

**EFFECT OF CHEMICAL FERTILIZERS, FYM AND THEIR  
CONJUNCTIVE USE ON YIELDS, RICE QUALITY AND NUTRIENT  
UPTAKE OF AROMATIC RICE – WHEAT SEQUENCE**

*THESIS*

SUBMITTED TO THE

G.B. PANT UNIVERSITY OF AGRICULTURE AND TECHNOLOGY  
PANTNAGAR - 263145 (UDHAM SINGH NAGAR)  
UTTARANCHAL, INDIA



BY

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**To  
My MENTOR,  
Who Gave Me an  
Insight to Peep Down  
the SOIL Profile.**

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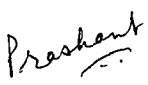
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Pantnagar  
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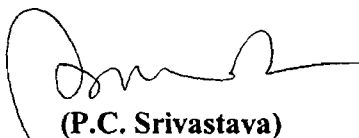
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## CERTIFICATE

This is to certify that the thesis entitled “EFFECT OF CHEMICAL FERTILIZERS, FYM AND THEIR CONJUNCTIVE USE ON YIELDS, RICE QUALITY AND NUTRIENT UPTAKE OF AROMATIC RICE – WHEAT SEQUENCE” submitted in partial fulfillment of requirements for the degree of *DOCTOR OF PHILOSOPHY* with major in *SOIL SCIENCE* and minor in *CHEMISTRY* of the College of Post Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bonafide* research carried out by Mr. PRASHANT SRIVASTAVA, Id. No. 22941 under my supervision and no part of the thesis has been submitted for any other degree or diploma.

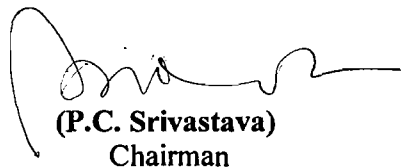
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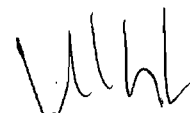
  
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# CERTIFICATE

We, the undersigned, members of the Advisory Committee of **MR. PRASHANT SRIVASTAVA**, Id. No. 22941, a candidate for the degree of **DOCTOR OF PHILOSOPHY** with major in **SOIL SCIENCE** and minor in **CHEMISTRY**, agree that the thesis entitled “**EFFECT OF CHEMICAL FERTILIZERS, FYM AND THEIR CONJUNCTIVE USE ON YIELDS, RICE QUALITY AND NUTRIENT UPTAKE OF AROMATIC RICE – WHEAT SEQUENCE**” may be submitted in partial fulfillment of the requirements for the degree.



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# INTRODUCTION

## 1. Introduction

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Rice – Wheat is a dominant agricultural system in the northern part of India covering an area of about 10 mha (Modgal *et al*, 1995). In north India, the farmers practice rice – wheat system, as it involves minimum risk and better profit possibilities. Aromatic rice varieties are being opted by farmers, as they fetch a high price in the domestic markets, besides their demand for export, as well. Basmati cultivation is localized to northwest Indian states – Punjab, Harayana and Uttaranchal, Western Uttar Pradesh and to a limited area in Himachal Pradesh, Jammu and Kashmir, Delhi and Rajasthan. The area under basmati rice fluctuates based on demand and price offered during a particular season. There is a substantial gain of basmati rice in traditional areas with Harayana toping in area, production and productivity. Although, the exact area, production and productivity of basmati rice is not well documented, tentative estimates indicate that it is cultivated in about 0.7 to 0.8 mha. In the earlier years (1983-86), more than 80% of Indian rice exported was only basmati. From 241,674 metric tones in 1990-91, basmati exports rose steadily over the years and nearly tripled by 1999-2000. The foreign exchange earned too during this period has gone up almost six times from Rs. 287.31 crores to Rs. 1866.248 crores. The production is about 1.2 MT (rough rice basis) with an average of 1.5 to 1.8 t/ha (Mishra, 2001). Out of nearly a million tons of *Basmati* rice produced in the country annually, about 60 per cent is exported mainly to Saudi Arabia, UAE, UK, Kuwait and others. Half the quantity of basmati exported from the country is *sela* (parboiled) basmati mainly to the gulf countries. In USA, demand for *Basmati* rice is increasing by about 50 per cent per annum (Hirannaiah *et al*, 2001). While, Thailand is the biggest exporter of non-basmati rice, India enjoys monopoly over basmati in the world markets. Aromatic rice varieties grown in sub Himalayan regions are traded at three times higher prices (US\$ 200 – 400 per metric tones) than normal and earn as much as Rs 1800 crores of foreign exchange for the country.

Gangwar and Sharma (1996) assessed the productivity and potential profitability of two traditional scented rice varieties, *Basmati 370* and *Pusa Basmati* with a check *Saket 4* during 1993. *Basmati 370* and *Pusa Basmati 1* recorded yields of 3 and 3.1 t/ha, respectively, which was lower than the check (3.4 t/ha). With regard to profitability, *Basmati 370* recorded the highest net returns (Rs. 16000/ha) compared with *Pusa Basmati 1* (Rs. 13600/ha) and *Saket 4* (Rs. 6400/ha), as *Basmati 370* fetches a higher market price because of its quality and aroma.

The production of aromatic rice is, however, declining fast even in the native areas of adaptation due to decline in yield and quality traits including aroma. The overall productivity of rice-wheat system is quite low and poor nutrient management is one of factors responsible for this. As farmers do not practice the proper use of chemical fertilizers including micronutrients, there exists a possibility that yield decline and loss of aroma could be due to some nutritional disorder, as well. The fertilizer requirement of country has already touched the mark of 16 MT. The government subsidy on fertilizer has suffered serious cuts. In view of these constraints, it has become all the more important to work out integrated use of chemical fertilizers in conjunction with organic sources, so that twin objectives of high productivity and economic use of fertilizers can be met with. To achieve this goal we need not only more research but also to change our policies. There should be a price support system to the farmers in the native aromatic rice growing areas to convince them not to shift to other cultivars of rice or to other crops.

Grain quality in rice is very difficult to define with precision as preferences for quality vary from country to country. The concept of quality varies according to the preparations for which grains are to be used. Although some of the quality characteristics desired by growers, millers and consumers might be the same; yet, each may place different emphasis on various quality characteristics. For instance, the millers' basis of quality is dependent upon total recovery and the proportion of

head and broken rice on milling. Consumers base their concept of quality on the grain appearance, size and shape, the behaviour upon cooking, the taste, tenderness and flavour of rice. The desired properties may vary from one ethnic group or geographical region to another and may vary from country to country (Juliano *et al*, 1964). The cooking quality preferences vary in different countries e.g. Indians prefer flaky rice, Chinese and Philipinos prefer sticky rice. The quality in rice may, therefore, be considered from viewpoint of milling quality, grain size, shape and appearance and cooking characteristics.

Among different quality traits, aroma is considered most important. A 'popcorn like aroma' component 2-acetyl-1-pyrroline, has been reported as an important flavour component of several aromatic varieties. However, pleasant aroma that we smell from cooked or un-cooked aromatic rice or in field at the time of flowering is a result of a large number of compounds present in specific proportion. It is now well realized that in addition to genetic composition, cultivation practices and environmental and soil factors do influence expression of aroma and quality traits in aromatic rices. Same variety cultivated at different places may not produce grain of similar quality. Singh *et al* (1997) reported that as per the farmers perception lighter soil and upland conditions, fertile soil, application of farmyard manure, direct sowing, cool weather during flowering and grain development, and manual dehulling were the factors favouring aroma formation/retention in aromatic rices while heavy soil, poor soil, transplanting, nitrogenous fertilizers particularly urea, hot weather during flowering and development, delayed harvesting after maturity, and mechanical dehulling led to poor aroma. Scientific community is yet to acknowledge the importance of factors augmenting best expression of aroma. Environmental, cultural, soil and nutritional factors affecting aroma formation in major cultivars of *Basmati* and non-*Basmati* type aromatic rices must be characterized.

In view of the above facts, field experiments were conducted with the following objectives:

1. To study the effect of soil application of chemical fertilizers (N, P, K and Zn) vis-à-vis farmyard manure application or their conjoint application on the yields, nutrient contents and uptake of aromatic rice-wheat rotation.
2. To study the effect of soil application of chemical fertilizers (N, P, K and Zn) vis-à-vis farmyard manure application or their conjoint application on quality parameters of aromatic rice.
3. To investigate the relationships between plant nutrient status and various grain quality parameters in aromatic rices.
4. To examine the effect of soil application of chemical fertilizers (N, P, K and Zn) vis-à-vis farmyard manure application or their conjoint application on post harvest build up of soil organic carbon and extractable contents of nutrients.

**REVIEW**  
**OF**  
**LITERATURE**

## 2. *Review of Literature*

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The literature on the effect of soil application of chemical fertilizers and farmyard manure and foliar application of individual micronutrients on yield, quality parameters, nutrient content and uptake of aromatic rice and wheat crops and availability of the nutrients in the soil has been reviewed. The literature on the effect of nutrition on quality parameters of scented rice is meager. However, an attempt has been made to cover as much work as possible. This chapter has been dealt under the following sections for the sake of systematic presentation.

- 2.1 Effect of soil application of chemical fertilizers on yield and yield attributes of aromatic rice – wheat sequence.
- 2.2 Effect of farmyard manure on yield and yield attributes of aromatic rice – wheat sequence.
- 2.3 Effect of conjoint application of chemical fertilizers and farmyard manure on yield and yield attributes of aromatic rice – wheat sequence.
- 2.4 Quality of aromatic rice and nutritional factors affecting it
  - 2.4.1 Effect of chemical fertilizers.
  - 2.4.2 Effect of conjoint application of chemical fertilizers and farmyard manure.
- 2.5 Nutrient content and uptake by rice-wheat crops.
  - 2.5.1 Effect of chemical fertilizers.
  - 2.5.2 Effect of farmyard manure.
  - 2.5.3 Effect of conjoint application of chemical fertilizers and farmyard manure.
  - 2.5.4 Residual effect of Zn and farmyard manure on yields and nutrient uptake of rice-wheat crops.
- 2.6 Effect of chemical fertilizers and farmyard manure on build up of extractable soil nutrients.

## 2.1 Effect of soil application of chemical fertilizers on yield and yield attributes of aromatic rice – wheat sequence

The response of soil application of different chemical fertilizers on yield and yield attributes of both fine quality scented rice and wheat crops have been reported in the literature.

A lot of work has been done on the effect of N on yield and yield attributes of fine quality rice and wheat. The optimum dose of N for these crops varies based on agroclimatic conditions and cultural practices.

In trials with two basmati [long-grained]-type dwarf rice cultivars grown at different spacings and N levels, Singh (1974) observed that application of 100 kg N/ha to cv *Sabarmati* grown at a spacing of 15 X 15 cm and to cv *Jamuna* at a spacing of 45 X 45 cm gave the highest paddy yields. Fateh *et al* (1978) studied the yields of coarse and fine rices as influenced by different nitrogen levels. They found that the yield and yield components of rice cv *IR6 and IR8* (coarse), and cv *Basmati 198 and Basmati 370* (fine) showed no significant response to varying N levels from 0 to 240 lb/ac. However, the 1000-grain weights of the coarse cv (18.110 and 19.3979 g, respectively) were significantly higher than those of the fine cv (14.207 and 14.002 g, respectively).

Miyagawa and Ito (1982), conducted pot experiments to study the effect of nitrogen application (0, 0.3, 0.6 or 0.9 g N/pot) on (a) native scented rice cv *Jakoumai* and *Iwaga*, (b) improved non-scented cv *Aikoku* and *Kamenoo* and (c) recently improved non-scented cv *Sasanishiki* and *Toyonishiki*. They observed that highest yield was obtained with 0.6 g N/pot and the covarieties (a) gave similar yields to (b) but lower yields than (c). Yields of cv *Jakoumai* were low due to lower number of ears/hill even though number of spikelets/panicle and ripening percentage were high. High rate of N in scented cv gave a low grain:straw ratio and a low efficiency of applied N fertilizers.

Padmajarao (1995) performed field trials in 1988-89 at Hyderabad, Andhra Pradesh, with rice cv *Basmati-370* to study the effect of nitrogen levels (0-80 kg N/ha). She also found that grain yield increased with N application.

Rao *et al* (1993) reported the data on the effects of N (0, 30, 60, 90 kg/ha) on three yield characters of seven varieties of scented rice raised during the wet

and the dry seasons of 1988-90 at Cuttack. They observed highest grain yield (3.21 t/ha) in the wet season by local variety *Badshahbhog*. They also found that among the long slender Basmati-grain type varieties, *Kasturi*, *Ranbir Basmati* and *IET8579* were promising, with mean yields of 2.22-2.58 t/ha: which were significantly higher as compared to *Basmati 370* and *Pakistan Basmati* in the dry season. The response of grain yield to N application in the wet season was up to 60 kg/ha and in the dry season up to 90 kg/ha.

Kumar *et al.*, (1996) conducted a field trial at Bihar Agricultural College, Sabour during kharif [monsoon] 1995 to study the effect of five levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) on four scented rice varieties (*Haryana Basmati-1*, *Pusa Basmati-1*, *Kasturi* and *Taraori Basmati*). They observed *Taraori Basmati* to be the highest yielder (3000 kg/ha). A rate of 60 kg N/ha was optimum for scented rice. Dwivedi (1997) applied 0-90 kg N/ha to six fragrant rice cultivars and observed yield increase with nitrogen levels up to 60 kg N. The yields were higher in cv *Kamini* and *Sugandha* than in cv *RP 615*, *Harbans*, *Basmati* and *Kasturi*.

Behera (1998) studied the performance of different genotypes of basmati rice under different rates of nitrogen fertilizers in a field experiment on sandy loam soil. He observed a marked increase in all the growth and yield-forming characters with the increase in N rate compared with the control, except 1000-grain weight. A significant linear increase in grain yield was recorded up to 90 kg N/ha and thereafter, the increase in grain yield was marginal. Response at 30 kg N/ha was maximum (9.3 kg grain/kg N). Jadhav and Sahane (1998) studied the response of Basmati type rice varieties to nitrogen (60, 75 or 90 kg N/ha). The varieties *Pusa Basmati-1*, *Basmati-370*, *Basmati-385* *Kasturi* produced mean grain yields of 3.19, 3.14, 2.86 and 2.35 t/ha, respectively. Grain yields were generally highest with 90 kg N. In 1995, yield was not affected by N rate. *Pusa-Basmati-1* fertilized with 90 kg N produced the highest grain yield of 3.52 t/ha.

Singh and Sreedevi (1997) compared dwarf scented rice cv *Haryana basmati-1*, *Pusa basmati-1* and *Kasturi* with traditional rice cv *Taraori basmati*, receiving nitrogen levels of 0 to 120 kg N/ha. They observed higher average grain yield in the scented cultivars (3.3-3.5 t/ha) than in the traditional cultivars

(2.4 t/ha). Grain yield increased with nitrogen application rates up to 90 kg/ha, whereas N use efficiency decreased with increasing rate of N application. Scented rice grain yield increased with application of nitrogen up to 90 kg/ha (2.98 t/ha) with the highest yielding cultivar *Kasturi* (2.71 t) followed by *Haryana basmati-1* (2.52 t) in a field experiment on silty clay soil supplied with 0-120 kg N/ha in 1995 in Bihar (Thakur *et al*, 1997). In an experiment under shallow lowland conditions, Moorthy <sup>et al</sup> (1998) observed increase in grain yield with increasing N dose (0, 30, 60 and 90 kg ha<sup>-1</sup>) in long, slender, non-scented rice varieties (*Lunishree*, *Sabita*, *Hathipanjari* and *CR662-2318*).

Choudhari *et al* (1998) found highest Mean grain yield (2.90 t/ha) with 100 kg N in the case of three fine quality rice varieties. Covarieties *Haryana Basmati*, *Kasturi* and *Pusa Basmati* produced mean grain yields of 2.46, 2.38 and 2.26 t, respectively. Raju *et al* (1990) recorded the grain and straw yields; net cash returns and four yield components for three varieties grown at 5 nitrogen levels. *Jeeragasamba* gave the highest average grain yield (3.51 t/ha) while the highest grain yield of all (3.85 t/ha) was achieved by *Basmati 217* at a nitrogen application rate of 120 kg N/ha.

Maqsood *et al* (1997) studied the effect of planting methods and variable rates of nitrogen application on yield and yield components of rice. They observed that yield was not significantly affected by establishment method in first year, but in subsequent year, it was 3.58 t/ha from direct sowing and 4.43 t from transplanting. Yield increased with increasing N rate in both the years. Number of productive tillers per hill was significantly higher from transplanting than direct sowing in both years. Net income was highest from transplanting and with application of 100 kg N/ha. Rafiq *et al* (1998) studied the biological response of *Basmati-385* to four fertilizer (NPK) levels (70:67:67, 100:67:67, 130:67:67 and 160:67:67 kg N:P:K ha<sup>-1</sup>) on a sandy clay loam soil. Application of 130:67:67 kg N:P:K ha<sup>-1</sup> significantly increased yield and yield components over other fertilizer levels. Increase in yield due to increased nitrogen level was mainly associated with increased nitrogen utilization efficiency, which caused a corresponding increase in respective yield components.

Amir *et al* (1984) reported that highest grain yield of Basmati – 370 was obtained at a plant population of 250000 plants per hectare (20 × 20 cm plant spacing) and with the application of 60 kg nitrogen + 30 kg phosphorus per hectare. The highest yield in the previous year was at 20 × 20 cm and with the application of 100 kg nitrogen and 50 kg phosphorus per hectare.

