significant at 0.01 level

Table 21. Interaction effects of M, F and S on available nutrient status of soil after the experiment

Effect	Nutrient status $N (kg\ ha^{-1})$	$P_2O_5 (kg\ ha^{-1})$	$K_2O (kg\ ha^{-1})$	S(ppm)
M_0F_0	241.76	27.45	162.96	8.52
M_0F_1	248.83	27.86	164.80	8.18
M_0F_2	256.48	28.92	156.70	7.88
M_1F_0	257.73	30.96	185.33	14.42
M_1F_1	267.35	33.29	188.11	12.87
M_1F_2	274.85	37.42	193.70	12.88
M_2F_0	269.94	29.98	214.27	9.15
M_2F_1	269.29	30.42	219.26	8.7
M_2F_2	279.32	30.14	221.30	8.38
$F_{4,22}$	1.198	7.866**	6.864**	1.221
SE	3.591	0.855	0.912	0.443
CD(0.05)	-	1.778	1.897	-
M_0S_0	252.55	29.18	165.61	4.3
M_0S_1	249.06	27.94	164.37	7.92
M_0S_2	245.45	27.12	163.48	12.37
M_1S_0	272.24	35.71	191.19	8.35
M_1S_1	265.69	34.07	188.68	13.98
M_1S_2	262.01	31.90	187.26	17.83
M_2S_0	279.29	31.06	221.97	4.92
M_2S_{11}	272.44	29.93	217.64	8.48
M_2S_{22}	266.82	29.55	215.22	12.83
$F_{4,22}$	0.318	1.069	3.339*	3.789*
SE	3.591	0.855	0.912	0.443
CD(0.05)	-	-	1.897	0.921
F_0S_0	261.03	30.70	190.88	6.12
F_0S_1	256.03	29.02	187.05	10.53
F_0S_2	252.38	28.67	184.62	15.43
F_1S_0	267.91	31.58	192.24	5.78
F_1S_1	260.80	30.31	190.45	9.93
F_1S_2	256.76	29.69	189.48	14.03
F_2S_0	275.14	33.67	195.66	5.67
F_2S_1	270.37	32.6	193.19	9.92
F_2S_2	265.14	30.21	191.85	13.57
$F_{4,22}$	0.112	0.943	1.906	1.630
SE	3.591	0.855	0.912	0.443
CD(0.05)	-	-	-	-

* Significant at 0.05 level

** Significant at 0.01 level

in influencing the available S status of soil. However at all levels of F, an increase in S level upto S_2 could increase the S status of soil.

4.8 Benefit : Cost ratio

4.8.1 Effect of M,F and S (Table 22)

Different levels and sources of organic manures had significantly influenced the benefit : cost ratio. The highest benefit-cost ratio of 1.59 was recorded by M_0. An increase in NPK levels showed a progressive increase in benefit : cost ratio. F_0 recorded the highest ratio of 1.57 which was significantly superior to the other two levels. Different sulphur levels had no significant effect in influencing the benefit : cost ratio. However an increasing trend was noticed with sulphur levels upto S_1 (1.49) followed by a reduction at higher level (S_2)

4.8.2 Interaction effects of M, F and S (Table 23)

All the interactions - MF, MS and FS showed significant influence on benifit : cost ratio. At M_0 and M_1 levels the ratio increased with NPK levels upto F_2. The highest ratio was observed with M_0F_2 (1.7), which was on par with M_1F_2 (1.63) and M_0F_1 (1.62). Among MS combinations, the highest benifit : cost ratio was recorded with M_0S_1 (1.66) and it was found to be on par with M_1S_0 (1.62). F_2S_2 recorded the highest ratio of 1.63, among FS combinations. This was found to be on par with F_2S_1 (1.57).

Among three factor combinations, $M_0F_2S_2$ recorded the highest **B** : C ratio of 1.86 which was on par with $M_0F_1S_1$ (Table 15).

Table - 22. Effect of M, F and S on benefit : cost ratio

Effects	Benefit : Cost ratio
M_0	1.59
M_1	1.54
M_2	1.25
$F_{2, 22}$	98.714**
SE	0.26
CD(0.05)	0.053
F_0	1.38
F_1	1.43
F_2	1.57
$F_{2, 22}$	28.245**
SE	0.026
CD(0.05)	0.053
S_0	1.46
S_1	1.49
S_2	1.43
$F_{2, 22}$	3.382
SE	0.026
CD(0.05)	-

* Significant at 0.05 level
** Significant at 0.01 level

Table - 23. Interaction effects of M, F and S on benefit : cost ratio

Effect	Benefit : Cost ratio
M_0F_0	1.45
M_0F_1	1.62
M_0F_2	1.7
M_1F_0	1.47
M_1F_1	1.52
M_1F_2	1.63
M_2F_0	1.23
M_2F_1	1.15
M_2F_2	1.38
$F_{4,22}$	4.256*
SE	0.044
CD(0.05)	0.092
M_0S_0	1.56
M_0S_1	1.66
M_0S_2	1.54
M_1S_0	1.62
M_1S_1	1.52
M_1S_2	1.48
M_2S_0	1.21
M_2S_1	1.30
M_2S_2	1.26
$F_{4,22}$	4.351**
SE	0.044
CD(0.05)	0.092
F_0S_0	1.40
F_0S_1	1.45
F_0S_2	1.31
F_1S_0	1.48
F_1S_1	1.46
F_1S_2	1.34
F_2S_0	1.51
F_2S_1	1.57
F_2S_2	1.63
$F_{4, 22}$	5.954**
SE	0.044
CD(0.05)	0.092

* Significant at 0.05 level
** Significant at 0.01 level

Discussion

DISCUSSION

A field experiment was conducted during the kharif season of 1998 to study the efficacy of organic manures in conjunction with varying levels of NPK nutrients and sulphur on the yield of transplanted rice. A critical analysis of the results of the experiment revealed marked response of the crop to various treatments which are discussed below.

5.1 Growth characters

5.1.1 Plant height

It is seen that the treatment combination which received the highest NPK level of 105:52.5:52.5 kg ha^{-1} and sulphur of 25 kg ha^{-1} recorded maximum height at 60 DAT and at harvest, as against the low input situation of low NPK and no sulphur. The NPKS interaction was also significant in increasing plant height. The influence of higher fertilization upon encouraging vegetative growth of plants, particularly plant height is a well established fact. The higher NPK and S uptake (Table 16) due to higher fertilizer application might have favoured the growth characters of rice including plant height. Similar enhancement in plant height of rice due to high input supply was reported by Sheela (1993) and Channabasavanna *et al.*(1996). Increased plant height in rice with 25 kg ha^{-1} sulphur application obtained in the present study is in accordance with results reported by Singh *et al.*(1993) and Nair(1995).

5.1.2Tiller count

Results presented in Table 3 showed that highest tiller counts were recorded for treatments with the highest rate of NPK application, ie 105:52.5:52.5 kg ha^{-1} and the highest level of sulphur application. This was due to the increased uptake of major nutrients as well as sulphur with adequate supply of these nutrients through fertilizers. It is well established that higher NPK fertilization is essential for rapid growth and production of more tillers. The increasing trend in tiller number due to higher nutrient levels noticed here is supported by similar results reported by Sheela(1993).The significant positive influence of sulphur application on S uptake and improvement in growth attributes has been reported by Nair(1995) in medium duration rice with a higher S level of 30 kg ha^{-1}.

Significant enhancement in the tiller number was noticed in an integrated approach combining 10 t ha^{-1} FYM and the highest NKP dose of 105 : 52.5 : 52.5 kg ha^{-1}. Apart from the improvement in efficiency of applied mineral nutrients, organic manures ensure a steady supply of essential plant nutrients including secondary and micronutrients throughout the growth period. This might have favoured vegetative growth in terms of tiller count. Addition of FYM is also found to increase the soil temperature by increasing heat absorbance from sun and thereby enhance germination and growth especially during kharif season. The improvement in growth characters of rice noticed in this study is supported by the research findings of Mathew *et al.* (1994),Rameshwar and Singh(1998) and

Mohiuddin and Ghosh(1998).

5.1.3 Leaf area index

Maximum LAI recorded at 40 DAT with the highest NPK dose of 105 : 52.5 : 52.5 kg ha^{-1} was comparable to that obtained with 87.5 : 43.75 : 43.75 kg NPK ha^{-1}. S application upto the highest level of 25 kg ha^{-1} could also influence the LAI significantly. Integration of 10 t ha^{-1} FYM with 25 kg ha^{-1} S recorded similar higher LAI as that with 5 t ha^{-1} of vermicompost. Combined application of the highest NPK dose with 25 kg ha^{-1} S also resulted in significantly higher LAI. Leaf area is a simple and appropriate measure of plant's photosynthetic potential (Watson, 1952). Leaf area index being a function of the number of tillers and the size of the leaf, an increase in any or both of these produces a corresponding increase in the leaf area index. The highest fertilizer level of 105 : 52.5 : 52.5 kg ha^{-1} NPK has recorded the highest tiller count and maximum height of plant. Increased height of plants is a resultant of increased length of leaves. Hence, it follows naturally that the same treatment produces the highest LAI. This observation is in conformity with the report of Babu (1996) where in LAI of medium duration rice varieties were higher with higher NPK level of 120 : 60 : 60 kg ha^{-1}. Nair(1995) also reported higher LAI of rice with higher S level of 30 kg ha^{-1}.