Akram *et al* (1985) studied the effect of planting date and fertilizer level on grain yield and protein content of rice. They observed that grain yields were highest with the high fertilizer rates (45 kg P<sub>2</sub>O<sub>5</sub> + 90 kg N/ha), which also gave the highest average protein content (9.34%). Sowing on 8 June resulted in significantly greater yields than sowing on 24 May or 24 June, but sowing date did not affect grain protein content. The crop sown on 8 July did not reach maturity due to low temperature during its growth period. Singh *et al* (1997) studied the effect of nitrogen and planting date on yield and quality of scented rice (*Oryza sativa*). They observed that delaying transplanting decreased grain yield. Grain yield was highest with 100 kg N (4.05 t/ha). *Pusa Basmati* gave higher grain yield than *Kasturi* (3.52 vs. 3.32 t/ha).

Zheng *et al* (1995) studied the effects of different fertilizer application methods and plant densities on yield and quality of rice. The cultivar had a greater effect of fertilizer application method than the effect of spacing on yield. Application of fertilizer at spikelet formation or grain filling was more effective than earlier application. Yosuf *et al*, (1979) showed that 60 kg N/ha as urea applied by point placement one week after transplanting, and 15 + 30 kg N/ha broadcast at rapid tillering and one week before panicle initiation gave high yields (23.97 and 27.4 t/ha, respectively). Application of 60 kg N/ha as S-coated urea (broadcast) was also equally effective in increasing the yield without large amount of fertilizer. Hussain *et al* (1989) studied the influence of rate and time of N application on growth and yield of rice in Pakistan. They observed that number of tillers/hill and straw yields increased with increasing N rates up to 16.4/hill and 9.1 t/ha, respectively, with a single application and 16.6/hill and 8.3 t/ha, respectively, with split applications. Grain yields were highest with 90 kg N/ha as a single application (3.7 t) and 150 kg N in split applications (3.9 t). Nitrogen recovery and N use efficiency generally decreased with increased N rate with a

single application but tended to increase with split applications. Asif *et al* (1999) studied the effects of Influence of NPK levels (60:0:0, 130:67:67 or 180:90:90 kg NPK/ha) and split N application on grain filling and yield of fine rice. Yields were higher with the second higher NPK rates than with the lowest rate, with the middle rate giving the best grain quality. Split applications of N gave higher yields than a single dose. Khalid *et al* (1999) studied the effect of different application methods and nitrogen levels on yield and yield components of fine rice (Basmati-385). Their study showed that fertilizer application by point placement method resulted in higher grain yield of Basmati-385 than with broadcast method. Nitrogen used @ 80 kg ha<sup>-1</sup> appeared to be optimum to get higher grain yield followed by nitrogen level of 120 and 40 kg ha<sup>-1</sup> in a descending order. Correlation between grain yield and yield components was significant and positive. Zhang *et al* (1999) studied the effects of application of N fertilizer at late growth stage on rice yield. They observed that N application increased the number of reproductive panicles by 8.29% and spikelet fertility by 10.14% but had no effect on the number of grains/panicle. Nitrogen application date had no effect on yield.

Asif *et al* (1997) studied the response of kernel dimensions of fine rice as influenced by different NPK levels (60 kg N/ha or 130-67-67 or 180-90-90 kg NPK/ha) and N-application techniques. Kernel length in primary and secondary branches of the panicle was lower with 60 kg N/ha than at either NPK treatment. Kernel width and thickness were not significantly influenced by different fertilizer levels. Applying N in equal splits at transplanting, tillering and panicle initiation gave the highest kernel length and length/width ratio.

Sajwan *et al* (1990) studied the effects of nitrogen and water management practices on yield of rice. They found that among varieties, *Jaya* had not only the greatest yield, it also responded the most to N fertilization. Pusa 2-21 had the poorest grain yields. Significant improvement in yield and yield attributes was noted at N application rates up to 90 kg N/ha during the wet season and up to 120 kg N/ha during the dry season. The beneficial effect of submergence on grain yield was observed only during the dry season.

Paliwal *et al* (1992) conducted a pot experiment to study the influence of increasing levels of nitrogen and sulphur application singly and in combination on the grain yield of rice var *Cauvery* grown under submerged soil condition in a silty chromustert. They found that the application of nitrogen and sulphur both, improved the grain yield and quality of rice grain. Their results showed that the grain yield increased significantly with increasing levels of nitrogen and sulphur applied singly and in combination. Dixit and Khanda (1994) conducted field trials in the summer seasons of 1991-92 at Bhubaneswar, Orissa, to study the effect of 0-90 kg N/ha and ZnSO<sub>4</sub> or Zn-EDTA as soil or foliar applications on rice cv *Sarathi*. They observed that grain yield and net returns were highest with N + Zn application, which increased with the rate of N application and were higher with ZnSO<sub>4</sub> and soil applications.

Suwanarit *et al* (1997) suggested that the best combination of yield and quality of aromatic rice cv Khaw Dauk Mali-105, K could be achieved at the rate giving the highest grain yield. At higher K rates, grain had a stronger aroma, was whiter and glassier, but was less soft. Sorour *et al* (1998) studied the effect of irrigation interval and potassium fertilization level on growth, yield and quality of rice. They observed that as irrigation interval increased, there was decrease in plant height, dry matter production, crop growth rate, number of tillers/m<sup>2</sup>, number of panicles/m<sup>2</sup>, panicle length, number of branches, filled grains/panicle, unfilled grain percentage, panicle weight, 1000-grain weight, grain/straw ratio, grain and straw yields/ha. The highest values of all traits were also obtained when plants were subjected to continuous flooding or irrigation on every 6 days with no significant differences between these treatments for most studied traits. Adding K fertilizer significantly increased plant height at later sampling dates, and gave higher grain numbers/panicle, panicle weight and N and K uptake.

Asif *et al* (1997) studied the effect of different levels of NPK and time of N-application on yield and yield components of *Basmati-385*. They observed that grain yield was highest with 130-67-67 kg NPK/ha, when N was applied in three equal dressings at transplanting, tillering and panicle initiation. Asif *et al* (1997) studied the effect of different NPK levels (60 kg N/ha or 130-67-67 or 180-90-90 kg /ha) and per hill seedling density (1, 2 or 3 seedlings/hill) on panicle structure,

kernel quality and yield of fine rice cv Basmati-385. They observed that grain yield was highest with 130-67-67 kg NPK/ha and at 2 seedlings/hill. Grain quality was generally best with 130-67-67 kg NPK/ha, while most quality parameters (percentage sterility, numbers of abortive, opaque and normal kernels) were not significantly affected by plant density.

Venkateswarlu (1969) obtained 40 per cent increase in rice (IR-8) yield with application of 50 kg zinc sulphate/hectare as a basal dressing. Application of zinc in rice crop has been found to increase zinc content of the plant with remarkable increase in dry weight of plants (IRRI, 1970). Bhardwaj and Prasad (1981) in a field experiment at CSWCRTI, Dehradun observed that rice grain and straw yield increased with the increase in dose of  $ZnSO_4$  up to 20 kg/ha and further increase showed slightly declined effect. Yadav (1985) reported that application of 5 and 10 mg Zn/kg soil significantly increased grain and straw yields and zinc content of rice. Saravanan and Ramanathan (1988) reported that the application of 25 kg  $ZnSO_4$  gave highest paddy yield of 5.2 ton/ha with cv ADT-36 and 4.0 ton/ha with cv IR-20 compared with 4.6 and 3.8 ton/ha, without zinc, respectively. Karim *et al* (1992) reported a significant yield increase (7-25%) due to zinc fertilizer in a large number of field trials with modern rice. The response of other crops to zinc application was not so distinct. Sakal *et al* (1993) reported the effect of zinc application on rice (cv Sita) grain yield grown on zinc deficient calcareous silt loam soils at two sites in Bihar. They observed that highest yield (5.41 ton/ha) was recorded with 25 kg  $ZnSO_4$ /ha applied at transplanting at one site while yield was highest (4.04 ton/ha) with 50 kg Zn/ha at the second site. Salam and Subramanian (1993) reported that in a field trial at Coimbatore, the rice (cv IR-20) yield was 4.75 ton/ha without applied zinc and 5.75 ton/ha with 25 kg  $ZnSO_4$ /ha. Applied zinc also increased plant height, tillering, leaf area index and root growth. Tiwari and Dwivedi (1994) observed that in the field trials with rice cv Saket-4 grown on low (<0.6 mg Zn/ha) and medium (0.61-1.00 mg Zn/ha) zinc soils, the application of zinc fertilizer at the rates of 1.25, 2.5 or 5 kg Zn/ha significantly increased the grain yield of rice. Without applied zinc, mean grain yields were 3.64 and 4.44 ton/ha in the low and medium zinc soils, respectively. The rice crop responded significantly up to 5 kg

Zn/ha in low zinc soils (34.8% increase in grain yield compared with controls) and up to 2.5 kg Zn/ha in medium zinc soils (10.6% increase in grain yield). Efficiency of zinc fertilizer utilization was also higher in low zinc soil. Saleem *et al* (1996) investigated the effect of different ZnSO<sub>4</sub> levels (0, 4, 8, 12 and 16 kg ha<sup>-1</sup>) on the ripening and yield of coarse rice varieties IR-6 and KS-282 on clay loam soil. Their results indicated that applied ZnSO<sub>4</sub> seemed to be appropriate and useful to get more paddy yield with better quality kernels. Zinc sulphate levels (12 and 16 kg/ha) produced maximum plant height (cm); number of panicle bearing tillers; number of spikelets per panicle; normal kernels; 1000-grains weight (gm); paddy and straw yields (kg), however, failed to differ from each other statistically. Similarly, the maximum reduction in sterility (%), abortive and opaque kernels (%) were recorded in treatments receiving 12 and 16 kg ZnSO<sub>4</sub> ha<sup>-1</sup> as compared to check.

Alam *et al* (1985) studied the effect of zinc application on yield of several rice varieties. They observed that application of 3 ppm Zn in pots increased dry matter yield of varieties in the order *PK177* > *Kashmir Basmati* > *IR8* > *Basmati 370* > *Jhona 349*. The degree of varietal response was significantly related to Zn concentration and P:Zn ratio in 44-day-old plant tops.

In soils deficient in nutrients or in problem soils, application of required soil amendment besides fertilizer application enhances the crop yields. Khan *et al* (1992) reported that in a field experiment on a coastal saline soil, the application of 60 kg gypsum and 5 kg Zn/ha increased the yield of rice (cv BR-10). Barbosa-Filho *et al* (1992) reported that application of zinc at the rate of 2.5 or 5 mg Zn/kg limed soil greatly increased the grain yield of rice cv Araguaia from 4.3 to 8.4 g/plant over the control under greenhouse conditions. Shah and De-Datta (1991) reported that in a field experiment with rice cv IR-262, grown on a soil deficient in both S and zinc, the application of 10 kg Zn/ha and 25 kg S/ha increased the dry matter yield. Grain yield was increased with zinc application and positively correlated with zinc uptake. Application of sulphur without zinc decreased dry matter yield. Alam *et al* (1998) studied the effect of zinc application with or without copper on yield and composition of rice genotype *Basmati-385* and a mutant *DM-25* in a pot culture experiment. Rice genotypes

responded to Zn application much more in presence of Cu than its application alone. The Zn x Cu interaction significantly increased grain and straw yield by both rice genotypes. However, *Basmati-385* compared to the mutant *DM-25* gave higher response to Zn in the presence of Cu. Mudjisihono and Koswara (1991) carried out an experiment to study the effects of phosphorus, zinc (Zn), and copper (Cu) fertilizers application on yield of low land rice variety IR-64. Their results indicated that application of zinc and copper fertilizer tended to increase yield.

Different methods of zinc application have been tested for their efficacy to correct zinc deficiency and increase the crop yields. Srivastava *et al* (1992) compared the effect of ZnSO<sub>4</sub> (20 kg/ha soil applied or 500 gm Zn/ha as foliar spray) and chelated zinc (1 kg/ha soil applied or 500 g/ha as foliar spray) on rice cv IET-4094 yields. They found that all zinc treatments increased yield compared with control plots. With both application methods, yield was highest when chelated zinc was applied. Soil application of chelated zinc gave the highest yield of 6.9 ton/ha. Das *et al* (1993) reported that in a field experiment on a zinc deficient calcareous sandy loam soil, the application of 5 or 10 kg Zn/ha as ZnSO<sub>4</sub>, ZnO, Zn-frits or chelamin increased the grain yield of rice(cv Sita). Rice grain yield was not affected by zinc source, but on an average it was higher with chelamin, followed by ZnO, Zn-frits and ZnSO<sub>4</sub>, respectively. Zinc uptake was positively correlated with grain and stover yield. Zhang *et al* (1992) reported that plant dry matter of rice cv Yue HU was unaffected by methods of zinc application including dipping of rice roots in 1.0% ZnSO<sub>4</sub> solution. However, Singh (1970) found that enrichment of rice seedlings with Zn compounds has been reported to increase grain and straw yields of rice. Kumar and Singh (1996) reported that dipping of the rice (cv Sita) seedling in 2% ZnSO<sub>4</sub> solution gave as high yield (5.15 ton/ha) as with the application of 25 kg ZnSO<sub>4</sub> (5.16 ton/ha) or spraying 0.5% ZnSO<sub>4</sub> once (5.22 ton/ha) or twice (5.19 ton/ha) to the transplanted crop.

Singh and Sharma (1994) reported that in field trials on a partially reclaimed saline silt loam soil, grain yield of rice (cv Sarju-52) was highest with a

basal application of 20 kg ZnSO<sub>4</sub>/ha (3.74 ton/ha) followed by three foliar sprays of 0.5, 0.1 and 0.1% ZnSO<sub>4</sub> (3.58 ton/ha). Ram *et al* (1995) carried out a field experiment with rice where zinc was applied as 40 kg ZnSO<sub>4</sub>/ha basally or top-dressed, or 1-3 sprays of 0.5% ZnSO<sub>4</sub> solution with or without 20 kg ZnSO<sub>4</sub> basally applied. They found that the grain yield was 2.7 ton/ha without applied zinc and 3.3-4.0 ton/ha with Zn fertilizer treatments. The highest yield was recorded in treatment receiving 20 kg ZnSO<sub>4</sub> + 3 foliar zinc application. The highest recovery of applied zinc (7.4%) was noticed in the case of two foliar zinc applications.

Response of Zn has also been reported in wheat crop from several places. Gattani *et al* (1975) noted that the highest yield of wheat was obtained at 5 ppm zinc level. Shinde *et al* (1977) reported that average grain yield of wheat increased from 2.27 ton/ha in untreated control to 3.53 and 3.13 ton/ha with application of 20 kg Zn/ha as zinc sulphate and zinc oxide, respectively. Higher level of zinc (30 kg Zn/ha) application decreased yield of wheat crop. Brar and Sekhon (1978) found that dry weight of wheat plants increased significantly with increase in the rate of zinc application up to 5 ppm. However, further increase up to 10 ppm zinc decreased it. Lower zinc rate increased the growth and dry matter of plant by correcting the deficiencies. However, at higher Zn level the yield decreased probably due to disturbance in plant metabolism and consequent reduction in absorption and translocation of other micronutrients. Mann *et al* (1978) found that application of zinc significantly increased the grain yield of wheat from 3.4 to 4.8 q/ha. Singh and Singh (1979) found that application of 4.0 and 8.0 kg Zn/ha as the optimum dose for grain and straw yield, increased the grain yield by 12.7 and 10.5 per cent over control in the first and second year, respectively while the extent of increase in straw yield over control at the optimum zinc dose was 10.9 and 9.2 per cent in the first year and second year, respectively. Application of 16 and 32 kg Zn/ha had no detrimental effect on yield due to tolerance of wheat to higher concentration of zinc. Bhardwaj and Prasad (1981) observed that the maximum wheat grain yield was recorded at 40 kg zinc sulphate/ha. Through all the three doses of zinc sulphate applied produced significantly higher grain yield over control, however, no significant

difference in yields was observed between 10 and 20 as well as 20 and 40 kg/ha ZnSO<sub>4</sub> rates. Straw yield also showed the similar trend. Prasad *et al* (1981) found that wheat varieties gave higher yields at the level of 5 kg Zn/ha and the magnitude of response varied with the variety. Shah *et al* (1987) reported an increase in average grain yield of wheat from 15.36 gm/plot without zinc to 18.79 gm/pot at 7.5 mg Zn/ha but had no effect on average straw yield. Bansal *et al* (1990) conducted field trials at nine locations having different levels of available soil zinc (0.35 to 1.50 mg Zn/kg soil) with addition of 11 or 22 kg zinc applied as ZnSO<sub>4</sub>/ha. They observed significant increase in yields with application of zinc in all the soils, except those having  $\geq 1.25$  mg Zn/kg soil. The increase was significantly higher when 22 kg Zn/ha was applied. The wheat yield increased from 2.05 ton/ha with no added zinc (soil containing 0.35 mg Zn/kg) to 3.20 ton/ha yield, when 22 kg Zn/ha was applied to the same soil. Dwivedi and Tiwari, (1992) reported that grain and straw yield of wheat increased with increasing rate of zinc. In a field study, Gupta *et al* (1992) reported that the mean grain yield of wheat (cv Sonalika) was 4.15, 4.61 and 4.85 ton/ha at 1.25, 2.5 and 5.0 kg Zn/ha, respectively. Similar results were also reported by Khamparia *et al*, (1994).

Reddy <sup>and Yadav</sup> ~~et al~~ (1994) observed that graded dose of phosphorus and zinc increased grain and straw yield of wheat. Application of 10 mg zinc + 100 mg phosphorus/kg soils gave the highest grain yield/pot.

Yilmaz *et al* (1997) concluded that soil application of Zn was economical and had long-term effects for enhancing grain yield of wheat grown on Zn deficient soils. When high grain yield and high Zn concentration in grains are desired, soil and foliar Zn applications were recommended.

Sagwal and Vijay Kumar (1994) conducted experiments on rice cv *Basmati-370* in the Karnal district, Haryana, on a sandy loam soil (typic ustochrept) using no fertilizer and combinations of N, NP, NPK and NPKZn; the rates used were 60 kg N, 30 kg P<sub>2</sub>O<sub>5</sub>, 30 kg K<sub>2</sub>O and 25 kg zinc sulfate/ha. Rice grain yields ranged from 1.6 t/ha with no fertilizers to 2.59 t with NPKZn. Financial returns were also greatest with NPKZn. Gangaiah <sup>et al</sup> (1999) applied 0, 60, 120 or 180 kg N/ha or 120 kg N + 60 kg P, NP + 60 kg K, NPK + 25 kg Zn or

NPK/ha to scented rice (cv *Pusa Basmati-1*) during *kharif* 1992/93 and 1993/94. He observed increase in yield attribute values, grain and straw yields with increasing N rate. Additional elements increased grain and straw yields compared with 120 kg N alone.

Tripathi *et al* (1995) studied the effect of fertilizers on rice cv *Madhuri*, *RWR-82-74-9-2* and *RWR-82-60-2-1*, the treatments were 60 kg N, 40 kg P and 25 kg K with or without ZnSO<sub>4</sub> or various mixtures of elements including Fe, Mn, Zn, Cu, Mo, B, Mg, Ca and S (Sat Rite SF, Boracol BSF-12 or Micnelf MS-12). It was observed that grain yield was not significantly different between different cultivars and it was highest with the Sat Rite SF mixture of nutrients + NPK.

Malik *et al* (1978) observed that zinc application in conjunction with N P or N P K to basmati rice gave higher yields (8.1 and 5.2%; 5.5 and 4.3%) than N P or N P K alone. Soil and foliar application of N P along with Zn, Fe and Mn increased yields of by 15.3% and 13.3% as compared to N P alone. Application of Mn, Fe and Zn in combination decreased the yields as compared to the treatment with Fe and Zn only. Bhuiya *et al* (1987) carried out a field experiment with rice cv BR-11 receiving fertilizer application of NPK (80:60:40) with or without 10 kg Zn/ha. The soil initially had 1.2 mg available Zn/kg soil. They found that NPK with zinc gave higher numbers of fertile tillers/hill, number of filled grains/panicle, weight of grains/hill and 1000-grain weight than other treatments. Kasana and Ropal (1982) reported that application of 66% of the N and 50% of the P at puddling and 33% of the N and 50% of the P at 21 and 25 days, respectively, after transplanting gave the highest yields of basmati rice varieties. The highest income with varieties IR – 6 and Basmati – 370 was obtained by 69 kg N + 46 kg P<sub>2</sub>O<sub>5</sub> + 41 kg K<sub>2</sub>O and 41 kg N + 27 kg P<sub>2</sub>O<sub>5</sub> + 27 kg K<sub>2</sub>O + 4.5 kg Zn per acre, respectively. Application of 1.4 kg Zn, 1.4 kg Cu, 2.0 kg Fe and 2.0 kg Mn per acre and NPK gave the highest yield with IR – 6.

Gangiah and Prasad (1999) studied the effect of fertilizers on the productivity of a rice (cv *Pusa Basmati-1*) – wheat cropping system in a sandy clay loam (Fluvent) soil. They observed that straw and grain yield and yield component values of rice increased with increasing N rate. Yields of wheat were

greater with N than with no application of N, while yield component values were greater with 60 kg and 120 kg N than without N, and were highest with 180 kg N. Phosphorus, K and Fe had little effect on either crop. Zinc increased some yield attributes and increased the rice grain and straw yields in the second year of the study. There was no residual effect on wheat yield.

## **2.2 Effect of farmyard manure on yield and yield attributes of aromatic rice – wheat sequence**

Since long the use of farmyard manure and compost to improve rice yield is widely recognized by farmers in many countries. Gaur *et al* (1971) has reviewed the strategies for efficient utilization of organic manure including the livestock manure, crop wastes and industrial organic wastes for better crop production.

Maskina and Meelu (1984) reported that application of 12 ton FYM/ha increased the mean grain yield of rice (5.8 ton/ha) grown on non-saline loamy sandy soils. Sharma *et al* (1985) reported that application of farmyard manure to rice and wheat increased grain yields and improved the physicochemical properties of soils. Hegde and Dwivedi (1992) claimed that it was possible to substitute 50 per cent N need of rice through farmyard manure without any adverse effect on the total grain productivity of rice-wheat system at Palampur. Ghosh and Sharma (1999) conducted experiments during the wet season of 1995 and 1996 at Cuttack, Orrisa to find out the effect of farmyard manure on rice grain yield. In 1995, they observed that application of 10 ton FYM/ha increased grain yield in comparison to no farmyard manure and yield was found similar to that obtain with 20 or 40 kg N/ha, but difference in grain yield was not significant due to the application of N fertilizer in plots treated with farmyard manure. In 1996, yields were increased to similar extent by farmyard manure or nitrogen and highest yield was obtained with farmyard manure + nitrogen.

### 2.3 Effect of conjoint application of chemical fertilizers and farmyard manure on yield and yield attributes of aromatic rice – wheat sequence

Integrated use of chemical fertilizers together with organic manures is advocated for maintaining the soil productivity in agricultural systems. Azolla in combination with N and P fertilizers has been reported to give high grain yields of basmati rice. (Bari *et al*, 1988). Pandey, *et al* (1999) studied the effects of farmyard manure and chemical N fertilizer on grain yield of scented rice (*Oryza sativa*) varieties cv Madhuri 11 and Pusa Basmati 1. They observed that application of farmyard manure (10 tonnes/ha), chemical fertilizer (80 kg N/ha) and a combination of farmyard manure (5 tonnes/ha) and chemical fertilizer (40 kg N/ha) were as effective as 120 kg N/ha for grain yield and N uptake of scented rice varieties.

Nazir *et al* (1984) observed that increasing organic matter markedly increased straw yield under flooded conditions, and increasing P rates increased yields, especially when applied as triple super phosphate. Straw and grain yields were greater in plants grown under submerged conditions, although, no grains were formed at the high organic matter rate. Surapol (1995) observed the response of growth retardants applied at different growth stages and rates of compost and chemical fertilizers on rice cultivar, *Khao Dawk Mali 105* (KDML 105). Compost in combination with chemical fertilizers (CP + CF) affected growth and yield of KDML 105. Yield components were not affected by CP + CF, but weight of 1000 filled seed was affected by it. The KDML 105 treated with compost gave 1000 filled seed weight greater than control. Applications of growth retardant at tillering stage resulted in reducing plant height and increasing plant numbers/hill and panicle numbers/hill. Gupta *et al* (1999) reported that rice (cv PC-19) grain yield was highest with 100 kg P<sub>2</sub>O<sub>5</sub> + FYM (5.20 ton/ha). Li *et al* (1999) observed that potassic fertilizer application had the greatest effect on yield of the quality early indica rice cultivar Zhou 903 followed in sequence by organic fertilizer, N fertilizer, N fertilizer application rate and P fertilizer. Broadcasting seedlings increased yield as a result of more tillers and spikes, but

the cultivar lodged easily. Productive tiller number had the largest direct effect on yield formation.

Tahir Hussain (1991) studied the influence of various combinations of N, P, K, ZnSO<sub>4</sub> and FYM on rice cv *Basmati-385* grown on a sandy clay loam at Faisalabad, Pakistan. He observed that the yield was 1.71 t/ha without fertilizers and 4.32 t with 60 kg N, 40 kg P<sub>2</sub>O<sub>5</sub>, 30 kg K<sub>2</sub>O and 5 t FYM/ha. Applying these fertilizers at double rates gave no further yield increase. Mutnal *et al* (1996) also reported that the application of 10 ton FYM, 100:100:120 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O and 20 kg ZnSO<sub>4</sub>/ha produced the highest mean grain (5.31 ton/ha) of rice (cv Rasi) and also highest net return. Yaseen *et al* (1999) obtained highest paddy grain and straw yields of *Basmati-385* with the combined application of NPK + GM + ZnSO<sub>4</sub>. It was observed that Zn application further increased the yields over those obtained by application of NPK + GM + FYM. Combined application of NPK, organic manures (GM or FYM) and Zn significantly increased the nitrogen and potassium concentrations while lowered the phosphorus concentration of paddy grain and straw due to the antagonistic effect of Zn on P absorption. They also indicated that Zn-application of soil was better than its foliar spray.

Patnaik and Raj (1999) conducted a field experiment with rice in a zinc deficient soil to study the direct, residual and cumulative effect of zinc. Soil application of ZnSO<sub>4</sub> increased the grain yield of rice. With application of 75 kg zinc sulphate (50 kg initially and 25 kg at 5<sup>th</sup> season), the yield was increased by 5.1 ton/ha over control. Application of 12.5 kg ZnSO<sub>4</sub>/ha in zinc deficient soil was not sufficient to get optimum yield. Farmyard manure did not substantially increase the yield compared to zinc sulphate application. Zinc content in the index leaf samples increased with increase in the rate of ZnSO<sub>4</sub> application. Initially applied ZnSO<sub>4</sub> had a strong residual effect.

Kumar *et al* (1999) compared ZnSO<sub>4</sub> @ 20 or 30 kg/ha incubated and blended separately with farmyard manure (each at 0.25 ton/ha) with the recommended rate of 40 kg/ha alone in a field experiment with rice on a sodic soil. They reported that application of 20 kg/ha ZnSO<sub>4</sub> with farmyard manure gave similar grain yields of rice and N and zinc content and uptake as with 40 kg

ZnSO<sub>4</sub> alone. Application of ZnSO<sub>4</sub> at 20 kg/ha with either of the organic materials also maintained almost equal amount of available zinc in soil and gave high recovery of applied zinc as compared to 40 kg/ha ZnSO<sub>4</sub> alone.

In a field trial during wet seasons with rice (cv HPU-2216) under different combinations of plant density, fertilizer rate and drainage, it was observed that the highest grain yield (5.11 ton/ha) and nutrient uptake by rice was obtained with 10 ton FYM/ha + 33% extra plant density + adjusted NPK fertilizer + ZnSO<sub>4</sub> (Bindra and Kalia, 1996). Giri *et al* (2000) studied the nutritional requirement of basmati rice under upland irrigated conditions on vertisols. They observed that the highest grain yield of 1865 kg/ha was obtained from 120:60:30 kg NPK + 10 t FYM/ha. The NPK alone gave the lowest yield. Net returns were greatest with 120:60:30 kg NPK/ha plus trace elements (foliar application of FeSO<sub>4</sub> and soil application of ZnSO<sub>4</sub>).

Das and Gupta (1996) conducted a field trial on wheat (cv Sonalika) with application of 40:20:20, 50:25:25 or 60:30:30 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O/ha with and without application of 25 kg ZnSO<sub>4</sub> or 10 ton FYM/ha. Grain yield was not significantly different between the 2 higher NPK rates and was highest with application of farmyard manure + zinc. Rajput (1997) reported that the highest yield of wheat (cv HD-2285) was obtained with basal application of 10 ton FYM/ha + 120 kg N/ha + 3 foliar application. Zinc application increased wheat yield, however no significant difference was observed between soil or foliar application methods.

In a field experiment on wheat cv WH 542 with 100% NPK fertilizers (100 kg N + 50 kg P<sub>2</sub>O<sub>5</sub> + 50 kg K<sub>2</sub>O/ha), 125 or 150% NPK with or without 20 kg Zn/ha and 10 ton FYM/ha, the increase in the fertilizer rate significantly increased the yield of wheat. Application of FYM at 10 ton/ha in conjunction with different fertilizer rate significant increased the grain and straw yields of wheat (Azad *et al*, 1998). Sharma *et al* (1999) stressed the need for balanced use of various nutrients for sustained increase in productivity of wheat. They showed that 150, 75 and 50 kg of N, P and K/ha in combination with zinc and farmyard manure was required for higher yields of wheat as compared to 120:60:40 kg

NPK currently recommended. Patra *et al* (1998) carried out a field trial on wheat cv UP 262 after rice at 100, 125 or 150% of the recommended rate of NPK fertilizer (120:60:40), 0 or 10 ton FYM and 0-25 kg Zn/ha. Application of the recommended rate NPK significantly increased grain and straw yields, while 150% of the recommended dose did not give significantly different results from the recommended rate. Application of FYM significantly increased yield as compared to no FYM application. Zinc application had no significant effect on yield of wheat.

In a field experiment conducted with wheat (cv HD 2329) and maize (cv GS-2) at optimum NPK (120:60:40 kg NPK/ha for wheat and maize), 100% optimum N or NP or 100% optimum NPK + S or NPK + Zn applied to wheat or NPK + farmyard manure applied to maize, the grain and stover / straw yields of maize and wheat were generally highest with NPK + farmyard manure treatment (Singh *et al* 1999).

Math and Trivedi (1998) compared the effect of addition of 10 or 20 ton FYM, 5 or 10 ton wheat straw and 12.5, 25 or 50 kg ZnSO<sub>4</sub>/ha on wheat (cv HDM-1553) yields. Grain yield was not significantly affected by treatments, while straw yield was increased significantly by higher farmyard manure rate.

Singh and Verma (1999) conducted a field experiment with rice and wheat at recommended rate of NPK and zinc (120, 60, 40 and 20 kg/ha) or 10 ton/ha of farmyard manure. Rice yield were highest with farmyard manure + 50% recommended rates N, followed by recommended NPK and Zn, while wheat straw yields were highest with recommended rate (RR) NPK and zinc followed by farmyard manure + 50% RR N. Rice yield, gross and net returns were also highest with farmyard manure + 50 recommended rate N.

Singh *et al* (1999) reported that under rice-wheat rotation various combination of N, P, K, Zn and farmyard manure resulted significant differences in the organic matter, available, P, K, S, B, Mo and DTPA extractable micronutrient cations in soil at 20 cm depth and crop productivity after ten year. The grain yield of rice-wheat in NPK + FYM and NPK + FYM + foliar zinc were also maintained during this period.

In a long term fertility trial, the addition of zinc or farmyard manure along with 100% NPK enhanced the mean grain yield of rice by 12 and 14% and that of wheat by 13 and 16% respectively, compared to 100% NPK alone (Nand Ram and Ram, 1996).

## 2.4 Quality of aromatic rice and nutritional factors affecting it

Different rice grain parameters, important for the assessment of quality of grains, are aroma, grain length and width, L:B ratio, grain elongation and swelling, amylose content, alkali score, gelatinization temperature, gel consistency and protein content etc. Ahmed <sup>et al</sup> (1998) analyzed the grain samples of nine scented rice cultivars to reveal their chemical compositions. The crude protein constituted 9.17 to 11.77% and soluble protein 4.62 to 6.48% on dry weight basis. The soluble protein fractions viz albumin, globulin, prolamin and glutelin were present in the proportion of 13:15:6:66 of the total extracted protein. The significant variation in the proteins, total soluble sugars, amylose, amylopectin and mineral content among the rice cultivars was attributed to their genetic constitution as well as environmental influences. Lin *et al* (1990) identified the "popcorn"-like aroma due to as 2-acetyl-1-pyrroline in scented rice. Cooked Della white rice contained almost 300 ng 2-acetyl-1-pyrroline per g (dry weight) rice, while cooked Lemont white rice (non-aromatic cultivar) contained 4 ng per g (dry weight). Della white rice contained almost four times more 2-acetyl-1-pyrroline as the average (73 ppb) in two batches of Jasmine white rice from Thailand.

### 2.4.1 Effect of chemical fertilizers

Miyagawa and Ito (1982) conducted pot experiments to study the effect of nitrogen application (0, 0.3, 0.6 or 0.9 g N/pot) on (a) native scented rice cv *Jakoumai* and *Iwaga*, (b) improved non-scented cv *Aikoku* and *Kamenoo* and (c) recently improved non-scented cv *Sasanishiki* and *Toyonishiki*. They observed that cv *Iwaga* had a lower percentage of ripened grain as compared to other cv especially at high N rates. Rao *et al* (1993) reported the data on the effects of N (0, 30, 60, 90 kg/ha) on five quality characters of seven varieties of scented rice raised during the wet and the dry seasons of 1988-90 at Cuttack. They found that

the application of N did not adversely affect different quality traits such as alkali value, volume expansion and water uptake of scented rice. Higher levels of N increased the amylose content of the long slender varieties by 3.0-9.9%. Suwanarit *et al* (1996) examined the effect of N fertilizer on cooking and eating quality of *Khaw Dauk Mali-105*. Aroma, softness, whiteness, stickiness and glassiness of cooked milled rice were inversely related to percentage N. The effects of N fertilizer on grain quality varied with the application rate. Soils low in N generally produced higher quality aromatic rice grain, and application of higher N rates than those required to produce maximum yield gave low quality grain. Moorthy <sup>et al</sup> (1998) assessed the optimum nitrogen requirement under shallow lowland conditions for quality related traits in long, slender, non-scented rice varieties (*Lunishree*, *Sabita*, *Hathipanjari* and *CR662-2318*) and observed no adverse influence of N levels used (0, 30, 60 and 90 kg ha<sup>-1</sup>) on the various quality traits. Dutta *et al* (1999) investigated the intensity of aroma in Basmati rice at different N levels (0, 25, 50 kg N/ha) grown at two locations in Bangladesh and observed that aroma intensity was higher with N application at 25 kg N/ha. Application of 50 kg N/ha gave no additional benefits regarding aroma synthesis over 25 kg N/ha.

Kumar *et al*, (1996) conducted a field trial at Bihar Agricultural College, Sabour during kharif [monsoon] 1995 to study the effect of five levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) on four scented rice varieties (*Haryana Basmati-1*, *Pusa Basmati-1*, *Kasturi* and *Taraori Basmati*). The grain quality of *Taraori Basmati* was the best having the longest kernels (7.85 mm) and the highest L/B ratio (4.67). *Pusa Basmati-1* was next to *Taraori Basmati* in respect to these grain quality parameters. A rate of 60 kg N/ha was optimum for scented rice. Nitrogen did not affect the grain quality markedly. With increase in N rate, the breadth of kernel increased marginally which caused the L/B ratio to decrease slightly.