5.1.4 Chlorophyll content

Higher chlorophyll contents were recorded with the application of 10 t ha^{-1} FYM both at 20 and 60 DAT. At 20 DAT, vermicompost applied @

5 t ha^{-1} resulted in higher chlorophyll content than FYM applied at the same rate. At all stages of growth, the maximum chlorophyll content was noticed with NPK application of 105 : 52.5 : 52.5 kg ha^{-1}. Sulphur level upto 12.5 kg ha^{-1} could increase the chlorophyll content at 60 DAT. The combination of 10 t ha^{-1} of FYM along with higher NPK levels of 87.5 : 43.75 : 43.75 kg ha^{-1} and 105 : 52.5 : 52.5 kg ha^{-1} could record higher chlorophyll content. The highest rate of 105 : 52.5 : 52.5 kg ha^{-1} could result in the highest chlorophyll content even without sulphur addition, whereas at lower rates of NPK, S addition increased chlorophyll content.

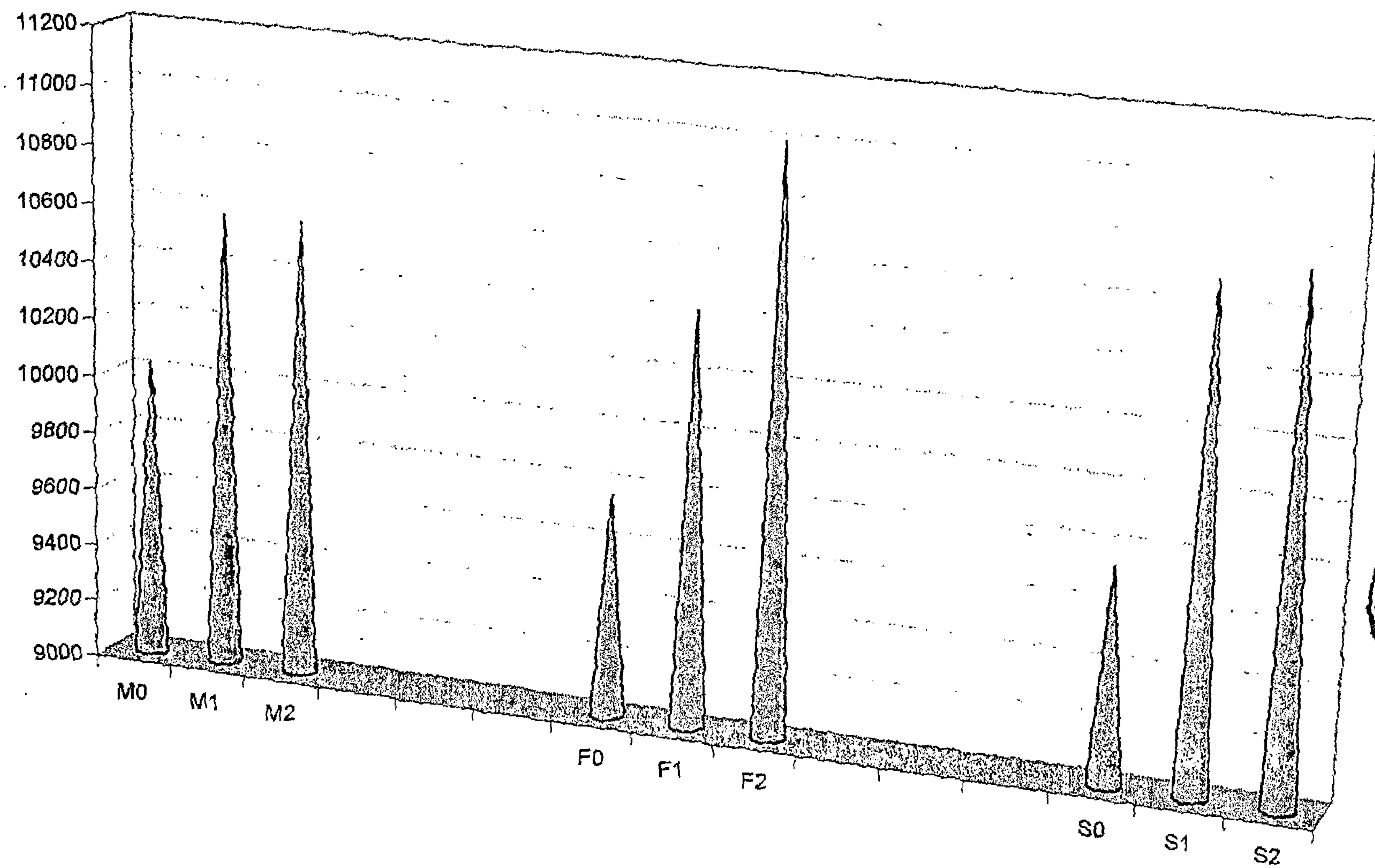
The improvement in chlorophyll content due to organic manuring might have resulted from the enhanced availability of micro and secondary nutrients including Mg in organic manure amended soils as reported by Rai *et al.* (1990). Among inorganic nutrients, nitrogen is believed to have a key role in influencing chlorophyll content (Tisdale *et al.*,1985). The enhanced NPK rates could significantly influence the chlorophyll fractions because of the higher N rates included in it. Babu (1996) could also observe higher chlorophyll content in medium duration rice with enhanced NPK rates. Eventhough S is not a constituent of chlorophyll, it has been identified as essential for chlorophyll synthesis (Tisdale *et al.*, 1985). This may be the reason for increased chlorophyll content with sulphur application upto S_1 level. At the highest S level, a reduction in chlorophyll content noted may be due to the competition of S with other secondary nutrients like Mg, which also is essential for chlorophyll synthesis. Nanawati *et al.* (1973) had observed reduction in chlorophyll content of rice under conditions of S deficiency.

5.1.5 Dry matter production

Increased DMP was noticed with the application of 10 t ha^{-1} FYM or 5 t ha^{-1} vermicompost. It may be seen from the Tables 2,3 and 5 that the tiller number and LAI were relatively more when higher doses of organic manure were applied and this could be the reason for the enhanced DMP. The nutrient uptake (Table 16) also was favourably influenced with organic manure. Unlike other organic manures, vermicompost addition has got the added advantage of quick nutrient absorption by plants which also can improve dry matter accumulation. Increase in dry matter production with the application of higher dose of FYM was previously reported by Babu (1996) and Rameshwar and Singh (1998).

An increase in NPK levels upto 105 : 52.5 : 52.5 kg ha^{-1} could produce the maximum dry matter. Higher S levels upto 25 kg ha^{-1} could also result in increased DMP in most of the growth stages. The DMP of rice as influenced by varying levels of manures, fertilizers and sulphur is given in Figure 3. The highest NPK level in combination with 10 t ha^{-1} FYM or 25 kg ha^{-1} S recorded higher DMP. Increased NPK and S addition might have increased the availability of these nutrients leading to higher uptake which in turn resulted in the improvement of growth characters like plant height, tiller number, LAI etc., and thereby the DMP. Similarly higher DMP of rice with enhanced N levels upto 160 kg ha^{-1} was reported by Jagathi (1990). Significant enhancement in DMP of rice has been previously reported by Rani *et al.* (1997) with higher NPK levels.

Fig.3. Effect of manures, fertilizers and sulphur on dry matter production at harvest (kg ha^{-1})



Nair (1995) found higher DMP in rice with sulphur addition.

5.2 Yield attributes

5.2.1 Panicle number m^{-2}

Maximum number of panicles were recorded with the highest level of 10 t ha^{-1} FYM, which was comparable to that obtained with 5 t ha^{-1} of vermicompost. This shows that vermicompost is equally good to produce optimum number of panicles in rice. Higher doses of organic manures could promote number of tillers resulting in higher panicle numbers. This finding is in conformity with that of Rathore *et al.* (1995) who observed higher panicle number m^{-2} in rice with FYM addition. A two fold increase in panicle number of rice with vermicompost application was reported by Janaki and Hari (1997). The richness of vermicompost in essential plant nutrients might be the reason for its comparable performance with higher rates of FYM.

Significantly higher panicle number was also noticed with increased NPK level of 105 : 52.5 : 52.5 kg ha^{-1} and S @ 25 kg ha^{-1}. This was due to the increased tiller production which could have resulted from the efficient utilization of nutrients, when enhanced rates of NPK and sulphur were applied. Channabasavanna *et al.* (1996) reported a similar increase in panicle number of rice with enhancement of NPK rate upto 150 : 75 : 75 kg ha^{-1}. Nair (1995) observed significantly higher panicle number in rice with sulphur addition.

5.2.2 Number of grain $panicle^{-1}$

An increasing trend in the grain number $panicle^{-1}$ was noticed with organic manure at higher levels though not significant. This might have resulted from a favourable condition of nutrient availability in the soil system, through a steady supply from organic manure during the entire growth period. Rathore *et al.*(1995) also observed higher grain number $panicle^{-1}$ in rice with FYM addition.

NPK application upto the highest level resulted in higher number of total and filled grain $panicle^{-1}$. The improved uptake of all the three nutrients especially nitrogen (Table 16) due to increased availability might have resulted in greater number of grains $panicle^{-1}$. Comparable grain number $panicle^{-1}$ were noticed with the NPK dose of 87.5:43.75:43.75 kg ha^{-1} also.Ghose *et al.* 1960) propounded that increased absorption of nutrients at panicle initiation stage favored increased production of grain $panicle^{-1}$ as noticed in the present study. Channabasavanna *et al.*(1996) also reported increase in grain number $panicle^{-1}$ in rice with higher NPK rates.

Sulphur application upto the highest level of 25 kg ha^{-1} could result in an increase in the grain number $panicle^{-1}$. Increased availability of sulphur might have resulted in higher sulphur uptake and synergistic effects on the absorption of other nutrients (Table 16) which can be the reason for higher grain number $panicle^{-1}$. Nair (1995) also reported significant increase in grain number $panicle^{-1}$ in rice with S addition.

Combined application of 10 t ha^{-1} of FYM along with 87.5:43.75:43.75 kg ha^{-1} of NPK recorded the highest grain number $panicle^{-1}$.

Similarly higher number of grain panicle^{-1} were also seen in a combination of 105 : 52.5 : 52.5 kg NPK ha^{-1} along with 25 kg ha^{-1} sulphur.

5.2.3 Chaff per centage

FYM @ 10 t ha^{-1} and vermicompost @ 5 t ha^{-1} recorded minimum chaff percentage. Apart from the improvement in the efficiency of applied mineral nutrients, organic manure ensure a steady supply of essential plant nutrients including secondary and micro nutrients throughout the growth period. This might be the reason for a reduction in chaff percentage with organic manure addition. Similar reduction in chaff percentage with the incorporation of FYM in rice was previously reported by Sharma and Sharma (1994) and Babu (1996).

At the highest level of NPK addition, there was significant increase in chaff percentage. With higher fertilizer doses, the vegetative growth was more resulting in higher LAI (Table 5) and this might have resulted in mutual shading which affected photosynthesis. The reduced translocation of the accumulated starch and decreased photosynthetic activity during the reproductive and ripening stages might have resulted in the production of more number of chaffy grains. Similarly Asif *et al.* (1999) also observed higher chaff percentage with enhanced NPK rate of 180 : 90 : 90 kg ha^{-1}.

5.2.4 Thousand grain weight

An increasing trend in test weight was noticed with higher levels of organic manure. This might be due to the continuous supply of nutrients through organic manure addition which resulted in more number of normal and filled grains.

Enhanced grain weight due to high organic manure addition was previously reported by Babu (1996).

With the highest NPK level of 105 : 52.5 : 52.5 there was slight reduction in test weight than with 87.5:43.75:43.75 kg ha^{-1} NPK. The formation of more chaffy and half filled grains due to lesser starch accumulation which resulted from the increased vegetative growth could be the reason for reduction in thousand grain weight. Similar reduction in thousand grain weight of rice with 25 per cent increase in the recommended fertilizer dose of 100 : 50 : 50 kg ha^{-1} NPK was reported by Singh *et al.* (1998).

Increased sulphur levels had recorded a slight increase in thousand grain weight. This could be due to the increased uptake of S as well as NPK with increase in S addition (Table 16), which might have led to the formation of more number of normal and filled grains. This is in agreement with the findings of Muraleedharan and Jose (1993) who reported an increase in thousand grain weight of rice variety Jyothi with S application.

5.3 Grain yield

An increasing trend in grain yield was noticed with higher doses of organic manure addition, though the effect wasn't significant. FYM @ 10 t ha^{-1} and vermicompost @ 5 t ha^{-1} were found to be equally good in grain production of rice. The increase in yield might be due to the increase in ammoniacal and nitrate nitrogen and enhanced availability of major and micro nutrients due to FYM addition (Mondal and Chettri, 1998). The problem of accumulation of auto toxins excreted by the roots of rice into the soil also is alleviated by the addition of FYM through its nutrient supplying power and positive effect on physico-chemical and biological properties of soils. All these might had positive influence on yield attributing characters including panicle number m^{-2}, filled grain $panicle^{-1}$, and thousand grain weight (Table 11), thus leading to higher grain yields. The richness of vermicompost in most of the major nutrients and their ready availability to crops made it comparable to FYM at higher levels. Singh *et al.* (1998) also reported significantly higher grain yield of rice with FYM addition. Increased grain yield of rice with the addition of vermicompost as observed in the present study is supported by the reports of Janaki and Hari (1997).

The highest levels of NPK and S recorded the maximum grain yield. The increased availability of these nutrients in soil followed by increased plant uptake (Table 16) might have contributed to the improvement in yield attributing characters (Table 12) which is reflected in the grain yield. These findings are in agreement with the reports of Channabasavanna *et al.* (1996) who obtained higher grain yield in paddy with enhanced NPK rates of 200 : 100 : 100 kg ha^{-1}. Increased grain yield of medium duration rice with the application of 30 kg S ha^{-1} was reported by (Nair 1995).The favourable effects of manures, fertilizers and sulphur on the grain yield of rice obtained in the present study is given in Figure 4.

The highest NPK level in combination with 5 t ha^{-1} vermicompost or 10 t ha^{-1} FYM recorded similar higher yields. The combination of vermicompost with lower and higher rates of S addition also were proved equally beneficial in improving grain yield. With the highest NPK level, addition of 25 kg ha^{-1} S was found good in increasing grain yield. However with lower NPK rates, increase in grain yield was noticed with S addition upto 12.5 kg ha^{-1} followed by a reduction at higher levels. Nitrogenous fertilizers including ammonium sulphate in combination with FYM are reported to increase the availability of phosphorus and potassium in addition to that of nitrogen (Chellamuthu *et al.* 1988). The overall improvement in the yield attributes of rice might be due to the additive effect of organic manure and NPK fertilizers. The improvement in efficiency of applied mineral nutrients and a steady supply of essential plant nutrients including secondary and micro nutrients throughout the growth period are added advantages of INM which ultimately leads to superior yields. Increased grain yield upto 5.6 t ha^{-1} for medium duration rice with combined application of organic and inorganic nutrients was previously reported by Babu (1996).

5.4 Straw yield

It is seen that maximum straw yield was obtained in treatments with 5 t ha^{-1} vermicompost. The increasing trend in the tiller production noticed with high dose of organic manuring (Table 3) and the improvement in vegetative characters including LAI and DMP (Table 5,9) might have contributed to higher straw yield. The richness of vermicompost in most of the essential plant nutrients, their steady supply throughout the growth period and improvement in soil properties might have given an added advantage in increasing straw yield. The favourable effects of organic manure addition on rice straw yield was previously reported by Deepa (1998).

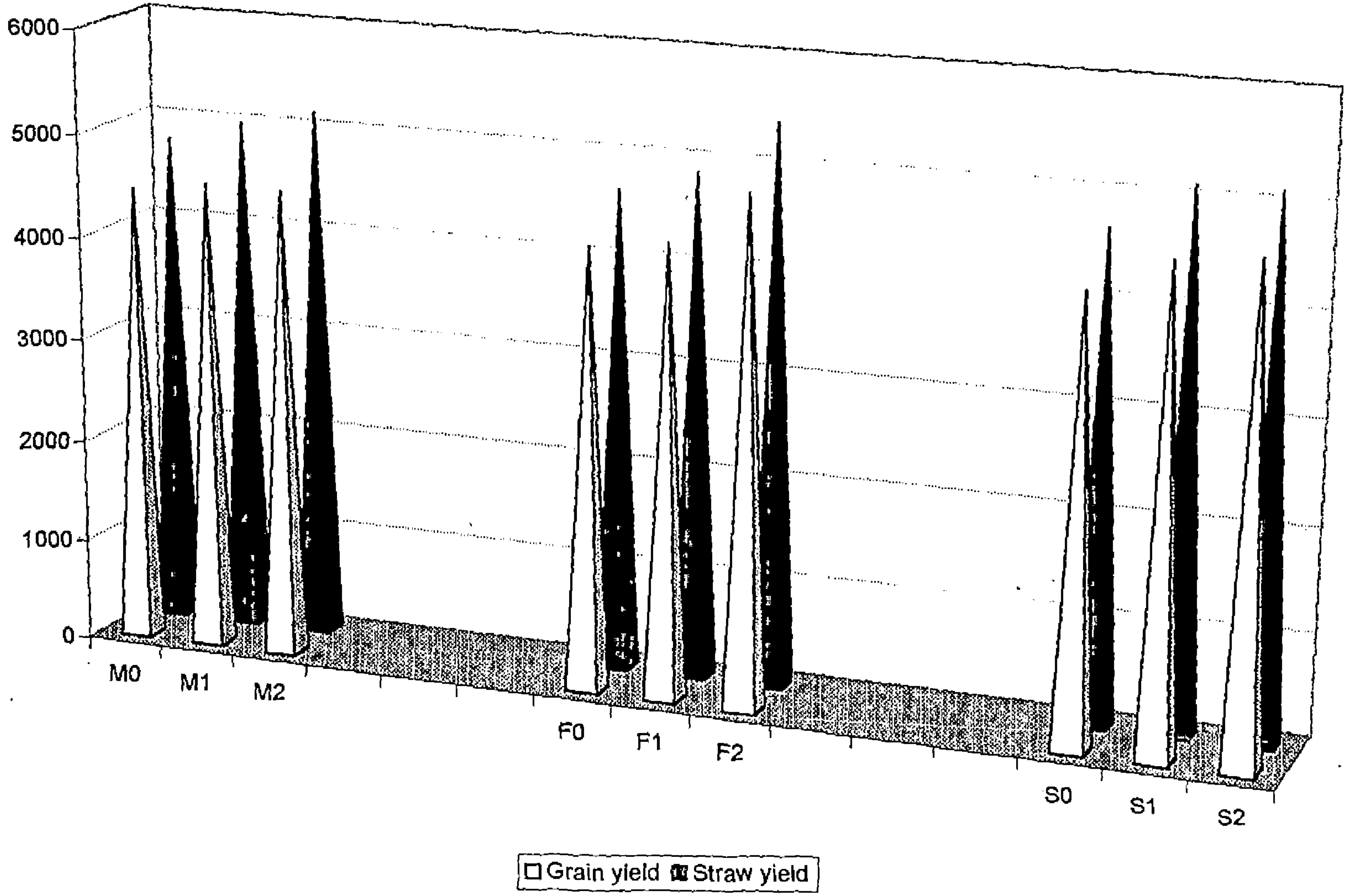
An increase in NPK levels upto 105 : 52.5 : 52.5 kg ha^{-1} could record an increased straw yield. The data presented in Table 2,3,5 & 9 clearly indicate that higher NPK levels had positive influence on plant height, tiller number, LAI and DMP which have direct bearing on the straw yield. Higher uptake of major nutrients (Table 16) due to increased availability of these nutrients might have also helped in the production of more straw yield of rice. This finding is in confirmity with the findings of Singh *et al.* (1998) who reported that higher straw yield with 25 per cent increase in the NPK level of 100 : 50 : 50 kg ha^{-1}.