The contents of protein, amino acids and amylose in rice grain are also affected by fertilizer application. Kaul and Raghaviah (1975) studied the influence of nitrogen levels (60, 120 and 180 ppm) on grain yield and quality of rice varieties. With increased N fertilization, a significant increase in yield and crude protein content was recorded but amylose content decreased slightly. Five

of the essential amino acids increased with N fertilization. Lysine content increased steadily when expressed on protein as well as meal basis. Two of the dicarboxylic amino acids did not increase significantly with N fertilization. Tsuzuki *et al* (1979) studied the effect of nitrogen application on grain protein and amino acid contents in 41 scented and 4 normal lines and cv of rice. Significant differences in grain protein content were found among scented cv with the highest being 12.14% in cv *Brimful* and 10.01% in cv *Sabarmati*. The effect of side-dressed N fertilizer on three cv's was greater when applied at early panicle formation than at ripening. Grain protein content was increased by high fertilizer rates with a greater effect when applied at ripening than at early panicle formation. Among rice cvs, significant differences in lysine and threonine contents, but not in methionine contents were found. There were significant correlations between protein content and the content of lysine/unit protein and between protein content and lysine or threonine content on a dry weight basis. Ahmad and Chughtai (1982) reported that protein content/kernel was positively correlated with 1000 kernel weight of rice. Amylose content was not correlated with any of the quality parameters. Increasing levels of fertilizers caused an increase in protein content in *Kashmir Basmati*, however, transplanting dates did not significantly affect the protein contents. Neither transplanting dates nor fertilizer levels had any effects on the amylose content of rice kernels. Souza *et al* (1993) conducted greenhouse trial to study the effect of 20 kg N/ha as urea ammonium nitrate (URAN) on rice cv IAC 47 applied at 5 d before anthesis or at anthesis or 5, 10, 15 or 20 days after anthesis, applied either to the soil or as a foliar spray. Application of URAN increased grain protein contents as compared to controls, with later applications having a greater effect. No differences in crude protein level were found between foliar and soil application. A negative correlation was found between crude protein content and grain weight. The levels of albumin + globulin were not affected by N applications. Glutelin fraction that contributed most to the protein increased in grain. A negative correlation was found between the levels of prolamin and glutelin, showing that increase in protein levels due to supplementary N increased the protein quality of rice grains. Islam *et al* (1996) reported that topdressing of N increased crude protein and each

protein fraction in the rice grain. The top-dressed  $^{15}\text{N}$  partitioned most effectively to the glutelin fraction when it was applied at the HD stage. On the other hand,  $^{15}\text{N}$  applied at HD+20 days contributed more to increased prolamin. Top-dressing of N was effective in obtaining rice grains with high quality protein (high glutelin content) in the indica variety, especially when N was top-dressed at HD and HD+20 days.

Matsue *et al* (1997) carried out a study to establish cultivation techniques for improving the eating quality of rice grown in Andosol paddy fields by the modification of nitrogen fertilizer application and the application of zeolite to suppress nitrogen absorption. They concluded that the production of highly palatable rice in AL paddy fields is possible by reducing the level of nitrogen absorption. To improve the eating-quality of rice grown in andosol paddy fields without reducing the yield, it was recommended that the application of the second top-dressing nitrogen at panicle formation stage be omitted from the standard application method, or that  $1 \text{ kg m}^{-2}$  zeolite be applied under the standard fertilizer application method. Okadome *et al* (1999) investigated the effects of applied N on protein content and palatability and the relationships between fertilizer treatment, grain quality, and physical properties of grain in Japonica rice cultivars (*Hinohikari*, *Reiho*, *Yumehikari*). The overall hardness based on the high compression test (compression ratio: 90%) varied with rice cultivars rather than with fertilizer treatment. Surface hardness based on the low compression test (25%) was positively correlated with protein content. The surface hardness could distinguish differences in protein content among rice samples of the same cultivar. With increasing nitrogen fertilizer applied, the surface hardness increased and the "overall evaluation" by the sensory test decreased. The ratio of stickiness and hardness in the middle compression test (45%) had a higher correlation with the "overall evaluation" than the protein content. They concluded that physical properties of grain could discriminate the effect of N fertilizer on protein content and palatability.

Borrell *et al* (1999) reported that grain quality of flooded rice was also affected by season, and plant type in addition to nitrogen rate. They found that grain size appeared to be affected more by genetic rather than agronomic factors.

since grain length and breadth were largely unaffected by N rate. The response of alkali digestion to N rate and genotype was small for all seasons. The differences in the responses of grain protein and grain yield to N rate highlighted the importance of developing N fertilizer strategies that optimize both grain yield and quality.

Sajwan *et al* (1990) studied the effects of nitrogen and water management practices on grain quality, and milling out-turn of rice. Pusa 2-21 had the highest protein content, grain hardness, and head yield. Significant improvement in protein content, grain hardness, and head yield was obtained from N applications up to 90 kg N/ha during the wet season and up to 120 kg N/ha during the dry season.

Poongothai (1994) studied the effect of different sources of phosphorus on the quality of rice grain. The treatments were 25, 50 or 75 kg P<sub>2</sub>O<sub>5</sub>/ha as diammonium phosphate (DAP), Mussoorie rock phosphate (MRP), 1/3 DAP + 2/3 MRP, or MRP + 10 t green leaf manure/ha. The grain crude protein content was highest with DAP and lowest with MRP. Application of 50 kg P<sub>2</sub>O<sub>5</sub> as DAP gave the highest grain crude protein content of 10.83%.

Suwanarit *et al* (1997) examined the effect of K fertilizer on grain quality of aromatic rice cv *Khaw Dauk Mali-105* and suggested that to produce the best combination of yield and quality, K should be applied at the rate giving the highest grain yield. At higher K rates, grain had a stronger aroma, was whiter and more glassy, but was less soft.

Chen and Li (1993) studied the effects of NPK application on grain production and quality of early quality rice. They found that the best ratio of N:P<sub>2</sub>O<sub>5</sub>:K was 1:0.5:1 at medium levels of N application. With higher or lower N rates, rates of P and K should also be increased or decreased to exert the optimum fertilizer effect and improve rice quality. The effect on rice quality was that the whole polished rice ratio was improved and chalky degree reduced. At a given N rate, rice quality improved and also the optimum production potential was achieved when P and K were applied simultaneously.

Suwanarit *et al* (1997) examined the effects of sulfur fertilizer on cooking and eating qualities of grains of *Khaw Dauk Mali-105* aromatic rice. Moderate

application of S fertilizer to a S deficient soil increased the aroma, softness, whiteness, stickiness and glassiness of boiled milled grains, but rates higher than the optimum S dose decreased these quality parameters. However, application of sulphur fertilizers at rate well above those giving maximum yield was required to obtain grains with the highest aroma and stickiness, such that rice yield decreased to 88% of the maximum. Sulphur fertilizer rates giving yields 96-98% of the maximum were required to obtain grains with highest softness and glassiness. Sulphur fertilizer at the rate giving maximum or near-maximum rice yield should be applied to obtain grains high in all of the five aspects of quality.

Chen *et al* (1997) studied the response to phosphorus and zinc fertilizers (0 - 5 kg Zn/ha and 60, 150 and 200 kg P/ha) on grain quality in rice genotype (*Xunza 29*, *Hexi 35* and *Yungeng 34*) grown on soils low in P and Zn). Application of Zn and P significantly increased yield, especially in *Hexi 35* and *Yungeng 34*. Grain protein contents were increased by P application and amylose contents of milled rice were increased by Zn application.

Suwanarit *et al* (1998) studied the effects of soil salinity and sodium (Na) on cooking and eating qualities of *Khaw Dauk Mali-105* aromatic rice grains in four pot experiments. Increasing salinity from the level that began to depress rice yield did not affect the aroma but decreased the softness and the stickiness of cooked milled rice. Salinity at levels that decreased rice yield affected the whiteness and the glassiness of rice. Application of Na to soil did not affect the aroma of rice. Application of Na at rates that did not affect yield did not affect the softness, whiteness or stickiness of rice but application at rates that reduced yield lowered these three qualities.

Bocchi *et al* (1997) showed that the highest contents of volatiles in rice (cv A301) grains were correlated with loose soils with a low clay content and a high sand content.

In wheat crop too, fertilizer application affects the quality of grains. Mohamed and Mohamed (1993) studied the response of wheat plants to foliar spray of urea (U) and micronutrients, grown on salt affected soils in Egypt. The highest protein yield at site 1 was obtained from application of U + Fe + Cu, at site 2 from Fe and at site 3 from U + Fe + Zn + Cu.

### **Milling and physical parameters of scented rices**

In rice (*Oryza sativa* L.) production, both grain yield and milling quality play an important role in determining the grower's income. Nitrogen is an essential input in maintaining a desirable yield level, but its effect on rice milling quality is less clear. Andrade *et al* (1995) reported that N had no significant effect on total rice grain yield or percentage of translucent grains but tended to increase the percentage of whole, unbroken grains and 1000-grain weight; the effects varied between sites and cultivars. Jongkaewwattana (1993) studied the effect of nitrogen and harvest grain moisture on head rice yield. This study examined optimal N input for rice milling quality and the combined effect of N and grain moisture at harvest on both grain yield and head rice yield. His results showed that the optimal harvest grain moisture to produce the maximum head rice yield depended on the levels of N applied and ranged between 220 and 270 g kg<sup>-1</sup> for variety S<sub>201</sub>, 210 to 270 g kg<sup>-1</sup> for variety M<sub>201</sub>, and 200 to 250 g kg<sup>-1</sup> for variety L<sub>202</sub>. The optimal N level for maximum head rice yield was 125 kg ha<sup>-1</sup> for S<sub>201</sub>, 112 kg ha<sup>-1</sup> for M<sub>201</sub>, and 130 kg ha<sup>-1</sup> for L<sub>202</sub>. These optimum N rates fell within the lower half region of the required N for 0.95 confidence of producing the maximum grain yield. He suggested that optimum N inputs for head rice yields were also likely to produce maximum grain yields.

Lee *et al* (1996) studied the effects of ripening temperature on appearance and chemical quality characteristics of rice grain. They found that the ratio of green-kernelled rice grain was higher at lower temperatures (22/16 and 26/18°C day/night). Higher daytime temperatures (22 and 30°C) caused chalkiness of milled rice especially in grains of primary rachis branches. Alkali disintegration value was higher whereas amylose content was lower at higher temperatures. Grain protein content in variety Dongjinbyeo was 7.4% at 22/16°, 7.5% at 30/22°, 8.2% at 26/18° and 9.2% at 22/22°. The Mg/K equivalent was lowest at 30/22 or 26/18° and highest at 22/22°. Leaf N content was higher with lower temperatures during ripening, whereas N content of stems and panicles was unaffected by temperature.

Heggy (1993) studied the effect of different nitrogen levels and time of application on the grain quality characters of different rice varieties. Grain protein

concentration increased with increasing N rate, and was highest when one-third of N (0-80 kg/feddan) was applied 20 days after transplanting and two-thirds at panicle initiation. Hulling and milling percentage decreased with increasing N rate, while percentage head rice increased. [1 feddan = 0.42 ha]. Koide and Takamatsu (1995) studied the effect of fertilizer application on the sake brewing rice cultivar *Wakamizu*. Sake rice was transplanted with the treatments of 40 and 60 kg N/ha as basal fertilizer and 20 and 30 kg N/ha at 15 and 25 days before ear emergence. The proportion of developed grains was highest with the latest transplanting date, and increased with delay in application of fertilizer at ear emergence stage. They observed a decrease in grain N content with delay in application of N at ear emergence stage and increase in grain N with delay in transplanting. Perez *et al* (1996) studied the effects of late nitrogen fertilizer application on head rice yield, protein content, and grain quality of rice. They observed that N application at flowering resulted in a 30-60% increase in head-rice protein content. In general, milled rice translucency improved, but Kett whiteness decreased with late N fertilizer application. Brown-rice weight was unaffected by late N application. In most cases, a significant positive correlation between head rice content, milled rice protein and translucency was observed. It was suggested that late N fertilizer application might improve the milling and nutritional quality of rice grain. Zhang *et al* (1999) also noted that head milled rice rate and grain protein contents were higher with N than with no N, especially with the later N application dates. Khalid and Chaudhry (1999) studied the response of kernel dimensions of fine rice to different levels and methods of nitrogen application. Longer kernel length was recorded with nitrogen application using point placement method compared to broadcast method. Nitrogen used @ 80 kg ha<sup>-1</sup> resulted in longer kernels than rest of the nitrogen levels in both the years of study. Maximum kernel width was noted also with 80 kg N ha<sup>-1</sup> in both the years. Higher length-width ratio was observed in control followed by nitrogen levels 80 and 120 kg ha<sup>-1</sup>, both being statistically equal.

High density (HD) grains are those with specific gravity greater than 1.20. Grain with HD is very important since it increases milling recovery and improve head rice yield, which is the final marketable product. Mosura (1991) studied the

influence of split nitrogen fertilization on grain density of modern rice varieties. He observed that split N application improved the number of HD grains. The HD grains increased from 10% to 24% in *IR58* and from 37% to 45% in *IR70* under field condition. The application of N at the middle growth stages (between panicle initiation [PI] and heading) was found necessary for grain development and production of HD grains. Further application of N beyond heading was not necessary for the production of HD grains. Rice cv *IR70* had more HD grains than *IR58*, however, this depended on the fertilization scheme and growing condition. Reduction of tillers of both *IR58* and *IR70* did not improve HD grains but increased the number of good grain (sp gr 1.20). The improved grain number and weight of detillered plants signify that less but large tillers can improve the distribution of assimilate among the grains in the panicle. Liboon *et al* (1995) performed a study to know the effect of late season N application to improve head rice yield and grain quality. For all cultivars, N applied at flowering resulted in 33 percent increase in the head rice yield, 27 percent for milled rice protein and 15 percent for translucency. In another experiment, N application at flowering did not increase grain yield but resulted in significant increase in head rice yield (+14 percent), milled rice protein (+16 percent), and translucency (+13 percent). Application of 40 kg N/ha at flowering had a larger effect on grain quality than a comparable increase in the basal or PI N rate. These results emphasize the importance of late season N supply for improving the nutritional status of rice grain and the head rice yield.

Paliwal *et al* (1992) studied the influence of increasing levels of nitrogen and sulphur application singly and in combination on the quality of rice var. *Cauvery* grown on silty chromustert under submerged condition. They found that the application of nitrogen and sulphur both, improved quality of rice grain. Their results showed that the rice/husk ratio increased significantly with increasing levels of nitrogen and sulphur applied singly and in combination. Nitrogen as well as sulphur applied singly and in combination increased the sugar and starch contents of grain.

Sorour *et al* (1998) studied the effect of irrigation interval and potassium fertilization level on quality of rice. They observed that as irrigation interval

increased, there was decrease in 1000-grain weight as well as hulling, milling and head rice percentage and protein content in milled rice. The highest values of all traits were obtained when plants were subjected to continuous flooding or irrigation every 6 days with no significant differences between these treatments for most studied traits. Adding K fertilizer significantly increased hulling percentage and protein content in milled rice than the control treatment.

Mudjisihono and Koswara (1991) carried out an experiment to study the effects of phosphorus, zinc (Zn), and copper (Cu) fertilizers application on physical and chemical characteristics of low land rice variety *IR-64*. Result indicated that at one site, application of phosphorus fertilizer (100 kg/ha) in combination with zinc (4-8 percent) and copper (2 percent) improved physical quality of the rice; while at another site, application of phosphorus fertilizer (200 kg/ha) and copper fertilizer (2 percent) tended to depress physical quality. Application of zinc and copper fertilizer did not negatively affect milling quality of rice (rendement of milled rice and head rice). Amylose content was affected by application of zinc and copper fertilizers; protein and ash content were slightly affected by the application of the fertilizer.

Ali *et al* (1990) studied the effect of harvesting and threshing time on field and milling losses in Basmati 385. They observed that paddy yield and milling recovery are influenced by harvesting and threshing time. Their study indicated that both paddy yield and head rice recovery were maximum when the crop was harvested 32-34 days after flowering followed by threshing within a day. Optimum harvesting time corresponded with grain moisture content of 20-22%. The study also showed that significant field and milling losses occur if harvesting and threshing were carried out before or after optimum time.

#### **2.4.2 Effect of conjoint application of chemical fertilizers and farmyard manure**

Surapol (1995) observed that grain quality (chemical and physical properties of rice grain as well as its aroma) of *KDML 105* was not affected by growth retardant in combination with Compost and Chemical Fertilizers.

Jeong *et al* (1996) studied the effects of organic matter application on rice growth and grain quality. In their field trial, rice was given the treatment containing 110 kg N + 120 kg P + 130 kg K/ha (100% NPK) alone or with 5 t rice straw/ha or half of these NPK rates (50% NPK) alone or with 5 t rice straw, 20 t compost, 20 t fermented pig manure, pig manure + compost, 3 t oil cake or 5 t fermented chicken manure/ha. Nitrogen content was higher and silicic acid content lower in plants which were given chicken manure, whereas phosphoric acid and Mg contents were higher in plants manured with oil cake in comparison to control. Application of organic manure + 50% NPK gave grain yields 9-17% lower than those obtained with 100% NPK rate except for 50% NPK + oil cake which gave 16% higher yields than 100% NPK. Grain protein content, alkali digestion value and gel consistency were unaffected by the treatments. Amylose content of grain was lower in plants manured with straw, compost or compost + pig manure as compared to 100% NPK treatment. In general, rice cooking quality and taste were not improved by organic fertilizers.