The straw yield was found to increase with S levels upto 12.5 kg ha^{-1}. S addition increased the availability of the nutrient, which resulted in higher uptake by the plant (Table 16). It had synergistic effects on the uptake of NPK nutrients also (Table 16). This might be the reason for increased plant height (Table 2), tiller number (Table 3), LAI (Table 5) and DMP (Table 9), which ultimately resulted in higher increase in straw yield. Nair (1995) reported similar increase in straw yield of medium duration rice with S levels upto 30 kg ha^{-1}. The influence of manures, fertilizers and sulphur on the straw yield of rice is given in Figure 4.

5.5 Harvest index

Higher HI was recorded for treatments which received a lower dose of 5 t ha^{-1} FYM. Higher NPK and S doses were found to decrease the HI,

Fig.4. Effect of manures, fertilizers and sulphur on the yield of rice (kg ha^{-1})



though not significantly. Under high input situations, the vegetative growth was more as seen from the data presented in Tables 2,3,5 and 9 on plant height, tiller number, LAI and DMP. This might be the reason for increase in biological yield as compared to economic yield, which resulted in a reduction in HI. Even with the addition of 10 t ha^{-1} FYM, Babu (1996) failed to obtain any significant increase in HI of medium duration rice. But there was a significant reduction of HI with enhanced fertilizer application. Nair (1995) reported higher HI of rice in treatments without S addition, which was due to low straw yield.

5.6 Uptake of nutrients

The influence of varying levels of manures, fertilizers and sulphur on the uptake of nutrients is given in Figure 5.

5.6.1 Nitrogen uptake

Comparable higher uptake of N was recorded by 10 t ha^{-1} FYM and 5 t ha^{-1} vermicompost. The increase in N uptake due to FYM or vermicompost was probably due to the improvement of soil environment, which encouraged root proliferation, which in turn drew more nutrients from larger areas and greater depths. Mishra and Sharma (1997) also could observe such improvement in N uptake due to FYM addition.

The highest NPK levels also resulted in increased N uptake. This may be attributed to the increased availability of the nutrient. The improved DMP (Table 9) with higher fertilizer levels also might have contributed to the higher N uptake. By the integration of the highest NPK dose of 105 : 52.5 : 52.5 kg ha^{-1}

with 10 t ha^{-1} FYM or 5 t ha^{-1} vermicompost, the N uptake was more. Babu (1996) also reported similar higher uptake of N in medium duration rice with increased NPK levels upto 120 : 60 : 60 kg ha^{-1}.

Increased S levels upto 25 kg ha^{-1} could improve S availability and result in higher N uptake due to the synergestic relation between N and S, which is evident from Table 16. The improvement in DMP with S addition (Table 9) also might have contributed to higher N uptake. Nair (1995) also noticed enhanced N uptake in rice with higher S levels.

5.6.2 Phosphorus uptake

It is seen that FYM @ 10 t ha^{-1} recorded higher P uptake. The combination of 10 t ha^{-1} FYM or 5 t ha^{-1} vermicompost along with 25 kg ha^{-1} S recorded higher P uptake. The organic acids produced during the degradation of organic materials might have resulted in the solubility and release of native and applied P, which in turn resulted in higher P uptake. The higher DMP due to increased organic manuring also might have contributed to higher uptake (Table 9). The findings are in agreement with that of Sharma and Mittra (1991), Hundal *et al.* (1992) and Kumar and Yadav (1995), who reported significantly higher P uptake in wetland rice with FYM addition.

With enhanced NPK rates also there was a natural increase in P uptake due to increased availability of P. Similarly the highest NPK level in combination with 25 kg ha^{-1} S also registered higher P uptake. The data presented in Table 9 showed an increase in DMP with higher fertilizers levels which might have contributed to the higher uptake of P. As reported by Agarwal (1980), increased K level also can improve the uptake of P due to the synergistic relationship between P and K. Mishra and Sharma (1997) also previously reported such increase in P uptake with enhanced NPK doses.

An increase in P uptake noticed with increase in S levels in this study is supported by the findings of Sarkar *et al.* (1994) and Sakal *et al.* (1999). This could be a direct result of the increased availability of S, which enabled the plants to absorb more P due to the synergistic effect. The increasing DMP with increased levels of applied S also helped in moulding this trend of uptake.

5.6.3 Potassium uptake

Comparable higher K uptake was recorded with 10 t ha^{-1} FYM or 5 t ha^{-1} vermicompost. The increase in K uptake was mainly associated with increase in the dry matter as a result of organic manure application at higher levels (Table 9). Varma and Dixit (1989) and Sharma and Mittra (1991) reported that addition of organic materials including FYM increased the K uptake in rice.

The highest NPK and S levels also recorded higher uptake of K. The treatment combination of FYM @ 10 t ha^{-1} along with the highest fertilizer level recorded superior K uptake. Rice crop absorb more potassium than N and P and the absorption occurs even at the later stages of growth. With higher NPK rates, the availability of K was more to result in higher uptake. This fact combined with the improvement in DMP must have resulted in increased uptake of the nutrient. Babu (1996) and Mishra and Sharma (1997) have also observed significant increase in K uptake with enhanced NPK rates. The beneficial effects of integrating organic manure and chemical fertilizers on improved K uptake have been reported earlier by Babu (1996), Mondal and Chettri (1998) and Deepa (1998). The increase in K uptake with S can be attributed to the synergestic effect of S on K. Further there was an increase in DMP with increasing S levels to result in an enhanced K uptake (Table 9). Sakal *et al.* (1999) observed similar increased K uptake in rice with the addition of 40 kg ha^{-1} S

5.6.4 Sulphur uptake

Higher uptake of S was noticed with FYM @ 10 t ha^{-1}. Vermicompost @ 5 t ha^{-1} also could record higher S uptake even without S addition. The richness of organic manures in secondary nutrients including sulphur and its steady supply throughout the growth period might have led to higher S uptake by plants. DMP was favourably influenced by higher levels of organic manure (Table 9) which also might have contributed to higher S uptake. Sarkar *et al.* (1994) and Mondal and Chettri (1998) could observe higher S uptake by rice in treatments where chemical fertilizers were supplemented with organic sources.

NPK levels upto 87.5 : 43.75 : 43.75 kg ha^{-1} in combination with 10 t ha^{-1} of FYM or 25 kg S ha^{-1} could register higher S uptake . The reduction in S uptake noticed at the highest NPK level of 105 : 52.5 : 52.5 kg ha^{-1} can be attributed to the antagonistic effect of P on S uptake at higher levels of P. The high uptake of S at lower NPK rates may be due to the synergestic relation between the nutrients. Aulakh *et al.* (1990) observed synergestic effect of P and S on uptake of both, when these nutrients were supplied at low rates. A higher P level of 52.5 kg ha^{-1} had an antagonistic effect on S uptake in rice as reported by Nair (1995).

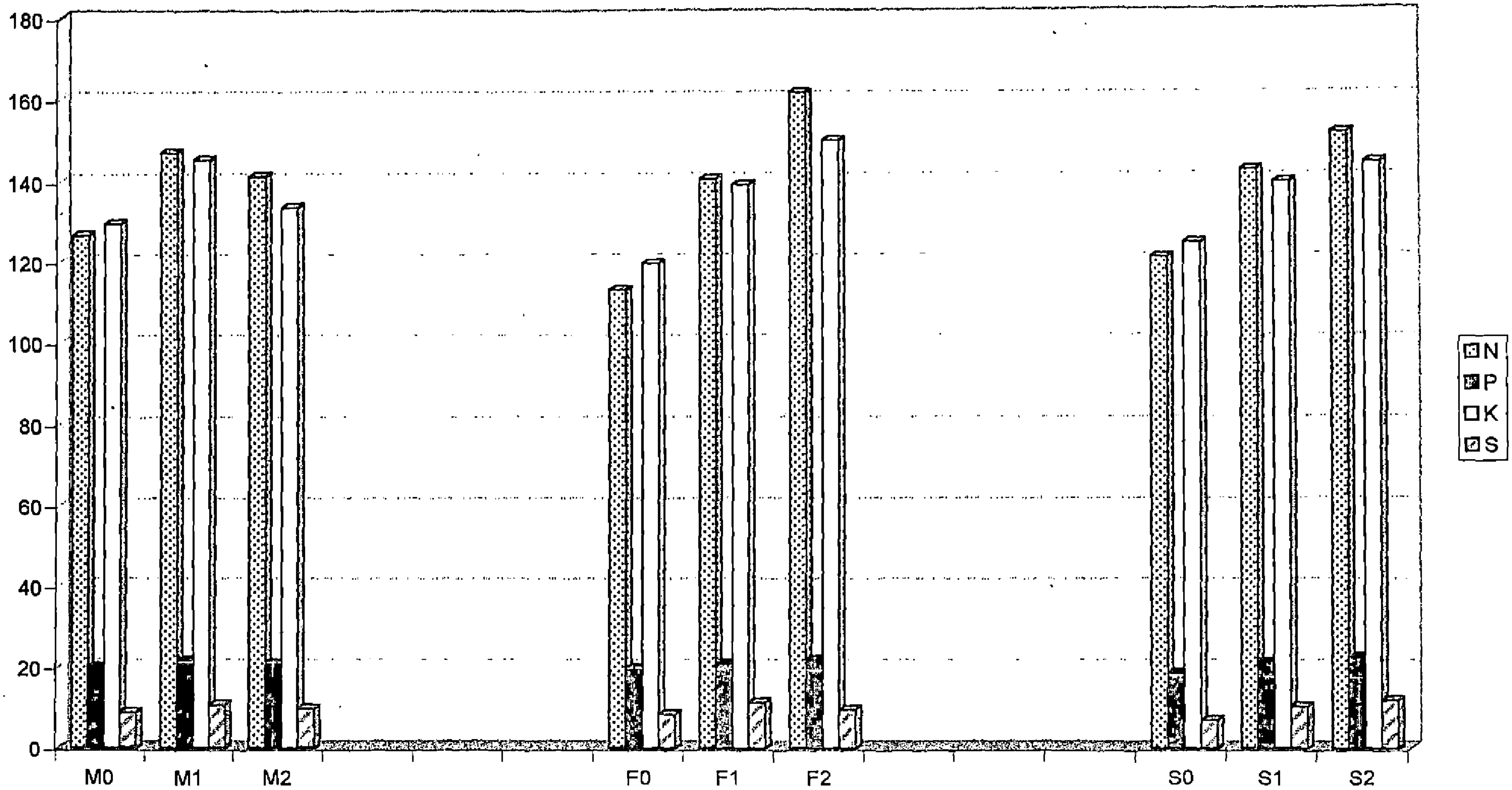
Sulphur addition upto 25 kg ha^{-1} could increase the availability of S which in turn resulted in higher uptake of the nutrients. The DMP also was favourably affected by increase in S levels (Table 9) in contributing to higher S uptake. Positive increase in S uptake with increasing S levels was reported by Subharao and Ghosh (1981), Jain *et al.* (1984) and Paliwal and Dikshit (1987) in rice. The finding is also in agreement with Mondal (1994) who reported higher S uptake with sulphur bearing fertilizers and Sakal *et al.* (1999) who could observe progressive increase in S uptake with increased levels of SSP.

5.7 Nutrient content in plant

5.7.1 Nitrogen content

The plant nitrogen content increased with higher levels of organic manure upto 10 t ha^{-1} FYM. At higher manure levels, the normal NPK rate was sufficient to produce higher N content. Highest N content was also recorded with increased dose of NPK upto 105 : 52.5 : 52.5 kg ha^{-1} . The same level in combination with 10 t ha^{-1} FYM also could produce higher N content in plants. The increasing supply of N through organic manure and chemical fertilizers containing N facilitates the crop roots to absorb more nitrogen, which is translocated to the shoot portion. Thus the content in shoot records higher value in this study

Fig.5. Effect of manures, fertilizers and sulphur on the uptake of nutrients at harvest (kg ha^{-1})



than the treatments receiving lower supply. This is in accordance with the reports of Babu (1996), who observed an increase in N content of rice grain and straw with an enhanced NPK rate of 120 : 60 : 60 kg ha^{-1}.

S level upto 25 kg ha^{-1} recorded highest N content in plant. This may be due to the synergestic effect of S on plant N content. As both N and S are constituent of proteins and are involved in chlorophyll formation, there is a direct link between N and S. Sarkar *et al.* (1994) also reported higher N content in rice with the supply of 100 per cent NPK through S bearing fertilizers. The synergistic effect of S on N content in plants have been previously identified by Singh *et al.* (1994), Nair (1995) and Sakal *et al.* (1999) as reported in the present study.

5.7.2 Phosphorus content

Organic manures or chemical fertilizers at higher levels had no significant influence on plant P content. Similar results have been reported by several scientists. According to Babu (1996) the P content in rice was not significantly influenced by the application of organic manures even at the rate of 10 t ha^{-1} FYM or by enhanced NPK rates upto 120 : 60 : 60 kg ha^{-1}.

S addition upto 25 kg ha^{-1} could significantly improve the plant P content. This might be due to the synergistic effect of sulphur with phosphorus. Sarkar *et al.* (1994) observed highest P content in rice with the supply of recommended NPK through S containing NPK fertilizers. Singh *et al.* (1994) and Sakal *et al.* (1999) also observed higher P concentration in rice with the application of sulphur.

5.7.3 Potassium content

An increase in organic manure application upto 10 t ha^{-1} FYM could record higher K content. Organic manures can favourably influence soil properties and can ensure steady supply of nutrients including K throughout the growth period. This might be the reason for better K uptake with higher levels of manures (Table 16) which in turn resulted in increased K content of plant.

Enhanced NPK rates upto 105 : 52.5 : 52.5 kg ha^{-1} could result in higher K content of plant . This may be due to the increased supply of nutrients as evident from the reports of Babu (1996). The combinations of 10 t ha^{-1} FYM along with the highest NPK rate could record significantly higher K content.

Sulphur levels upto 25 kg ha^{-1} recorded increased K content, probably due to the synergestic interaction of S on K content. Sarkar *et al.* (1994) reported similar increase in K content of rice, when the recommended NPK was supplied through chemical fertilizers which contained S also. Increased K content in the grain and straw of rice with S addition upto 40 kg ha^{-1} has been reported by Nair (1995). Though not significant, the combination of 10 t ha^{-1} FYM along with the highest S level also could increase K content in rice. The favourable effect of sulphur containing NPK fertilizers along with organic manuring on K uptake has been previously discussed by Sarkar *et al.* (1994). This holds the possibility of increased K content in plants, which may be attributed to the improvement in the efficiency of mineral fertilizers with an integrated approach in supplying plant nutrients.

5.7.4 Sulphur content

FYM @ 10 t ha^{-1} could increase the S content of plant. The richness of organic manures in secondary nutrients including S and its availability throughout the growing period might have led to an increase in S uptake with enhanced organic manure addition. The same could be the reason for increased S contents in plant also.According to Sahoo and Panda (1985), the S content in plant increased upto 0.15 per cent with the combined application of recommended NPK along with FYM, over the sole application of NPK. Sarkar *et al.* (1994) could record higher content of S in rice with the combined application of NPK nutrients and FYM @ 10 t ha^{-1}, which stood next to that with 100 per cent NPK through fertilizers which contained S also.

NPK rates upto 87.5 : 43.75 : 43.75 kg ha^{-1} significantly improved S content in plant, because of the synergestic relation maintained between the nutrients on uptake and hence nutrient content. N and K nutrient supply even at high levels can positively influence the S content, but P at higher levels is found to have antagonistic relationship with S. This is in confirmity with the findings of Nair (1995). The same can be the reason for reduction in S content at higher NPK levels, where P addition was at a higher rate of 52.5 kg ha^{-1}.

Increase in S levels upto 25 kg ha^{-1} resulted in higher S content of plant. This might have resulted from the higher S uptake with increased availability of the nutrient. Supporting the result obtained in this study is the findings of Singh *et al.* (1993) and Singh *et al.* (1994) where in increase in S content were obtained with increased application of S. A three fold increase in S content in rice straw with 40 kg S ha^{-1} was reported by Nair (1995).

5.8 Soil nutrient status after the experiment

The influence of manures, fertilizers and sulphur on the nutrient status of soil after the experiment is given in Figure 6.

5.8.1 Nitrogen status

Organic manure addition maintained higher N status in soil even after experimentation. The highest N status of soil was recorded with 5 t ha^{-1} of vermicompost. The higher buildup of available N in the soil is attributed to the mineralization of organic sources or solubilization from the native source during the process of organic matter decomposition. In a rice-rice based cropping system, application of 5 t ha^{-1} vermicompost in both the season increased the availability of soil N status by 42.9 per cent (Vasanthi *et al.* 1995). Similar enhancement in N buildup in soil due to organic matter addition was reported by Swarup (1993) and Kumar and Yadav (1995).

NPK @ 105 : 52.5 : 52.5 kg ha^{-1} recorded higher N status of soil than before the experiment. With higher NPK rates, the availability of the nutrient was more which resulted in higher soil content. Mishra and Sharma (1997) also reported high N status due to higher NPK addition.

Higher S level anyhow recorded a decreasing trend in soil N content. With increased S levels, the uptake of N was significantly increased (Table 16), resulting in a reduction in soil N. Nair (1995) also could observe an increase in N uptake with increased sulphur levels.

5.8.2 Phosphorus status

Organic manuring at higher doses could improve the available P status of the soil even after the experiment. FYM @ 10 t ha^{-1} recorded higher P status of soil. The solubilising action of organic acids produced during the decomposition of organic materials might have resulted in an enhanced release of native and applied P. Dhargawe *et al.* (1991) observed increased P availability in soil by the addition of 10-20 t ha^{-1} FYM. Hundal *et al.* (1992) and Kumar and Yadav (1995) also reported similar results of higher P status of soil with organic manure addition.