Pandey, *et al* (1999) studied the effects of farmyard manure and chemical N fertilizer on quality of scented rice varieties (cv *Madhuri 11* and *Pusa Basmati*). The head rice recovery and alkali value were higher with the application of 10 tonnes of farmyard manure or 80 or 120 kg N/ha as compared to other treatments during both years. Application of N fertilizer increased kernel length, length:breadth ratio, kernel length after cooking and elongation ratio. Covariety *Madhuri 11* had higher grain yield and N uptake than *Pusa Basmati 1*, whereas *Pusa Basmati 1* was better in kernel length, length:breadth ratio, kernel length after cooking, elongation ratio and alkali value. Hemalatha *et al* (1999) studied the influence of organic, biofertilizer, and inorganic forms of nitrogen on rice quality and found that grain quality (amylose and crude protein content) was greatest with *Sesbania aculeata* and 50% N + *Azospirillum*.

Dahiphale *et al* (2000) studied the quality characters of upland irrigated Basmati rice as influenced by nutrient management. They applied different combinations of NPK, trace elements and FYM to basmati rice and observed that grain yield was highest (1865 kg/ha) with 120:60:30 kg NPK plus 10 t FYM/ha.

Kernel size was highest in the highest yielding treatment, while amylose content was not affected by treatment.

## 2.5 Nutrient content and uptake of rice-wheat crops

### 2.5.1 Effect of chemical fertilizers

Subhash Chander and Pandey (1997) observed that uptakes of N, P and K of rice cv Pusa Basmati were significantly higher under transplanted (85.5-112.8 kg N, 10.8-17.0 kg P and 150.5-172.3 kg K/ha) than direct-sown rice (35.1-35.8 kg N, 4.4-5.9 kg P and 58.5-64.3 kg K/ha). Uptake of these nutrients was markedly higher at 120 kg N than that at 60 kg N/ha. Gangaiah <sup>et al</sup> (1999) observed increase in N, P, K and Zn uptake with increasing N rate. Additional elements increased N, P, K and Zn uptake compared with 120 kg N alone. The foliar spray of Fe had no effect on nutrient uptake.

Gangiah and Prasad (1999) conducted field experiments on a sandy clay loam (Fluvent) soil to study the effect of fertilizers on NPK removal of a rice (cv *Pusa Basmati-1*) – wheat cropping system. They observed that N, P, K and Zn uptake of rice increased with increasing N rate. Nutrient uptake of wheat was greater with N than with no application of N. Phosphorus, K and Fe had little effect on either crop. The rice-wheat cropping system resulted in the removal of 257-406 kg NPK ha<sup>-1</sup>year<sup>-1</sup> (107-167 kg N, 15-26 kg P and 135-kg K), which was greater than the amounts of these nutrients applied by the farmers. To produce 1 t of grain 20 kg N, 3 kg P and 25 kg K were removed from the soil.

Miyagawa and Ito (1982) conducted pot experiments to study the effect of nitrogen application (0, 0.3, 0.6 or 0.9 g N/pot) on (a) native scented rice cv Jakoumai and Iwaga, (b) improved non-scented cv Aikoku and Kamenoo and (c) recently improved non-scented cv Sasanishiki and Toyonishiki. They observed higher N content in non-scented cv at high rates of N. Marr *et al* (1999) studied the effect of nitrogen fertilizer on yield, nitrogen and mineral elements in Australian brown rice. They found that nitrogen application increased yield, grain N content and the content of some minerals. In two successive years, 125 kg and 100 kg N/ha increased yields by 63% and 71% (from 6.8 to 11.1 t and from 5.9 to 10.1 t/ha), respectively. The same N rates increased grain N content from 12.9 to

14.5 g/kg in first year, and from 11.4 to 12.6 g in second year. Grain S was significantly increased in first year from 1.04 to 1.21 g/kg, and from 0.82 to 0.94 g/kg in second year. The concentrations of grain Mn also increased significantly with N application in the second year. Total accumulation of all minerals except B and Na in first year and Cu in second year increased with N application. Yield increase, driven by N fertilizer, was the major influence on increased uptake of N, S, P, K, Mg, Ca, Fe, Mn and Zn from the soil.

Kansal *et al* (1974) studied the effect of N and P levels on the cation exchange capacity of roots of improved and local cultivars of basmati rice and wheat. The root CEC of all cultivars increased with application of N, but P application had little effect. Uptake of N was positively correlated with the root CEC and N and P supply. The P content of basmati rice varieties increased with P supply to the soil, but was poorly correlated with the CEC of the roots. Nitrogen application had a depressing effect on P uptake in basmati rice varieties. Hassan *et al* (1993) studied the yield response of Basmati rice to applied P at different soil P values. They observed that yield increased significantly up to 33 kg P/ha for all soil P test values, but significant responses to the next higher dose was observed only when test values were less than or equal to 11 mg P/kg soil.

Paliwal *et al* (1992) conducted a pot experiment to study the influence of increasing levels of nitrogen and sulphur application singly and in combination on the nutrient content of rice var. *Cauvery* grown under submerged soil condition on a silty chromustert. Their results showed that the content of nitrogen and sulphur of grains increased significantly with increasing levels of nitrogen and sulphur applied singly and in combination. Nitrogen application decreased phosphorus content of rice grain significantly while sulphur application increased it. No effect of sulphur was found on potassium content of rice grain while nitrogen increased it significantly.

Qayyum and Athar (1981) studied the effect of nitrogen, phosphorus and potassium on the uptake pattern of zinc and copper in rice. They observed that the mean P and K contents of straw and grain generally increased with increasing rates of N, P and K, but P and K application did not affect N contents of straw and grain and K content of grain. Zinc contents generally decreased with

increasing rates of NPK, but increased significantly with increasing rates of K. Copper contents generally increased with increasing rates of NPK, but were significantly reduced by higher rates of P. Yaseen *et al* (1999) observed that combined application of NPK, organic manures (GM or FYM) and Zn significantly increased the nitrogen and potassium concentrations while lowered the phosphorus concentration of paddy and straw. Reduction in phosphorus was probably due to the antagonistic effect of Zn on P absorption. Results also indicate that Zn-application of soil was better than its foliar spray.

Application of nitrogen, potassium and zinc also significantly increased their respective uptake by the wheat crop (Bajwa and Paul, 1978). Choudhary *et al* (1995) studied the effect of NPK and Zn on the concentration of Zn in plant tissue of two durum wheat lines in greenhouse experiments. They observed that foliar application of Zn resulted in Zn loading of the leaf and stem. Application of P and N + P fertilizers decreased stem and leaf Zn concentration to near insufficiency, while application of Zn to soil with N + P fertilizers increased tissue Zn concentration to sufficiency level. Srinivas and Satyanarayana (1997) conducted a field experiment with three wheat cultivars supplied with 80, 120 or 180 kg N/ha and 25 kg zinc sulfate/ha. They observed the highest grain yield (3.53 and 3.01 t/ha in two years) with 160 kg N. Soil application of Zn was superior in first year only. Nitrogen use efficiency decreased with increasing N rate.

Duraisamy *et al* (1988) conducted a pot experiment to study the effect of 10 and 20 mg Zn/kg soil on the uptake of zinc by rice grown in sodic soil. Their study showed that application of zinc improved zinc availability in soil and zinc uptake by rice grain and straw. High level of zinc (20 mg Zn/kg soil) increased zinc content and uptake in rice grain and straw over the control. Mukhi and Shukla (1991) reported that application of zinc (10 or 50 mg/kg) generally increased sulphur content in root, shoot and grain of rice under submerged soil conditions. Damodar Reddy and Yadav (1994) reported that in a pot experiment increasing level of zinc significantly increased its content and uptake in different part of wheat plant. With increasing zinc level (0 to 25 ppm), its translocation to grain increased significantly by 19 per cent.

An increase in the rate of zinc sulphate gave progressive increase in plant zinc content in rice crop in a rice-wheat rotation (Bhardwaj and Prasad, 1981). Net returns, nitrogen uptake and grain yields were recorded higher with foliar application of 5 kg zinc sulphate/ha in wheat than with 10 kg zinc sulphate/ha as basal and no zinc fertilizer (Rajput *et al*, 1995). Khurana *et al* (1996) observed that in a field experiment, zinc applied at the rate of 2.8, 5.6 and 11.2 kg/ha increased zinc uptake by wheat crop mainly due to the increase in dry matter yield. These finding indicated that the maximum yield was obtained with 11.2 kg Zn/ha.

Khan and Zende (1976) observed that the application of 10 to 20 mg Zn/kg soil significantly reduced phosphorus, calcium, magnesium, iron and manganese content in maize and wheat, whereas content of nitrogen and potassium were less affected. Maximum nutrient uptake by both species occurred with the application of 185 mg phosphorus/ha +10 mg zinc/kg soil. Singh and Singh (1979) reported that zinc contents in grain and straw of wheat crop increased with increase in zinc (0, 4, 8, 16 and 32 kg/ha) application rate, but decreased with increasing phosphorus (90 kg/ha) application. Reddy and Yadav (1994) observed that graded doses of phosphorus and zinc increased grain and straw yields of wheat. Application of 10 mg zinc + 100 mg phosphorus/kg soil gave the highest yield of grains/pot. Increasing levels of phosphorus (0 to 100 mg phosphorus/kg soil) and zinc (0 to 20 mg Zn/kg soil) increased concentration of phosphorus as well as zinc in plant. Sharma and Bhardwaj (1998) suggested that the application of 90 kg phosphorus/ha along with 2.3 kg zinc increased wheat grain yield by 12 per cent as compared to control. Phosphorus and zinc fertilizers markedly increased phosphorus and zinc uptake by the crops. Rajput *et al* (1995) reported that application of 5 kg zinc sulphate/ha increased nitrogen uptake and yield more than the 10 kg zinc sulphate/ha. Alam *et al* (1985) studied the effect of zinc application on nutrient composition of several rice varieties. The degree of varietal response was significantly related to Zn concentration and P:Zn ratio in 44-day-old plant tops. Fine-grained varieties appeared to translocate less Zn to the grain than coarse-grained varieties.

Ishizuka and Ando (1968) reported that the increasing level of zinc markedly reduced manganese concentration and uptake in rice. In their study, the percentage increase in manganese uptake over control was reduced from 24 to 2 when the level of zinc was raised from 5 to 10 kg/ha. Khan and Zende (1976) observed that in a medium black zinc deficient soil of Maharashtra, application of zinc at 10 and 200 ppm significantly increased the zinc content of wheat crop, while the content of iron and manganese were significantly reduced. Brar and Sekhon (1978) observed that zinc content of the roots, stems and leaves increased with increase in zinc application at all used rates. Zinc application decreased the content of manganese in plant root, but concentration in the nutrient medium at which the interference became effective, depended upon the nature of ion. Sakal (1981) reported that zinc concentration and its uptake by wheat plant progressively increased with the level of its application. Zinc application decreased manganese concentration in grain and straw indicating some inhibitory effect on manganese nutrition. Sakal and Singh (1977) reported that application of calcium carbonate and zinc progressively decreased the iron and manganese content of different plant parts of wheat while zinc content increased from 33.13 to 35.40 gm/pot with the incorporation of calcium carbonate. Alam *et al* (1998) studied the effect of zinc application with or without copper on rice genotype *Basmati-385* and a mutant *DM-25* in a pot culture experiment. Rice genotypes responded to Zn application much more in presence of Cu than its application alone. The Zn x Cu interaction significantly increased total Zn uptake by both rice genotypes.

Kuligod *et al* (1994) observed that application of sulphur and zinc fertilizer increased uptake of nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, zinc and manganese by the wheat crop.

A study conducted by Bhardwaj and Prasad (1979) revealed that 20 kg zinc sulphate/ha was most effective in increasing 1000-grain weight and zinc uptake in wheat and resulted in the highest grain yield of 4.03 ton/ha compared to 3.28 ton/ha without zinc. Singh and Singh (1979) found a significant increase in the zinc content of grain and straw of wheat with corresponding increase in zinc

dose. Application of zinc at the rate of 4, 8, 16 and 32 kg Zn/ha increased the zinc content of grain by 3.5, 5.9, 8.9 and 12.5 per cent and that of straw by 3.1, 4.5, 6.6 and 7.8 per cent, respectively over control in both the first and second years of experiment. Bhardwaj and Prasad (1981) observed that the zinc content of wheat increased with increasing level of zinc. The uptake of zinc was found to continue up to the harvest of crop. Prasad *et al* (1981) observed that application of zinc increased its concentration and uptake considerably in grain. The highest zinc concentration in grain was obtained at 5 kg Zn/ha level.

Sachdev *et al* (1988) reported that the fertilizer zinc uptake by wheat increased with increasing zinc level, but percentage utilization was much lower with 10 kg Zn/ha application (0.65%), as compared to 5 kg Zn/ha (1.22%). Zinc derived from fertilizers was significantly effected by the level of zinc application only in wheat straw but not in grain. The wheat crop required only 405 gms of Zn/ha with a harvest of 4.7 tonnes of grains and 6.4 tonnes of straw but under zinc deficient soil condition, even this amount could not be met and consequently zinc deficiency resulted in low dry matter production. Only about 66 gms of applied zinc was utilized by the crop but it gave an extra yield of 3.2 q/ha of grain and 9.8 q/ha of straw compared to yields obtained with no zinc application.

### **2.5.2 Effect of farmyard manure**

Nazir *et al* (1984) observed that P uptake of basmati rice was enhanced by increasing rates of organic matter and  $P_2O_5$  and was greater under submerged conditions than at field capacity. Organic matter also promoted grain P uptake which was greatest under flooding. Swarup (1985) reported that use of farmyard manure and rice husk resulted in marked improvements in iron and manganese concentration in the rice crop, and enhanced the uptake of phosphorus, potassium, calcium, magnesium iron, manganese, zinc and copper by the crop under submerged condition in a highly sodic soils. Singh and De (1987) observed that application of 10 ton FYM/ha or 80 kg nitrogen/ha in the form of urea, increased uptake of nitrogen, phosphorus and potassium and also increased the grain yield of wheat under dry land conditions. Sharma and Deb (1991) recorded that uptake of zinc increased with the application of FYM in four soils. The

increase in the zinc uptake with the application of lowest level (5 ton/ha) of farmyard manure was marginal in each soil.

Brar *et al* (1995) found that the application of 12 ton FYM/ha to rice gave the highest grain yield of 6.7 ton/ha. The application of farmyard manure to rice increased nitrogen and phosphorus uptake of rice and phosphorus and potassium uptake of wheat. Dhillon *et al* (1998) observed that application of farmyard manure increased the availability and uptake of nitrogen, phosphorus and potassium in rice crop. They also reported that continuous use of farmyard manure left a residual effect on the soil and residual nutrient availability enhanced grain yield of both the crops. Scherchan <sup>and Gureng</sup> ~~et al~~ (1998) observed that 15 ton compost/ha had a residual effect on wheat crop after rice. They found that total uptake of nitrogen, phosphorus and potassium by wheat (straw and grain) were also highest for the treatment giving the highest wheat yield.

Sadana *et al* (1995) reported that incorporation of green manure significantly increased the dry matter yield and iron, manganese, zinc, nitrogen and sulphur contents of rice plant under submerged conditions.

### **2.5.3 Effect of conjoint application of chemical fertilizers and farmyard manure**

Nemeth *et al* (1987) reported that in wheat cv MV-8 grown with 34.7, 69.4 or 104.1 ton FYM/ha, without inorganic fertilizer or with NP or NPK, Fe content significantly increased with application of 34.7-69.4 ton FYM/ha. Application of inorganic fertilizers favoured Mn, Zn and B content compared with FYM but Mo contents were greater in crop manured with FYM. Lal and Huda (1993) observed that application of phosphorus, sulphur,  $K_2SiO_3$  and farmyard manure singly and in combination increased dry matter yield and total sulphur uptake by wheat. Application of farmyard manure +  $K_2SiO_3$  gave significantly higher sulphur uptake than, when each one was applied separately.

Sharma and Deb (1991) studied the effect of application 5, 10 or 15 FYM/ha and 10 kg Zn/ha in different soil under controlled environment experiment. They found that uptake of zinc increased with farmyard manure application than zinc alone in different soils. Application of manure increased

zinc uptake in case of all the soils, the magnitude of increase was loamy sand (11 or 12), in (9 to 11) sandy loam, in (4 to 8) sandy clay loam and in (3 to 7) loam soils per cent.

Bhardwaj and Verma (1993) observed that lowest yields of wheat were obtained from control plots and highest from 100 per cent of recommended nitrogen, phosphorus and potassium + 10 ton FYM/ha application. The uptake of nutrients also followed the same pattern.

Gupta *et al* (1987) reported that application of zinc increased the concentration of zinc but decreased the concentration of copper, manganese and iron in pigeon pea shoots. Application of manures increased the iron and zinc concentration but decreased copper and manganese concentration in wheat straw.

The application of zinc and farmyard manure along with 100% NPK resulted in increased uptake of zinc in mollisol (Nand Ram and Ram, 1996).

#### **2.5.4 Residual effect of zinc and farmyard manure on yields and nutrient uptake of rice-wheat crops**

Application of zinc sulphate in rice increased paddy yield but had no residual effect on yields of subsequent wheat crop (Bhardwaj <sup>and Prasad</sup> ~~et al~~ 1981 and Gangiah *et al* 1999). Brar *et al* (1995) also found that wheat grain yields in a field experiment at Ludhiana were not significantly affected by soil fertility or residual effect of farmyard manure. Some workers have reported that the application of farmyard manure to rice had a residual effect on succeeding wheat crop. The wheat yield increased up to 4.3 ton/ha when 12 ton FYM/ha was applied to the previous rice crop (Maskina <sup>and Meelu</sup> ~~et al~~ 1984). Prasad *et al* (1989) studied the residual effect of organic sources of zinc and observed that zinc persisted even after the harvest of the fourth crop of wheat and rice. Rajput *et al* (1992) also observed that the grain yield of wheat after rice was highest (2.69 ton/ha) in plots previously supplied with 10 ton farmyard manure + 100 kg nitrogen and lowest in the control plots. Prasad and Umar (1993) reported that zinc uptake by wheat increased due to the residual effect of applied zinc but there was no significant effect of zinc on grain or straw yield of wheat. However, Nahar *et al* (1995) reported that the application of *Leucaena leucocephala* leaves as leaf manure and

cattle manure during the previous rice crop increased wheat yield to 1.98 and 2.2 ton/ha, respectively. Scherchan <sup>and Gaurang</sup> ~~et al~~ (1998) observed that application of 15 ton compost/ha rice had a residual effect on wheat crop. Rajput (1997) reported that zinc application increased wheat yield and the yield of the succeeding rice crop was increased due to the residual effect of farmyard manure. Farmyard manure applied to wheat also had significant residual effect on succeeding rice crop.

Indulker and Malewar (1994) observed that application of 10 ton FYM/ha decreased the grain yield of sorghum but increased it due to application of 4 kg Zn/ha. The residual effects of both zinc and farmyard manure were noted on zinc uptake and DTPA extractable zinc in soil.

## 2.6 Effect of application of chemical fertilizers and farmyard manure on build up of extractable soil nutrients

Bajwa and Paul (1978) reported that continuous cropping with wheat and maize with nitrogen alone depressed the available phosphorus, potassium, nitrogen and DTPA extractable zinc level in soil. Alok Kumar *et al*, (1995) reported that organic plus mineral fertilizer treatment decreased exchangeable sodium percent at faster rate and depleted micronutrient cations (copper, manganese, zinc and iron) at slower rates than inorganic fertilizers alone. In a long term rice-wheat rotation receiving various combinations of N, P, K, Zn and FYM, Singh *et al* (1999) reported that the difference in the organic matter, available P, K, S, B, Mo and DTPA extractable micronutrient cations in soil at 20 cm depth and crop productivity were significant after 10 years. Organic matter content decreased markedly except the plots receiving SSP and FYM. There was a general increase in the DTPA extractable Cu, Mn, Fe and available B and Mo during the period in the plots treated with SSP and FYM. The combined effect of deficiency of Zn, toxicities of Fe, Mn, Cu and B and imbalances due to the antagonisms between mainly P-Zn, Fe-Zn, B-Cu, Cu-Zn and S-Zn seemed to be responsible for the loss of productivity of rice-wheat.

Regular application of farmyard manure increased the organic matter content of the soil (Havangi and Mann, 1970; Gattani *et al*, 1976; Prasad, 1983; Sharma *et al*, 1985; Nahar *et al*, 1995). Scherchan <sup>and Gaurang</sup> ~~et al~~ (1998) observed that

organic matter content decreased from 1.98 to 1.55 per cent in the control plot, but increased where compost had been applied. Exchangeable calcium and magnesium were also significantly affected by the treatment but no significant improvement was observed in the cation exchange capacity of the soils.

Sharma and Gupta (1998) reported that organic residues, farmyard manure and white popinac leaves left a residual effect on the succeeding wheat crop after maize. The water holding capacity, organic carbon, available nitrogen and phosphorus in soil were increased, while available potassium and bulk density decreased by the organic residues.

Santhy and Channel (1997) studied the effect of long term fertilizer experiment with treatments having combination of 50, 100 and 150 per cent nitrogen, phosphorus and potassium fertilizer, zinc sulphate or farmyard manure, nitrogen and phosphorus alone, phosphorus alone, phosphorus and potassium fertilizers from a sulphur, free source on finger millet-maize-cowpea rotation. They observed that available sulphur increased from surface (0-15 cm) to subsurface soil (15 to 30 cm). Total sulphur content decreased from 0-15 cm to 45 to 60 cm depth.

Awad *et al* (1996) reported that application of sulphur with organic manure and nitrogen, phosphorus fertilizers in wheat decreased soil pH and increased the availability of iron, zinc and manganese in highly calcareous soils of Egypt. The highest concentration and uptake of iron, zinc and manganese occurred at higher sulphur levels.

Sakal ~~et al~~ (1981) reported that  $ZnSO_4$  application raised the level of available zinc in soil and left substantial amount of zinc for the succeeding crop. However, zinc application did not affect the availability of copper and manganese in soil. The presence of organic matter may promote the availability of zinc in soil by complexing with the substances capable of fixing zinc. According to Mann *et al* (1978), the application of FYM appreciably increased the availability of applied and native micronutrient cations, the order of increase was:  $Fe > Cu > Mn > Zn$ . As these elements are known to form complexes of different stability with organic ligands to decrease their susceptibility to adsorption or

fixation or precipitation reaction in soil, application of FYM might have resulted in the formation of such metalo-organic complexes of higher extractability. The increase in the availability of native cations appeared to have resulted from the transformation of their solid phase forms to soluble metal complexes. Further, as iron and copper form metalo-organic complexes of higher stability constant than that of zinc and manganese, the relative increases in available contents of former two, were more than that of the latter two. Eswarappa *et al* (1989) reported a positive significant correlation between organic matter and available zinc in red, lateritic and black soil type in Mysore.

Application of farmyard manure in conjunction with 100 per cent nitrogen, phosphorus and potassium has been found most beneficial both from a biophysical and economic point of view (Biswas *et al*, 1997).

Indulkar and Malewar (1994) observed that application of 10 ton FYM/ha resulted in significantly higher availability of nitrogen, phosphorus and zinc over control for sorghum and improved the magnitude of availability of nitrogen, phosphorus and zinc for succeeding crop. The build up of zinc in soil was adequate even after its removal by sorghum-wheat cropping system. Bhoyar *et al* (1998) studied the effect of manure and mineral fertilizers on the physicochemical properties of soil under a sorghum-wheat crop sequence. Availability of micronutrients increased with increasing NPK rate. Available zinc status was greatest in surface soil with application of 10 kg ZnSO<sub>4</sub>/ha in combination with 120:60:60 kg/ha. Available iron, manganese and copper in surface and subsurface soils were greatest with 120:60:60 kg N:P:K/ha + 10 kg FYM/ha. Available iron, manganese and copper content were lower in surface than subsurface soil; however, available zinc was higher in surface soil.

**MATERIALS**  
**AND**  
**METHODS**

### ***3. Materials and Methods***

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To ascertain the effect of chemical fertilizer, FYM and their conjoint application on the yields, nutrient contents and uptake of aromatic rice and wheat and quality of aromatic rice, field experiments were conducted at Research Station, Nagina, District Bijnor, U.P. during *Kharif* and *Rabi* seasons of 1998-2000. The details of the materials used and experimental methods followed in this study are given below.

#### **3.1 General description of the area**

##### **3.1.1 Location**

The present investigation was carried out at Nagina Research Station, G.B. Pant University of Agriculture & Technology (now a part of Sardar Vallabh Bhai Patel University of Agriculture and Technology), District Bijnor, Uttar Pradesh. Nagina lies between latitude 29° 28' N and longitude 78° 32' E. The area has an altitude of about 245 meters above mean sea level. The land of research station has a gentle slope of 0.5 to 1.0 percent.

##### **3.1.2 Climate**

The climate of the area can be classified as Sub tropical with three well defined seasons i.e. winter (December to March), summer (April to mid June) and rainy (mid June to September). During the experiment, the average annual rainfall in the area was about 1342.2 mm. Most of the rainfall was received from southwest monsoon, starting from mid June and extending till the end of September. About 75 to 80 percent of the total annual precipitation was received during four months (June to September) and rest of the precipitation was distributed over eight months, of which the largest precipitation was received during December to January. The mean summer temperature was 28.5 °C and the mean winter temperature was 15.9 °C. The maximum average weekly temperature was 41.7 °C and the minimum average weekly temperature was 4.3 °C. The lowest mean maximum temperature (11.6 °C)

was in month January 1999 and the highest (41.7 °C) in the month April 1999. The mean monthly minimum temperature was lowest (4.3 °C) in month January 2000 and highest (28.3 °C) in month June 1999. The mean relative humidity remained more than 90 percent in July to February. From March onward, it decreased to about 55 percent till the mid June and steadily rose till August. When winter rains were deficient, there might be moderate to severe frost during nights from mid December to mid January.

### 3.1.3 Natural Vegetation

At Research Station, experimental trials are being conducted on common crops like Rice, Wheat, Maize, Lentil, Gram, Peas and Sugarcane; and also on some vegetable crops like Brinjal, Okra, Tomato, Cauliflower and Cabbage for seed and commercial production. In the relevant area, native vegetation includes Shesham (*Delbergia sissoo*), Jamun (*Syzgium cumini*), Imli (*Tamarindus indica*), Kikar (*Acacia arabica*), Khair (*Acacia catechu*), Sal (*Shorea robusta*), *Eucalyptus* sp, Ber (*Ziziphus mauritiana*), Babul (*Acacia nilotica*), Neem (*Azadirachta indica*). The orchards of mango (*Mangifera indica*), Gauva (*Psidium guajava*), Citrus (*Citrus* sp) and some other fruit crops are also present. Common weeds of the area are *Cyperus rotundus*, *Phalaris minor*, *Melilotus indica*, *Medicago lenticulata*, *Chenopodium album*, *Cynodon dactylon*, *Saccharum spontanium*, *Ziziphus rotundifolia*, *Cannabis sativa*, *Tamarix dioicea* and *Saccharum munj*.

### 3.1.4 Geology

The study area is a part of alluvial region of *Indo-Gangetic* plains: The soil characteristics are affected by sub-humid climate.

The geology of the area is the ordinary *Gangetic* alluvium, which consists mostly of gravel, sand, silt, clay and *kankar* (nodular limestone). Its deposition commenced in the Pleistocene period after the final upheaval of the Himalayas and it is still in progress.

### 3.1.5 Topography

The land is leveled or nearly leveled. The gradient is up to one percent. In general, alluvial belt is flat with very gentle undulations. These regions are made from the flood deposition

### 3.1.6 Soil

Study area is a part of northern *Gangetic* alluvial plain. Soils of this area, in general, are coarse textured; moderately well to well drained and considerably deep. The texture becomes finer in Southeast. As per the USDA Soil Taxonomic Classification System, the soils belong to Natrustalfs, Eutrochrepts, Haplaquepts, Dystrochrepts, Ustrochrepts, Ustipsamments great groups. (Sharma *et al*, 1993).

## 3.2 Cropping History of the Experimental Area

During the preceding years, the experimental field was under rice – wheat rotation only.

## 3.3 Experimental Details

Two year field experiments were conducted to study the effect of different levels of chemical fertilizer, FYM and their combinations on the yields, nutrient contents and uptake of aromatic rice and wheat and quality parameters of rice. Thirteen treatments with various levels of NPK, NPKZn and FYM were given. The recommended fertilizer dose (RD) for the experiment was 60 kg N, 40 kg P<sub>2</sub>O<sub>5</sub>, 40 kg K<sub>2</sub>O/ha and 50 kg ZnSO<sub>4</sub>/ha for scented rice and 120 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 60 kg K<sub>2</sub>O/ha for wheat. The FYM was applied at the rate of 12 t/ha, based on 0.5% N, 0.3% P and 0.7% K (Appendix II). The application of zinc was limited to the first rice crop only, as the amount of zinc is generally sufficient for 4-6 crops. The recommended dose of fertilizers or manure was given through chemical fertilizers (RD<sub>NPK</sub> or RD<sub>NPKZn</sub>) as urea, single superphosphate, muriate of potash and zinc sulphate; or farmyard manure (RD<sub>FYM</sub>). The experimental layout and treatments are detailed below:

**1. Treatments:**

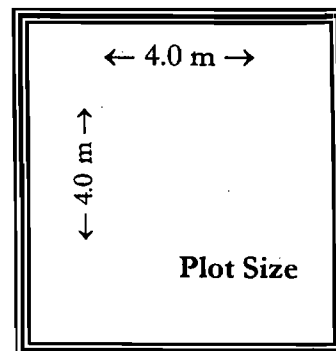
T <sub>1</sub>	Control
T <sub>2</sub>	25 % RD <sub>NPK</sub>
T <sub>3</sub>	50 % RD <sub>NPK</sub>
T <sub>4</sub>	75 % RD <sub>NPK</sub>
T <sub>5</sub>	100 % RD <sub>NPK</sub>
T <sub>6</sub>	25 % RD <sub>NPKZn</sub>
T <sub>7</sub>	50 % RD <sub>NPKZn</sub>
T <sub>8</sub>	75 % RD <sub>NPKZn</sub>
T <sub>9</sub>	100 % RD <sub>NPKZn</sub>
T <sub>10</sub>	25 % RD <sub>FYM</sub> + 75 % RD <sub>NPKZn</sub>
T <sub>11</sub>	50 % RD <sub>FYM</sub> + 50 % RD <sub>NPKZn</sub>
T <sub>12</sub>	75 % RD <sub>FYM</sub> + 25 % RD <sub>NPKZn</sub>
T <sub>13</sub>	100 % RD <sub>FYM</sub>

One third of the N dose as urea and full doses of P as single super phosphate and K as muriate of potash and required amount of FYM were applied as basal application. Rest of the Nitrogen was applied in two splits as urea at 30 and 60 days after transplanting in rice and at 30 and 60 days after sowing in wheat.

<b>2. Replications</b>	<b>:</b>	<b>Four</b>
<b>3. Experimental Design</b>	<b>:</b>	<b>Randomized Block Design (RBD)</b>
<b>4. Plot size</b>	<b>:</b>	<b>4 × 4 m</b>
<b>5. Row to row distance</b>	<b>:</b>	<b>20 cm (rice), 22.5 cm (wheat)</b>
<b>6. Plant to plant distance</b>	<b>:</b>	<b>10 cm (rice), 5 cm (wheat)</b>
<b>7. Crop variety</b>	<b>:</b>	<b>Taraori (rice)</b> <b>UP 2338 (wheat)</b>
<b>8. Location</b>	<b>:</b>	<b>Experiment Station, Nagina</b>

## Layout

R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>
T <sub>1</sub>	T <sub>2</sub>	T <sub>1</sub>	T <sub>3</sub>
T <sub>2</sub>	T <sub>12</sub>	T <sub>8</sub>	T <sub>10</sub>
T <sub>7</sub>	T <sub>6</sub>	T <sub>9</sub>	T <sub>13</sub>
T <sub>13</sub>	T <sub>11</sub>	T <sub>2</sub>	T <sub>4</sub>
T <sub>6</sub>	T <sub>3</sub>	T <sub>10</sub>	T <sub>9</sub>
T <sub>4</sub>	T <sub>5</sub>	T <sub>7</sub>	T <sub>12</sub>
T <sub>11</sub>	T <sub>9</sub>	T <sub>11</sub>	T <sub>5</sub>
T <sub>8</sub>	T <sub>13</sub>	T <sub>12</sub>	T <sub>8</sub>
T <sub>12</sub>	T <sub>4</sub>	T <sub>13</sub>	T <sub>6</sub>
T <sub>5</sub>	T <sub>10</sub>	T <sub>3</sub>	T <sub>11</sub>
T <sub>9</sub>	T <sub>7</sub>	T <sub>6</sub>	T <sub>7</sub>
T <sub>10</sub>	T <sub>8</sub>	T <sub>4</sub>	T <sub>1</sub>
T <sub>3</sub>	T <sub>1</sub>	T <sub>5</sub>	T <sub>2</sub>



### **3.4 Schedule of operations**

The details of various cultural operations performed for different crops during the period of experiment starting from nursery raising for scented rice crop to the harvesting of wheat crop are given below:

#### **3.4.1 Field preparation for rice**

The field was ploughed in summer and then harrowed twice and leveled.

#### **3.4.2 Cultural operations**

##### **3.4.2.1 Raising the paddy nursery**

Rice seedlings were raised in the wet beds of  $8 \times 1.25$  m size. A mixture of 200 g urea, 500 g single super phosphate and 100 g muriate of potash was applied to each bed before raising the seedlings. The seeds of scented rice variety Taraori were soaked overnight and sown.

##### **3.4.2.2 Treatment application and Sampling of Index Leaf**

Experiment was laid out in randomized block design and individual plots were separated by well-raised strong bunds. Puddling was done manually with the help of a spade. Different combinations of fertilizers and FYM were applied to the plots just after puddling and incorporated into the puddled soil with the help of spade. Two equal split doses of rest N ( $1/3 + 1/3$ ) as urea were top-dressed at 30 and 60 days after transplanting.

Fully opened third leaf from the top was sampled randomly from 15 plants at 45 d after transplanting for nutrient analysis.

#### **3.4.3 Transplanting and Gap Filling**

In the puddled field, two 25 days old seedlings were transplanted per hill at a spacing of  $20 \times 10$  cm. Gap filling was done four days after transplanting, wherever needed.

#### **3.4.4 Water Management**

All plots were kept submerged by maintaining 5-10 cm water level over soil surface up to the milk stage by irrigation as and when required. No surface drainage was allowed.

### **3.4.5 Yields**

#### **3.4.5.1 Grain yield per hectare**

From the individual plot, net plot area ( $3.6 \times 3.6$  m) leaving border rows was harvested, air-dried and the produce was threshed and cleaned. Final grain yield was recorded at 14 percent moisture level in terms of kg per plot and converted to quintals per hectare.

#### **3.4.5.2 Straw yields per hectare**

The straw yield was also recorded after threshing on oven dry weight basis. The final weight was recorded in kg per plot and converted to quintals per hectare.

### **3.5 Wheat**

After the harvest of rice crop, wheat crop was grown in the *rabi* seasons of the year 1998 and 1999. The experimental details were as described in the preceding section.

#### **3.5.1 Pre Sowing Operations**

After rice harvesting all experimental plots were ploughed once with the help of one-way plough and harrowed thrice. The plots were marked according to the layout plan and properly dressed with spade.

#### **3.5.2 Sowing**

Seeds of wheat (cultivar UP 2338) were sown at the rate of 120 kg seeds per hectare with the help of seed drill. After sowing, bunds were made according to the layout plan.

#### **3.5.3 Treatment Application and Sampling of Index Leaf**

Different combinations of fertilizers and FYM were applied to the plots. The treatments were then incorporated into the soil with the help of spade. The dose of N was divided into three parts ( $1/3$  basal and two top dressings of rest  $1/3 + 1/3$  N at CRI and before ear emergence stages).