Higher NPK dose of 105 : 52.5 : 52.5 kg ha^{-1} recorded increased P status of soil. With enhanced NPK rates, the P added to the soil was more and thereby resulted in higher soil P content. With an enhancement of NPK rates from 60 : 25 : 20 kg ha^{-1} to 120 : 50 : 40 kg ha^{-1}, Mishra and Sharma (1997) observed higher P status of the soil which is in agreement with the results of the present study.

With increased S levels, a reduction in P status was recorded in the present study. S addition especially at lower rates are found to have a synergistic effect on the uptake of P (Table 16). This might have led to the reduction in P content of the soil with S application. Singh *et al.* (1994) observed a similar reduction in the P content of soil with S @ 20 kg ha^{-1}.

5.8.3 Potassium status

An improvement in the available K status of soil was recorded with higher levels of organic manuring, the highest K being in treatments with 5 t ha^{-1} vermicompost. Organic manures like vermicompost are very rich sources of potassium when compared to FYM. This might have resulted in higher K status in treatments with vermicompost. Bhawalkar (1992) could obtain 10 per cent more of K_2O in soils with vermicompost application.

The improvement in available K status with increased rates of 105 : 52.5 : 52.5 kg ha^{-1} of NPK may be due to the increased K supply to soil which resulted in higher K content. Ammal and Muthiah (1995) and Mishra and Sharma (1997) also reported higher K content in soils with enhanced K addition.

Treatments which received no sulphur registered higher K content in soil. At all levels of K and S, there existed a synergestic relationship as evident from the data on K uptake (Table 16). The increased K uptake with S addition might have resulted in a reduction in soil K content. Sakal *et al*. (1999) noticed a similar increase in K uptake of rice with sulphur addition.

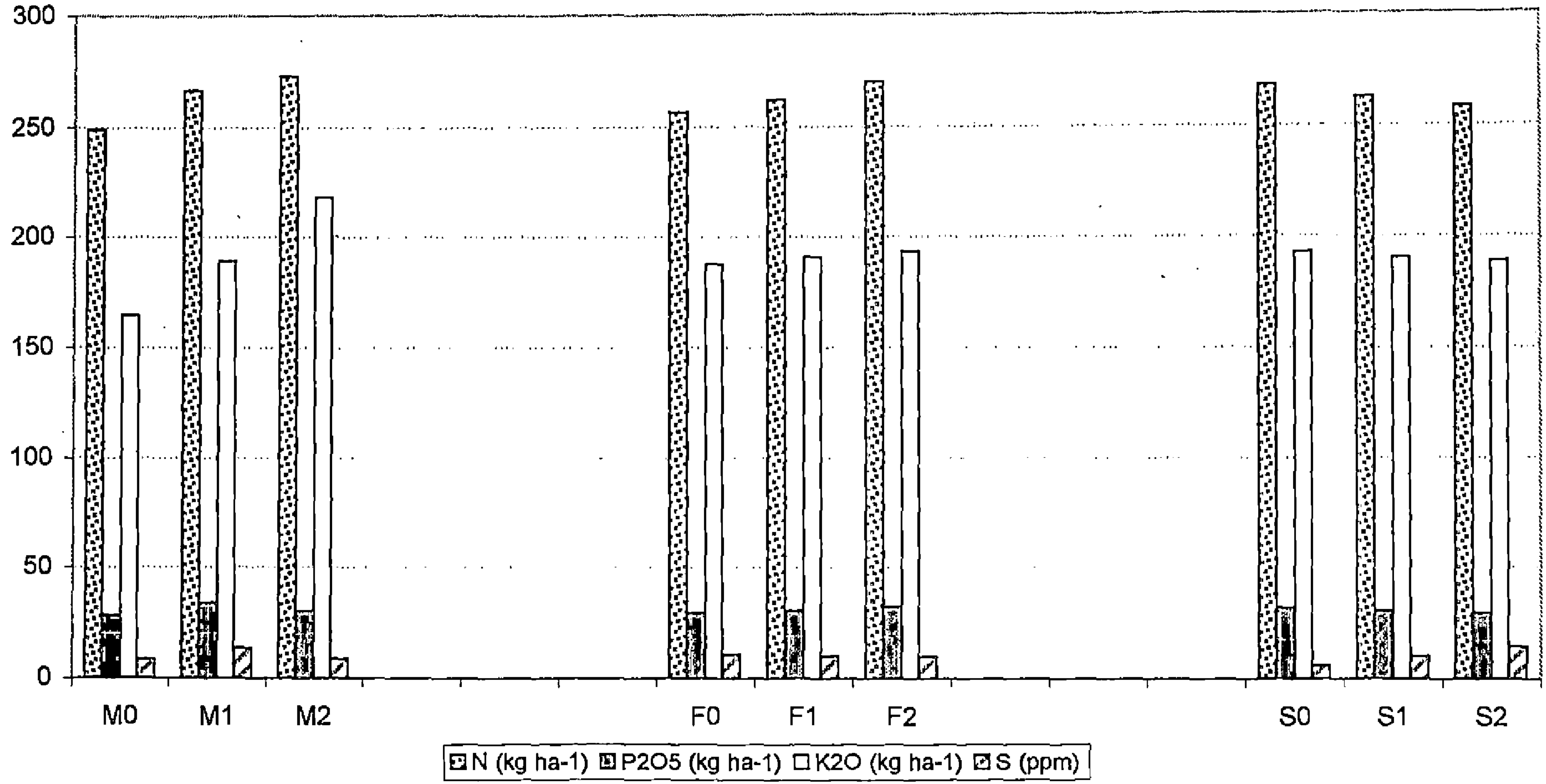
5.8.4 Sulphur status

Organic manuring improved the sulphur status of the soil, the highest S content being in treatments with 10 t ha^{-1} FYM. Organic manures are rich sources of secondary nutrients including S and this might have resulted in higher content of the nutrient in the soil. Sarkar *et al*. (1994) noticed that S status declined in treatments where FYM or chemical fertilizers containing S were not supplied. They also reported higher sulphur status in treatments where crop residues were incorporated in addition to NPK fertilizers.

Eventhough NPK at normal and enhanced rates could maintain a superior sulphur status than that before the experiment, a decreasing trend in S content of soil was noticed with enhanced NPK levels than with the normal rate. It is well established that an increase in N and K at all levels and P in levels ranging around 52.5 kg ha^{-1} can influence S uptake synergestically. The higher S uptake with enhanced NPK rates might have contributed to a reduction in S status. Naturally the sulphur status was higher in treatments with normal NPK rates due to a lesser S uptake. The increase in S uptake with enhanced NPK rates has been observed by Nair (1995).

Increased S levels upto 25 kg ha^{-1} could increase the S status of soil and a reduction in available S content was noticed with no sulphur. The combination of 10 t ha^{-1} FYM with the highest S rate of 25 kg ha^{-1} also could significantly prove better in maintaining higher S status. Improvement in S status of soil with increased application of gypsum can be attributed to the enhanced availability of the nutrient. This finding is in agreement with the reports of Singh *et al.* (1994). Sarkar *et al.* (1994) reported a negative S balance in soils with treatments receiving no sulphur containing fertilizers or FYM. Sakal *et al.* (1999) reported that continous application of SSP could raise the available S status of soil from deficiency to sufficiency.

Fig.6. Effect of manures, and fertilizers and sulphur on available nutrient status of soil after the experiment



5.9 Economics

The lowest level of manure addition by 5 t ha^{-1} of FYM recorded the highest benefit : cost ratio. Vermicompost @ 5 t ha^{-1} recorded the least benefit : cost ratio. Vermicompost is a costly input than FYM. This might be the reason for a reduction in the B : C ratio with vermicompost. Singh *et al.* (1998) obtained similar results of significantly higher net returns from rice cultivation with the addition of FYM @ 5 t ha^{-1}. Further addition of FYM was found to be non-economical.