Fully opened third leaf from the top was sampled randomly from 15 plants at 45 d after emergence for nutrient analysis.

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### **3.5.4 Post Emergence Operations**

#### **3.5.4.1 Thinning**

Thinning was done after four weeks of the crop.

#### **3.5.4.2 Water Management**

Four irrigations were given to raise the crop at different physiological stages of crop growth.

#### **3.5.4.3 Weed control**

Isoproturan at the rate of 1.5 kg a.i. per hectare in 100 litre water was sprayed 30 days after sowing to control the weeds.

#### **3.5.4.4 Harvesting and Threshing**

The net plot (3.6 × 3.6 m leaving border rows) area was harvested at maturity. Manual harvesting was done in each plot and the produce was tied into bundles. Threshing was done plot-wise separately with the help of thresher.

### **3.5.5 Yields**

#### **3.5.5.1 Grain yield per hectare**

Threshed grains from the net plot were cleaned and finally, grain yield was recorded at 14 percent moisture level in terms of quintals per hectare.

#### **3.5.5.2 Straw yield per hectare**

The straw yield was also recorded after threshing on oven dried weight basis. The final straw yield was recorded in quintals per hectare.

### **3.6 Chemical Analysis**

#### **3.6.1 Plant Chemical Analysis**

##### **3.6.1.1 Plant sample preparation**

Leaf, grain and straw samples were washed in sequence, first in tap water, then dilute HCl (0.1 N HCl solution) and finally in deionized water. The extra moisture was wiped out and the sample was placed in new bags and dried in an oven at 70°C.

### **3.6.1.2 Wet digestion of plant samples (Jackson, 1962)**

Leaf, grain and straw samples were finely ground in a stainless steel grinder. One gram of finely ground plant sample was weighed on an electrical balance (Mettler). The weighed sample was then carefully transferred to a 150 ml conical flask. About 10 ml of conc  $\text{HNO}_3$  was added to each flask and left overnight. Next morning, the content was placed on a sand bath for 30 minutes. The content was then cooled and 10 ml of diacid mixture ( $\text{HNO}_3$ :  $\text{HClO}_4$  3:1 v/v) was added to the flask and the flasks were again placed on the sand bath. The contents were heated until a colourless residue was left in the bottom of the flask. Then 5ml 6 N HCl was added to each flask and a gentle boiling was allowed on a hot plate. After cooling, the digested material was diluted to about 30-35 ml and was filtered through Whatman no. 40 filter paper. The filter paper was washed several times with distilled water and the filtrate was collected in a 50 ml volumetric flask and the final volume was made up to the mark. The digest was used for determination of various elements except nitrogen.

## **6.3 Determination of total macroelements in plants**

### **6.3.1 Determination of Phosphorus**

Phosphorus was determined by yellow colour phospho-vanado-molybdate complex method as described by Jackson (1962). A 5 ml aliquot was taken in a 25 ml volumetric flask and 5 ml vanado-molybdate reagent was added. The contents were shaken for a while and then volume was made up to the mark. The intensity of yellow colour developed was measured on a UV-visible spectrophotometer at a wavelength of 470 nm. The concentration of P in the extracts was computed by comparing the absorption with that of calibration curve plotted between a range of standard P solution (0-20 ppm) on x-axis and their absorbance on y-axis.

### **3.6.3.2 Determination of Potassium**

Potassium in the diluted plant digests was determined by Flame photometry using a range of standard solutions of 0-5 ppm K.

### 3.6.3.3 Determination of Sulphur

The sulphur in the plant digests was determined by turbidimetric method (Chesnin and Yien, 1950). To a suitable amount of aliquot of the digest (5-10 mL) into a 25 mL volumetric flask, barium chloride crystals (1gm) were added and it was shaken for one minute. Then, 1.0 mL of 0.25% gum acacia solution was added and the volume was made up to the mark. After a uniform shaking for one minute the turbidity developed was measured on "spectronic-20" spectrophotometer at 420 nm. Sulphur concentration was determined from the standard curve prepared with each set of determination.

### 3.6.3.4 Determination of Micronutrient Cations

The micronutrient cations viz. Zn, Cu, Fe and Mn were determined by Atomic Absorption Spectrophotometer (AAS) (GBC 902 and GBC – Avanta  $\Sigma$ ). The contents of nutrients in plant material were expressed in terms of mg kg<sup>-1</sup> plant tissue.

### 3.6.3.5 Determination of Micronutrient Anions

#### 3.6.3.5.1 Determination of Boron

Dried plant tissue (1.2 gm) was weighed in a silica crucible and ashed at 550°C in an electric muffle furnace and the residue was dissolved in 2 mL of 6 N HCl. The contents were diluted to 12 mL using B-free distilled water. Boron in the extract was determined calorimetrically by Azomethine – H method (John *et al*, 1975) as described by Page (1982). A suitable aliquot of blank, diluted standard or sample solution was transferred into a 10 or 15 mL polypropylene tube. To each tube, 2 mL buffer was added and mixed. Thereafter, 2 mL of azomethine – H reagent was added and mixed. The absorbance was read at 420 nm after 30 minutes. The absorbance of unknown samples were compared to that of standard curve prepared with 0 – 10 ppm B.

#### 3.6.3.5.2 Determination of Molybdenum

The concentration of Mo in plant digests was determined by Atomic Absorption Spectrophotometer (AAS) (GBC 902 and GBC – Avanta  $\Sigma$ ). The

contents of nutrients in plant material were expressed in terms of  $\text{mg kg}^{-1}$  plant tissue.

### 3.6.3.6 Determination of Calcium and Magnesium

The concentration of Ca and Mg in plant digests was determined by Atomic Absorption Spectrophotometer (AAS) (GBC 902 and GBC – Avanta  $\Sigma$ ). The contents of nutrients in plant material were expressed in terms of  $\text{mg kg}^{-1}$  plant tissue.

### 3.6.3.5 Determination of Nitrogen

Total nitrogen in the plant material was determined by macrokjeldahl method with a Kjeltex autoanalyzer (Tecator Foss). Finely ground plant material (0.2 g) was taken in kjeldahl tubes, to which 0.5 g digestion mixture ( $\text{Na}_2\text{SO}_4 + \text{CuSO}_4 + \text{Se}$  powder 50:10:1 w/w) was added. Then, 10 mL concentrated sulphuric acid was added to it. The contents were heated on kjeldahl digestion assembly until clear residue was obtained in the bottom. The contents were cooled down and 50 mL distilled water was added to it and the sample was distilled by adding 50 mL 40 % NaOH to it. The released ammonia gas was trapped into 4 % Boric Acid containing mixed indicator (Methyl red and bromocresol green) until the volume of the solution increased about 4 to 5 times. The trapped ammonia was titrated against 0.1 N standard  $\text{H}_2\text{SO}_4$ . The N content in the plant tissue was expressed in terms of % N:

$$\% \text{ N in plant material} = \frac{(S - B) \times 0.014 \times N}{W} \times 100$$

Where, S = volume of titrant used with sample (mL)

B = volume of titrant used with blank (mL)

0.014 = milliequivalent weight of nitrogen

N = normality of  $\text{H}_2\text{SO}_4$

W = weight of plant sample digested (g)

## **3.6.2 Soil Analysis**

### **3.6.2.1 Sampling and processing of soil for analysis**

#### **3.6.2.1.1 Collection of initial soil sample**

Before starting the experiment, initial representative surface (0-15 cm) soil samples of experimental area were collected with the help of a tube auger for monitoring its basic properties. The samples were, then, mixed for homogenization and dried in air under shade. The samples were ground with a wooden roller and sieved to pass through a 2 mm sieve. The samples were then preserved in polybags for various chemical analyses.

#### **3.6.2.1.1 Collection of final soil samples**

After the completion of a rice – wheat cropping sequence in each year, the surface soil was sampled with the help of a tube auger from four spots at random in each plot. The samples were, then, mixed for homogenization and dried in air under shade. The samples were ground with a wooden roller and sieved to pass through a 2 mm sieve. The samples were then preserved in polybags for various chemical analyses.

### **3.6.2.2 Physical and chemical properties of soil**

Some physical and chemical properties of the initial soil sample were determined and listed in Table 1. The details of the procedures followed are as under:

#### **3.6.2.2.1 Mechanical analysis**

Mechanical analysis of the soil sample was done by International Pipette Method, after the removal of organic matter by H<sub>2</sub>O<sub>2</sub> (30%) treatment and dispersion with sodium hexametaphosphate (5 percent) (Kilmer and Alexander, 1949).

#### **3.6.2.2.2 Soil pH**

Exactly 10 gm soil was taken in a 50 ml beaker, to which, 20 ml distilled water was added. The contents were stirred vigorously with a clean glass rod for 10 minutes and then occasionally for the next twenty minutes. The pH of soil, water suspension was determined by using a pH meter equipped with a combined glass electrode (Jackson, 1962).

**Table 1. Some Physical and Chemical Properties of Initial Soil Sample of Experimental Area at Nagina**

SN	Characteristics	Value	References
1	Mechanical analysis		International Pipette Method (Kilmer and Alexander, 1949)
	Sand %	25.8	
	Silt %	46.0	
	Clay %	28.2	
2	pH (1:2 soil water suspension)	7.9	(Jackson, 1962)
3	Electrical conductivity (dSm <sup>-1</sup> at 25°C)	0.46	(Bower and Wilcox, 1965)
4	Organic carbon (%)	0.55	(Walkley and Black, 1932)
5	Cation exchange capacity (C mol p <sup>+</sup> /kg)	20.5	Neutral normal ammonium acetate method (Black, 1965)
6	Alkaline KMnO <sub>4</sub> hydrolysable Nitrogen (kg/ha)	106	(Subbaiah and Asija, 1956)
7	Mehlich-3 extractable Phosphorus (ppm)	15.1	Page (1982)
8	Mehlich-3 extractable Potassium (ppm)	51.4	(Black, 1965)
9	0.15 % CaCl <sub>2</sub> extractable Sulphur (ppm)	26.3	(Chesnin and Yien, 1950)
10	Mehlich-3 extractable Calcium and Magnesium (ppm)	107; 68	By AAS, (Page, 1982)
11	Mehlich-3 extractable micronutrients (ppm)		By AAS, (Page, 1982)
	Zn	1.2	
	Cu	1.1	
	Fe	135	
	Mn	25	
12	Mehlich-3 extractable B (ppm)	1.1	John <i>et al</i> (1975)

### 3.6.2.2.3 Electrical conductivity

The electrical conductivity of 1:2 soil water suspension prepared for pH estimation was recorded with the help of an electrical conductivity meter. The observed conductance was corrected for temperature compensation and expressed as specific conductance of soil water (1:2) suspension in terms of  $\text{dSm}^{-1}$  at  $25^\circ\text{C}$  (Bower and Wilcox, 1965).

### 3.6.2.2.4 Cation exchange capacity

Cation exchange capacity of soil was determined by neutral normal ammonium acetate method (Black, 1965).

### 3.6.2.2.5 Organic carbon

Soil organic carbon content was determined according to modified Walkley and Black (1934) Method as described by Jackson (1962). One gram of soil was placed in a 500 ml conical flask. Then 10 ml of 1 N potassium dichromate ( $\text{K}_2\text{Cr}_2\text{O}_7$ ) solution was pipetted into the conical flask and the contents were mixed by swirling the flask. Then 20 ml of concentrated sulphuric acid ( $\text{H}_2\text{SO}_4$ ) was added and the mixture was allowed to stand for 20-30 minutes. A Blank (without soil) was also run in the same manner. The mixture was then diluted to 200 ml with distilled water. To it, 10 ml of 85 percent orthophosphoric acid, 0.2 gm sodium fluoride and 30 drops of diphenylamine indicator were added. The solution was back titrated with 0.5 N ferrous ammonium sulphate till a turbid blue colour changed to brilliant green, giving one drop end point.

The result was calculated as:

$$\text{Organic carbon \%} = \frac{(\text{m.e. of oxi. agent} - \text{m.e. of red. agent})}{100} \times 0.003 \times$$

$$\text{Weight of soil sample} \times 0.76$$

Where,

- |                    |   |   |
|--------------------|---|---|
| m.e. of oxi. agent | = | Volume of potassium dichromate x normality of potassium dichromate            |
| m.e. of red. agent | = | Volume of ferrrous ammonium sulphate x normality of ferrous ammonium sulphate |
| 0.003              | = | Milliequivalent weight of carbon  |

- 0.76 = Fraction of organic carbon which was oxidized to carbon dioxide  
 100 = Percentage conversion factor

### 3.6.2.2.6 Available Nitrogen Determination:

Available nitrogen was determined by Alkaline  $\text{KMnO}_4$  method (Subbiah and Asija, 1956). Twenty gram soil was taken in an 800 mL kjeldahl flask, to which 100 mL 0.32 %  $\text{KMnO}_4$  was added. Then 2 – 3 mL of paraffin liquid was added. Then, 100 mL of 2.5 %  $\text{NaOH}$  was added and the flask was immediately attached to the rubber stopper fitted in the alkali trap. The distillation is continued and the distillate was collected in 20 mL of 2 % boric acid containing mixed indicator in a 250 mL conical flask, until the volume of the solution became about 4 – 5 times. Then this trapped amount of ammonia was titrated against 0.1 N  $\text{H}_2\text{SO}_4$ . A blank was also run with each set of samples. The nitrogen was calculated using the following formula:

$$N \text{ (Kg N/ha soil)} = \frac{(S - B) \times 0.014 \times N}{W} \times 1,000,000 \times 2.24$$

- where, S = volume of titrant used with sample (mL)  
 B = volume of titrant used with blank (mL)  
 0.014 = milliequivalent weight of nitrogen  
 N = normality of  $\text{H}_2\text{SO}_4$   
 W = weight of soil sample (g)

### 3.6.2.2.7 Available Phosphorus Determination:

Mehlich-3 extractable phosphorus, was determined by the method as outlined by Murphy and Riley (1962). Six gram soil sample was taken in a 250 mL Erlenmeyer flask, to which 50 mL of extracting solution Mehlich-3 was added. The flask was shaken on a mechanical shaker for 30 minutes. The suspension was filtered through whatman no. 40 filter paper.

A 10 mL aliquot was taken in a 25 mL volumetric flask and pH was adjusted in the presence of para-nitrophenol indicator (2 drops). Then 4 mL of reagent B (appendix II) was added, mixed thoroughly and volume made up to the mark. The transmittance was measured at 882 nm on "spectronic-20" using red filter. The concentration of phosphorus in the coloured solution was worked out with the help

of a standard curve prepared for this fraction in 0 ppm to 0.4 ppm P range in the final solution.

#### **3.6.2.2.8 Available Potassium Determination:**

Mehlich-3 extractable potassium was determined by flame photometer. The readings were recorded for each of the soil extract and working standards of K after adjusting blank to zero. A standard curve was drawn by plotting the readings against K concentration. The concentration of K in the soil was worked out from the standard curve.

#### **3.6.2.2.9 Available Micronutrient Determination:**

##### **3.6.2.2.9.1 Mehlich-3 extractable Micronutrient Cations:**

Available micronutrient cations (Zn, Fe, Mn and Cu) were determined by using Mehlich-3 extraction. The extract was analyzed for Zn, Fe, Mn and Cu with a double beam atomic absorption spectrophotometer (GBC-902).

##### **3.6.2.2.9.2 Boron Determination:**

Boron in the Mehlich-3 extract was determined by azomethine-H method (John *et al*, 1975). One mL aliquot of blank, diluted standard or soil extract was transferred into a 10 or 15 mL polypropylene tube. To this, 2 mL buffer was added and mixed. Thereafter, 2 mL of azomethine – H reagent was added and mixed. The absorbance was read at 420 nm after 30 minutes. The absorbance of unknown samples were referred to that of standard curve prepared with 0 – 10 ppm B.

##### **3.6.2.2.10 Determination of Available Sulphur**

The available sulphur (0.15 %  $\text{CaCl}_2$  extractable) in the soil samples was determined by turbidimetric method (Chesnin and Yien, 1950). Five gram soil sample was taken in a conical flask, to which 25 mL of 0.25 % 0.15 %  $\text{CaCl}_2$  was added. The contents were shaken on a horizontal shaker for 30 minutes and filtered through a Whatman no. 40 filter paper. To a suitable amount of aliquot of the extract (5-10 mL) transferred into a 25 mL volumetric flask, 1 g of barium chloride crystals was added and it was shaken for one minute. Then, 1.0 mL of 0.25% gum acacia solution was added and the volume was made upto the mark. After a uniform

shaking for one minute the turbidity developed was measured on “spectronic-20” spectrophotometer at 420 nm. Sulphur concentration was determined from the standard curve prepared with each set of determination.