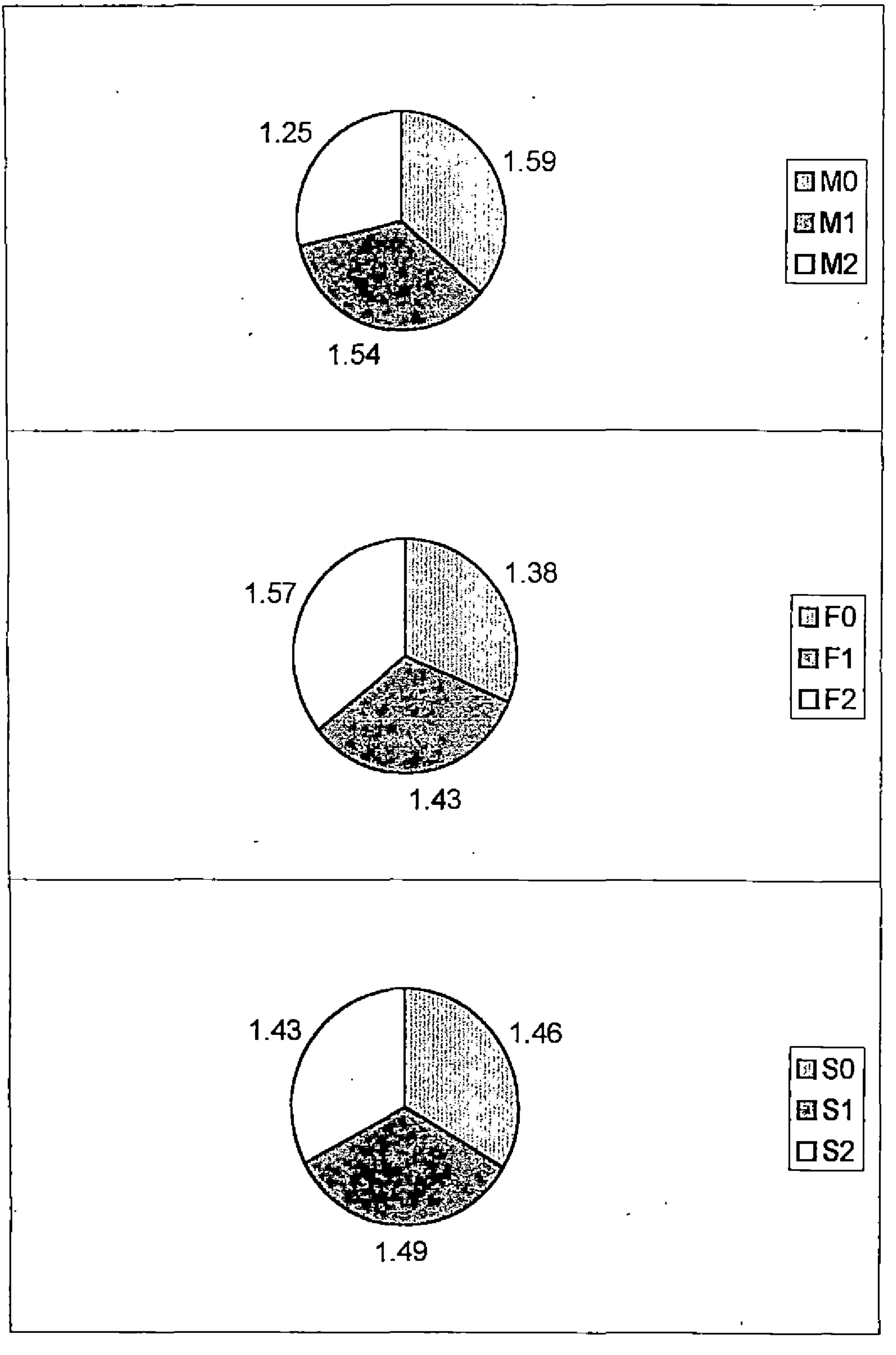
There was progressive increase in the benefit : cost ratio with increase in NPK levels upto 105 : 52.5 : 52.5 kg ha^{-1}. The inorganic NPK nutrients are less costly and added much to the grain yield in recording higher benefit : cost ratio. Increase in net returns with 100 per cent NPK than with 75 per cent the recommended dose in rice cultivation has been reported by Singh et al. (1998) as observed in the present study with enhanced NPK rates.

Sulphur application upto 12.5 kg ha^{-1} was economical and resulted in higher benefit : cost ratio and a reduction in the ratio was noticed at higher S levels of 25 kg ha^{-1}. Sulphur being a costly input, the application at higher levels didn't prove economical. The influence of different levels of manures, fertilizers and sulphur on the benefit : cost ratio is given in Figure 7.

Based on the B : C ratio, the following conclusions can be suggested.

- For maximising the yield, $M_0F_2S_2$ can be recommended.
- For resource constraints situations, $M_0F_1S_1$ can be suggested.

Fig.7. Effect of manures, fertilizers and sulphur on benefit : cost ratio



Summary

SUMMARY

An experiment entitled "Nutrient management for yield improvement of transplanted rice (*Oryza sativa* L.) in the southern region of Kerala" was carried out to study the efficacy of organic manures in conjunction with varying levels of NPK nutrients and sulphur in enhancing rice yields. The study was carried out at the Cropping Systems Research Centre (CSRC) Karamana, during the kharif season of 1998.

Observations on the vegetative and productive characters of rice, nutrient uptake by the plant and the nutrient status of the soil before and after the experimentation were studied. The results obtained were statistically analysed.

The various levels and sources of organic manures could not make any significant influence on plant height. However with enhanced NPK rates and sulphur levels, notable difference in plant height was observed towards the later stages of growth. Maximum plant heights were recorded with NPK rate of 105 : 52.5 : 52.5 kg ha^{-1}, S at 25 kg ha^{-1} and the combination of NPK @ 87.5 : 43.75 : 43.75 kg ha^{-1} along with 25 kg ha^{-1} sulphur.

Increased tiller counts over 5 t ha^{-1} of FYM were noticed with the use of FYM @ 10 t ha^{-1} or vermicompost @ 5 t ha^{-1} at all stages of growth, even though the effect wasn't significant. Enhanced NPK rates upto 105 : 52.5 : 52.5

kg ha^{-1} could record 15 per cent increase in tiller at harvest. With a sulphur level of 25 kg ha^{-1} also 10 per cent increase in tiller count was noticed at harvest stage than in conditions without S addition. The combination of 10 t ha^{-1} of FYM along with the highest NPK dose of 105 : 52.5 : 52.5 kg ha^{-1} recorded maximum tiller counts in most of the growth stages studied.

Leaf area index was high with enhanced NPK doses and sulphur addition. The combination of 10 t ha^{-1} FYM along with the enhanced NPK dose 87.5 : 43.75 : 43.75 kg ha^{-1} recorded higher LAI. The highest NPK level of 105 : 52.5 : 52.5 kg ha^{-1} along with highest rate of S addition, ie., 25 kg ha^{-1} could record higher LAI. When vermicompost was used, even without supplementation of S, higher LAI was registered as that with 10 t ha^{-1} of FYM and 25 kg ha^{-1} in S combination.

Organic manuring at a higher level with 10 t ha^{-1} of FYM was found to increase the chlorophyll content of leaf. At all stages of growth, an enhancement in NPK dose could significantly increase the chlorophyll content, with the maximum being with 105 : 52.5 : 52.5 kg NPK ha^{-1}. The significant influence of sulphur levels on chlorophyll content was noticed towards the later growth stage of 60 DAT. However at all the growth stages increase in chlorophyll content was noticed with sulphur levels upto 12.5 kg ha^{-1} and a reduction with levels of 25 kg ha^{-1} S. The combination of 10 t ha^{-1} of FYM with the highest NPK dose was found helpful in producing more chlorophyll in most of the growth stages. At lower rates of manure addition ie., 5 t ha^{-1} of FYM, supplementation of sulphur @ of 12.5 kg ha^{-1} was needed to produce similar chlorophyll content as that with sole application of 10 t ha^{-1} FYM. Similarly with normal and 25 per cent enhanced NPK rates, sulphur application @ 12.5 kg ha^{-1} could increase the leaf chlorophyll content. However with highest NPK rate there was no need for supplementing sulphur in producing the highest chlorophyll content.

Addition of higher doses of organic manure, increase in NPK rates and sulphur levels enhanced dry matter accumulation. It was seen that vermicompost at lower levels could enhance DMP comparable to that with higher doses of FYM. The highest NPK rate of 105 : 52.5 : 52.5 kg ha^{-1} along with 10 t ha^{-1} FYM or 25 kg ha^{-1} could register higher DMP.

The maximum panicle number were observed with higher levels of FYM, NPK and S. 5 t ha^{-1} of vermicompost was found equally good as 10 t ha^{-1} FYM in enhancing the panicle number. The highest NPK rate of 105 : 52.5 : 52.5 kg ha^{-1} along with 10 t ha^{-1} of FYM or 25 kg ha^{-1} of sulphur could also record higher panicle number m^{-2}.

Though not significant, and increase in the grain number $panicle^{-1}$ was noticed with organic manure addition at higher levels and sulphur application. Significantly higher number of total and filled grains $panicle^{-1}$ was noticed with enhanced NPK levels of 87.5 : 43.75 : 43.75 and 105 : 52.5 : 52.5 kg ha^{-1}. The combination of NPK @ 87.5 : 43.75 : 43.75 kg ha^{-1} with 10 t ha^{-1} FYM and NPK @ 105 : 52.5 : 52.5 kg ha^{-1} with 25 kg ha^{-1} S was found superior in increasing the grain number $panicle^{-1}$.

A reduction in chaff percentage was observed with vermicompost application as well as with higher levels of FYM. The enhanced NPK doses increased the chaff percentage. However the addition of sulphur at varying levels couldn't influence the chaff per centage. In all the treatments the chaff percentage remained within the range of 14 per cent, which was reasonably good for higher yield.

Eventhough no significant effect of various treatments were noticed on thousand grain weight, there was an increasing trend with sulphur and organic manure levels. The enhanced NPK doses also could register higher test weight than with the normal dose.

Organic manuring with FYM @ 10 t ha^{-1} and vermicompost @ 5 t ha^{-1} were found equally good in producing better grain yields than that with 5 t $ha^{-1}$of FYM. The effect was however not significant. Higher grain yields upto 4.9 t ha^{-1} and 4.7 t ha^{-1} were obtained with enhanced NPK level of 105 : 52.5 : 52.5 kg ha^{-1} and S @ 25 kg ha^{-1} respectively. The combination of 5 t ha^{-1} of vermicompost along with the highest NPK dose registered a superior grain yield of upto 5 t ha^{-1}, comparable to that with FYM @ 10 t ha^{-1} and the highest NPK dose. Vermicompost was also found good to be combined with 25 kg ha^{-1} of S in producing higher grain yield upto 4.8 t ha^{-1}. Among all the combinations, the highest grain yield was observed with the highest NPK and S dose, which could produce 5.5 t ha^{-1} of rice grain. By following the PPR alone, grain yield upto 3.4 t ha^{-1} only was produced.

The combination of 5 t ha^{-1} of FYM or vermicompost along with the highest NPK level of 105 : 52.5 : 52.5 kg ha^{-1} and 25 kg ha^{-1}.S recorded the highest grain yields of 5.8 t ha^{-1} and 5.7 t ha^{-1} respectively . Straw yield was found to be high for treatment which received vermicompost @ 5 t ha^{-1}. An enhancement in NPK levels brought about a significant increase in straw yield. The highest straw yield of 5.4 t ha^{-1} was recorded with 105 : 52.5 : 52.5 kg ha^{-1} of NPK addition. Sulphur levels upto 12.5 kg ha^{-1} increased the straw yields to 5.13 t ha^{-1} and a reduction was noticed with higher sulphur levels.

Maximum input situations reduced the harvest index. The highest harvest index of 0.48 was noticed with 5 t ha^{-1} FYM addition.

A significant increase in Nitrogen uptake upto 15 per cent was noticed when FYM level was raised from 5 to 10 t ha^{-1}. This was found comparable to lower rates of vermicompost addition. The enhanced NPK level of 105 : 52.5 : 52.5 kg ha^{-1} and S level of 25 kg ha^{-1} could improve N uptake by 43 and 25 per cent respectively than with normal NPK rates and no sulphur. Combinations of the highest NPK level with 10 t ha^{-1} of FYM or 25 kg ha^{-1} of S also resulted in higher N uptake.

The phosphorus uptake was superior with 10 t ha^{-1} FYM, which recorded 8 per cent increase over that with 5 t ha^{-1} of FYM and 4 per cent increase over vermicompost addition. The highest NPK levels could increase P uptake by 10 per cent and 20 per cent than in conditions with normal NPK rate and no sulphur. Sulphur levels at 25 kg ha^{-1} could record highest P uptake in combination with 5 t ha^{-1} of vermicompost or the highest NPK rate.

Potassium uptake increased with increased organic manure, NPK and S levels and reached the highest value with 10 t ha^{-1} FYM, 105 : 52.5 : 52.5 kg ha^{-1} NPK or 25 kg ha^{-1} of S. An increase of upto 9 per cent and 12 per cent were noticed over that with 10 t ha^{-1} FYM over that with 5 t ha^{-1} vermicompost and FYM respectively. With the highest NPK and sulphur rates increased K uptake upto 25 per cent and 16 per cent respectively were obtained than in conditions with normal NPK rates and no sulphur.

Sulphur uptake increased with enhanced doses of manures as well as sulphur and NPK nutrients upto 87.5 : 43.75 : 43.75 kg ha^{-1}. Increased S uptake upto 22 percent and 10 per cent were observed with 10 t ha^{-1} FYM over that with 5 t ha^{-1} FYM and 5 t ha^{-1} vermicompost respectively at harvest stage. With S addition @ 25 kg ha^{-1}, a considerable increase in S uptake upto 71 per cent was observed over conditions with no sulphur. With the highest NPK level, the S uptake was found to be reduced. Increase in the nutrient uptake occurred due to an increase in DMP. The combination of 10 t ha^{-1} FYM and NPK level of 87.5 : 43.75 : 43.75 kg ha^{-1} also could significantly increase the S uptake.

The N, P, K and S content in plant at harvest were found to be higher in treatments which received 10 t ha^{-1} FYM or S @ 25 kg ha^{-1}. With the highest NPK level, the N and K content were found to be high. There was a reduction in P content with enhanced NPK levels. The S content was however found to increase with NPK levels upto 87.5 : 43.75 : 43.75 kg ha^{-1}. 10 t of FYM in combination with the normal NPK level recorded highest N content. Similarly the same rate of FYM along with enhanced NPK doses of 87.5 : 43.75 : 43.75 and 105 : 52.5 : 52.5 kg ha^{-1} recorded higher S and K contents respectively .

After the experiment the NPK status of the soil was found to be raised from the initial level. A reduction in S status was however noticed in treatments without S addition. Treatments involving organic manures and varying levels of NPK could maintain a higher S status than the initial level. The NPK status was found to be highest in treatments receiving the enhanced NPK rate of 105 : 52.5 : 52.5 kg ha^{-1} or no S addition. The P and S status were more in treatments with 10 t ha^{-1} of vermicompost. A normal NPK level of 70 : 35 : 35 kg NPK ha^{-1} registered highest value for available S in soil.

The highest NPK level along with 10 t ha^{-1} FYM recorded the highest P_2O_5 status of soil whereas the same rate with 5 t ha^{-1} vermicompost recorded highest K_2O status. Sole application of vermicompost even without supplementation of S also could record highest K_2O status in soil. The integration of 10 t ha^{-1} FYM along with the highest sulphur level of 25 kg ha^{-1} recorded higher S status of soil.

The highest benefit : cost ratio was recorded for treatment combinations of 5 t ha^{-1} FYM, enhanced NPK rates of 105 : 52.5 : 52.5 kg ha^{-1} and sulphur levels at 25 kg ha^{-1}. The combination of 5 t ha^{-1} of FYM along with the higher NPK level of 87.5 : 43.75 : 43.75 kg ha^{-1} and S @ 12.5 kg ha^{-1} also could record higher benefit : cost ratio.

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Originals not seen

Appendix

Appendix I

Weekly Weather data during the cropping period from 23-6-1998 to 17-10-1998.

Period		Average Max. temp	Average Min. temp	Average R.H.	Rainfall
From	To	°C	°C	per cent	mm
22-6-98	28-6-98	29.86	23.29	90.86	98.0
29-6-98	05-7-98	29.71	22.71	90.86	66.0
06-7-98	12-7-98	31.29	24.14	84.29	11.0
13-7-98	19-7-98	30.14	23.57	90.57	26.0
20-7-98	26-7-98	29.14	23.29	88.43	51.0
27-7-98	02-8-98	29.71	24.29	91.0	17.0
03-8-98	09-8-98	30.0	23.86	87.71	15.0
10-8-98	16-8-98	30.71	24.29	87.43	18.0
17-8-98	23-8-98	30.14	23.29	91.43	119.0
24-8-98	30-8-98	30.17	23.67	87.17	57.0
31-8-98	06-9-98	30.91	23.57	86.14	103.0
7-9-98	13-9-98	29.71	23.86	87.71	110.0
14-9-98	20-9-98	30.14	23.57	88.14	54.0
21-9-98	27-9-98	28.43	23.29	92.29	79.0
28-9-98	4-10-98	29.14	23.57	90.00	45.0
5-10-98	11-10-98	27.50	23.00	95.50	98.0
12-10-98	18-10-98	29.00	23.28	92.86	151.0

NUTRIENT MANAGEMENT FOR YIELD IMPROVEMENT OF TRANSPLANTED RICE (*Oryza sativa* L.) IN THE SOUTHERN REGION OF KERALA

BY
SUDHA. B

ABSTRACT OF THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE

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FACULTY OF AGRICULTURE

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Abstract

ABSTRACT

An experiment entitled "Nutrient management for yield improvement of transplanted rice (*Oryza sativa* L.) in the southern region of Kerala" was conducted at Cropping Systems Research Centre (CSRC) Karamana, during the kharif season of 1998 to study the efficacy of organic manures in conjunction with varying levels of NPK nutrients and sulphur in enhancing rice yield using the variety Kanchana.

The experiment was laid out in 3^3 partially confounded factorial RBD with two replications. Combinations of three levels each of organic manures (M), inorganic NPK fertilizers (F) and sulphur (S) constituted the treatments. FYM @ 5 and 10 t ha^{-1} as well as vermicompost @ 5 t ha^{-1} included the different manure levels. The normal NPK rates of 70 : 35 : 35 kg ha^{-1} and enhanced rates of 87.5 : 43.75 : 43.75 and 105 : 52.5 : 52.5 kg ha^{-1} were the three fertilizer levels. The different S levels were no sulphur, S @ 12.5 and 25 kg ha^{-1}. Higher order interactions of MFS and M^2FS were confounded in Rep I and Rep II respectively.

Results of the field experiment revealed that the main effects of organic manures, chemical fertilizers and sulphur as well as their combinations exerted significant positive influence on most of the growth and yield attributing characters of rice. The higher NPK levels upto 105 : 52.5 : 52.5 kg ha^{-1} and S levels of 25 kg ha^{-1} were found significantly superior to lower levels. Organic manuring with FYM @ 10 t ha^{-1} and vermicompost @ 5 t ha^{-1} were found to be equally good in influencing growth and yield of rice.

The available NPK status of soil after the experiment was maintained well above the initial status. The available sulphur status of soil was found to be considerably reduced in treatments which didn't receive sulphur addition.

FYM levels recorded better benefit : cost ratio over vermicompost addition. Increase in NPK levels upto 105 : 52.5 : 52.5 kg ha^{-1} and sulphur addition @ 12.5 kg ha^{-1} was found profitable. The combination of 5 t ha^{-1} FYM along with the highest NPK level of 105 : 52.5 : 52.5 kg ha^{-1} and S @ 25 kg ha^{-1} recorded the highest B : C ratio, but this was comparable to that obtained with the combined effect of 5 t ha^{-1} FYM, NPK @ 87.5 : 43.75 : 43.75 and S @ 12.5 kg ha^{-1}.