### 3.6.2.2.11 Determination of Calcium and Magnesium

Calcium and magnesium in the Mehlich-3 extract were determined by atomic absorption spectrophotometer (GBC – 902)

## 3.7 Nutrient uptake in grain and straw

Nutrient uptake in grain and straw of rice/wheat was calculated using the following formula:

$$\text{Nutrient uptake by grain/straw (g/ha)} = \text{nutrient content (mg/kg)} \times \text{yield (q/ha)} \times 0.1$$

### 3.7.1 Total nutrient uptake by crop

Total nutrient uptake by rotation was calculated as sum of total nutrient uptake of both the crops. The total nutrient uptake by individual crop was calculated with the help of following formula:

$$\text{Total uptake (g/ha or kg/ha)} = \text{Nutrient uptake to grain (g/ha or kg/ha)} + \text{nutrient uptake in straw (g/ha or kg/ha)}$$

## 3.7 Rice Quality Evaluation

### 3.7.1 Dehusking of Paddy Samples

Sample (200 g) of each variety was dehulled in a dehuller (Indosaw, Osaw industrial products, Ambala) after standardizing the clearance between two rubber rollers. The husk as well as brown rice obtained during dehulling were weighed. The percent yield of brown rice and hulls was calculated as under:

$$\% \text{ Brown rice} = \frac{\text{Weight of brown rice}}{\text{Weight of paddy}} \times 100$$

$$\% \text{ Hulls} = \frac{\text{Weight of hulls}}{\text{Weight of paddy}} \times 100$$

### 3.7.2 Polishing of rice

The brown rice obtained above was polished in a laboratory polisher (Indosaw, Osaw industrial products, Ambala). Initially, polishing time was standardized by milling 100 g brown rice of two varieties for 30 to 90 seconds. Polishing time of 80 seconds was found optimum and was used for subsequent milling studies. The polished rice was separated into broken rice and head rice by sieving and then manually. The weight of each portion was recorded. The yield of head rice and broken kernels obtained during milling were calculated as under:

$$\% \text{ Milling yield} = \frac{\text{Weight of polished rice}}{\text{Weight of paddy}} \times 100$$

$$\% \text{ Broken rice} = \frac{\text{Weight of broken rice}}{\text{Weight of brown rice}} \times 100$$

$$\% \text{ Yield of head rice (based on paddy)} = \frac{\text{Weight of head rice}}{\text{Weight of paddy}} \times 100$$

$$\% \text{ Yield of head rice (based on brown rice)} = \frac{\text{Weight of head rice}}{\text{Weight of brown rice}} \times 100$$

The samples of head rice obtained from each variety were stored separately in airtight containers at ambient conditions (22 – 30 °C, 60 – 85 percent RH).

### 3.7.3 Quality Tests

All the samples of paddy and rice were subjected to various quality parameters using following methods:

### **3.7.3.1 Physical Characteristics of Paddy and Rice**

#### **3.7.3.1.1 Grain Dimensions**

The length and breadth of ten randomly selected paddy and rice grains were measured with the help of a graph paper / screw guage and the average value was expressed in mm. The thickness was measured with the help of a screw gauge (Kaul, 1970).

#### **3.7.3.1.2 Length to Breadth (L:B) Ratio**

The average value of length was divided by the average value of breadth of grains/kernel (Kaul, 1970).

#### **3.7.3.2 Chemical characteristics of rice**

Polished rice kernels were ground into powder in a domestic grinder (Sumeet) to pass through 60-mesh sieve. Samples obtained were kept in airtight containers before chemical analysis. Following methods were employed for various determinations.

#### **3.7.3.3 Alkali Score**

Six polished whole rice kernels of each variety were placed evenly in petri dishes of 9 cm diameter containing 10 ml of 1.4 percent potassium hydroxide solution. The petri dishes were covered and left undisturbed at room temperature for 23 hr. The samples were then rated photographically for the degradation of kernel on a scale of 1 to 7 as described by Little et al (1958). Average score of the six kernels was taken as the alkali score of the sample.

#### **3.7.3.4 Organoleptic characteristics**

The rice samples cooked for their optimum cooking time were evaluated by a panel of 10 members for appearance, texture, taste, aroma and over all acceptability on a 5 point Hedonic scale (Appendix III). The evaluation was carried out in two phases. First comparative analysis of different varieties grown at different locations was carried out by taking one variety at three locations at one time. Secondly,

comparative evaluation of different varieties at one location was carried out using Basmati – 370 as control (IRRI, 1971).

### **3.8 Statistical analysis**

The experimental data were processed and statistically analyzed with the help of a computer. The data were analyzed using analysis of variance. The significance of the variance was determined by 'F test' at 5 percent level of significance as outlined by Cochran and Cox (1959). Critical difference values were calculated at 5 percent level of significance.

**RESULTS**  
**AND**  
**DISCUSSION**

## 4. *Results and Discussion*

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Field experiments were conducted at Research Station, Nagina, District Bijnor, U.P. during *Kharif* and *Rabi* seasons of 1998-2000 to ascertain the effect of soil application of chemical fertilizers, FYM and their conjoint use on the yields, nutrient content and uptake of aromatic rice – wheat sequence and quality parameters of aromatic rice. The results obtained in this investigation are presented and discussed in this chapter. This chapter has been dealt under the following sections for the sake of systematic presentation.

4.1 Effect of chemical fertilizers, FYM and their conjoint use on the yields of aromatic rice – wheat sequence.

4.2 Effect of chemical fertilizers, FYM and their conjoint use on the quality parameters of aromatic rice.

4.3 Effect of chemical fertilizers, FYM and their conjoint use on the nutrient content of aromatic rice – wheat sequence.

4.4 Effect of chemical fertilizers, FYM and their conjoint use on nutrient uptake of aromatic rice – wheat sequence.

4.5 Relationship between quality parameters and nutrient content of leaf and grain of aromatic rice.

4.6 Effect of chemical fertilizers, FYM and their conjoint use on the build up of extractable soil nutrients.

### **4.1 Effect of chemical fertilizers, FYM and their conjoint use on the yields of aromatic rice – wheat sequence**

Grain, straw and total dry matter (DM) yield of aromatic rice and subsequent wheat crop obtained under different treatments of chemical fertilizer, FYM or their combinations during 1998-99 and 1999-2000 are presented in figure 1a and table 2.

It is evident from Figure 2 that application of different levels (25, 50, 75 and 100%) of recommended fertilizer dose of NPK ( $RD_{NPK}$ ) significantly increased the grain, straw and total DM yields of aromatic rice over control in

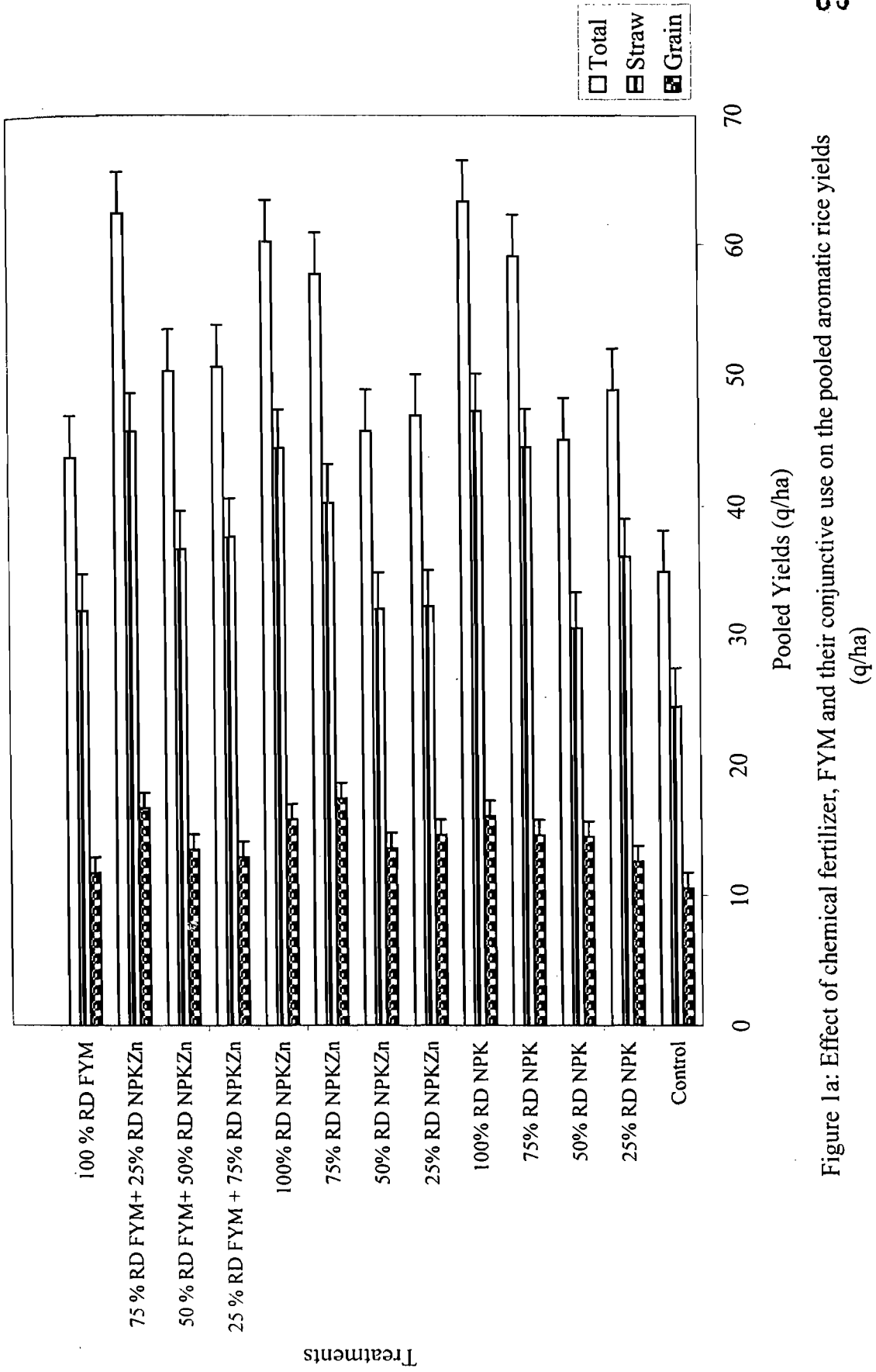


Figure 1a: Effect of chemical fertilizer, FYM and their conjunctive use on the pooled aromatic rice yields

**Table 2: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Yields (q/ha) of Aromatic Rice – Wheat in Two Successive Years**

Treatment	Aromatic Rice (Taraori) Yield (q/ha)					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	11.06	25.69	36.75	10.06	23.19	33.25
25% RD <sub>NPK</sub>	14.05	27.12	41.16	11.21	45.24	56.45
50% RD <sub>NPK</sub>	15.44	24.76	40.20	13.60	36.17	49.77
75% RD <sub>NPK</sub>	16.31	34.36	50.67	12.96	54.53	67.49
100% RD <sub>NPK</sub>	14.71	37.32	52.03	17.44	57.08	74.52
25% RD <sub>NPKZn</sub>	13.55	32.68	46.22	15.72	31.77	47.49
50% RD <sub>NPKZn</sub>	12.87	30.37	43.24	14.36	33.69	48.05
75% RD <sub>NPKZn</sub>	18.19	34.75	52.94	16.71	45.75	62.46
100% RD <sub>NPKZn</sub>	17.30	33.67	50.96	14.36	55.10	69.46
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	13.55	32.72	46.27	12.30	42.66	54.96
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	14.25	33.07	47.32	12.77	40.44	53.21
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	17.52	32.88	50.40	15.91	58.44	74.35
100 % RD <sub>FYM</sub>	12.95	28.64	41.59	10.53	35.25	45.78
CD (p=0.05)	1.59	2.72	3.21	1.82	5.22	5.51
	Wheat Yield (q/ha)					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	12.36	20.67	33.03	6.72	18.19	24.91
25% RD <sub>NPK</sub>	14.42	24.17	38.60	12.13	22.34	34.47
50% RD <sub>NPK</sub>	14.10	25.81	39.91	11.27	24.22	35.49
75% RD <sub>NPK</sub>	15.43	27.07	42.50	15.00	45.23	60.24
100% RD <sub>NPK</sub>	18.08	32.65	50.74	16.96	47.91	64.86
25% RD <sub>NPKZn</sub>	12.98	22.88	35.86	9.46	22.76	32.22
50% RD <sub>NPKZn</sub>	16.34	28.13	44.47	10.29	31.45	41.74
75% RD <sub>NPKZn</sub>	18.18	29.43	47.60	16.88	44.61	61.49
100% RD <sub>NPKZn</sub>	18.80	33.31	52.11	18.28	46.49	64.77
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	13.14	24.98	38.12	9.96	24.45	34.41
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	16.16	26.79	42.95	10.43	26.80	37.22
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	16.28	26.57	42.86	16.02	36.64	52.66
100 % RD <sub>FYM</sub>	12.65	22.75	35.40	7.89	17.11	25.00
CD (p=0.05)	1.62	3.85	4.54	2.02	3.81	4.78

both the years, except for the increase noted in grain at 25% RD<sub>NPK</sub> during 1999-2000, in straw at 25 and 50% RD<sub>NPK</sub> during 1998-99. The highest response of RD<sub>NPK</sub> in grain yield over control was recorded at 75% RD<sub>NPK</sub> (47.5%) during 1998-99 and at 100% RD<sub>NPK</sub> (73.4%) during 1999-2000. In both the years, the highest response of RD<sub>NPK</sub> in straw and total DM yields over control was recorded at 100% RD<sub>NPK</sub> level. Statistical analysis of the yearwise pooled data revealed that among different levels of RD<sub>NPK</sub>, the highest grain, straw and total DM yields of aromatic rice was recorded at 100% RD<sub>NPK</sub> level, the magnitude of increase over control was 52.3% for grain, 93.1% for straw and 80.8% for total DM yield. Increase in yield due to increased fertilizer levels may possibly be associated with increased fertilizer utilization efficiency, which caused a corresponding increase in respective yield components. Rafiq *et al* (1998) found similar biological response of *Basmati – 385* to four fertilizer levels on a sandy clay loam soil. Amir *et al* (1984) also observed highest grain yield of *Basmati – 370* with the application of 100 kg N and 50 kg P per hectare.

Application of different levels (25, 50, 75 and 100%) of recommended fertilizer dose of NPKZn (RD<sub>NPKZn</sub>) also significantly increased grain, straw and total DM yields of aromatic rice over control. The highest response of RD<sub>NPKZn</sub> in grain yield over control was recorded at 75% RD<sub>NPKZn</sub>; 64.5% during 1998-99, 66.1% during 1999-2000 and 65.2% for yearwise pooled data. The highest response of RD<sub>NPKZn</sub> in straw and total DM yield over control was recorded at 75% RD<sub>NPKZn</sub> during 1998-99 and at 100% RD<sub>NPKZn</sub> during 1999-2000 and also for yearwise pooled data. Several other workers (Venkataswarlu, 1969; IRRI, 1970; Bhardwaj and Prasad, 1981; Yadav, 1985; Saravanan and Ramnathan, 1998; Karim *et al*, 1992; Sakal, *et al*, 1993) have also observed similar response in rice yields with application of zinc along with NPK fertilizers. Malik *et al* (1978) observed that zinc application in conjunction with NP or NPK to basmati rice gave higher yields than NP or NPK alone.

Application of recommended fertilizer dose of NPK through FYM (RD<sub>FYM</sub>) alone at a rate equivalent to that of 100% RD<sub>NPK</sub> significantly increased aromatic rice grain yield by 17.1%, straw yield by 11.5% and total DM yield by 13.2% over control during 1998-99. However, application of FYM alone failed to

increase grain yield significantly over control in the second year i.e. 1999-2000 and also for yearwise pooled grain yield over control. Application of FYM alone significantly increased straw yield by 52.0% and total DM yield by 37.7% over control during 1999-2000. The yearwise pooled data revealed that FYM alone was effective to increase straw yield by 30.7% and total DM yield by 24.8% over control. A favourable effect of farmyard manure application on grain yield of rice has been recorded earlier by Maskina and Meelu (1984); Sharma *et al* (1985); Ghosh and Sharma (1999).

Different combinations of chemical fertilizers (NPKZn) and FYM together also significantly increased the grain, straw and total DM yields over control in both the years. Among different combinations, the highest grain yield was recorded in the treatment receiving 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>; the magnitude of increase in grain yield over control was 58.4, 58.2 and 58.3 percent during 1998-99, 1999-2000 and for yearwise pooled data. The highest straw and total DM yields during 1999-2000 and also for yearwise pooled data were also recorded under this treatment. The highest straw yield during 1998-99 was noted under treatment receiving 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub>. Kumar *et al* (1999) also observed that application of 20 kg ZnSO<sub>4</sub> with press mud or farmyard manure gave similar grain and straw yields of rice as with 40 kg ZnSO<sub>4</sub>/ha alone.

Among all the treatments, the highest grain yield (18.2 q/ha) of aromatic rice was recorded at 75% RD<sub>NPKZn</sub> level during 1998-99; the yield obtained was significantly higher over 75% RD<sub>NPK</sub>, but *at par* with 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>. In the second year, the highest grain yield (17.44 q/ha) was recorded at 100% RD<sub>NPK</sub> which was *at par* with yields obtained at 75% RD<sub>NPKZn</sub> or 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>. Tahir Hussain (1991) also observed that the yield increased with the application of 60 kg N, 40 kg P<sub>2</sub>O<sub>5</sub>, 30 kg K<sub>2</sub>O and 5 t FYM/ha and also noted that applying these fertilizers at double rates gave no further yield increase. Mutnal *et al* (1996) reported highest mean grain (5.31 ton/ha) of rice (cv. Rasi) and also highest net return from the application of 10 ton FYM, 100:100:120 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O and 20 kg ZnSO<sub>4</sub>/ha.

Application of different levels (25, 50, 75 and 100%) of RD<sub>NPK</sub> significantly increased grain, straw, and total DM yields of wheat over control in

both the years and also for yearwise pooled data except for the increase in straw yield of 25% RD<sub>NPK</sub> during 1998-99 (figure 1b, table 2). The highest response of RD<sub>NPK</sub> level in grain, straw and total dry matter yields over control was noted at 100% RD<sub>NPK</sub> level; the magnitude of increase in grain, straw and total DM yields over control was 46.3, 58.0 and 53.6 percent during 1998-99; 152.4, 163.4 and 160.4 percent during 1999-2000 and 83.7, 107.3 and 99.5 percent for yearwise pooled data, respectively.

Application of different levels (25, 50, 75 and 100%) of RD<sub>NPKZn</sub> also significantly increased the grain, straw and total DM yield of wheat over control in both the years, except for the increase noted at 25% RD<sub>NPKZn</sub> level during the first year i.e. 1998-99. The highest response of RD<sub>NPKZn</sub> in grain, straw and total DM yields over control was noticed at 100% RD<sub>NPKZn</sub>; the magnitude of increase in grain yield was 52.1, 172.0 and 94.3 percent during 1998-99, 1999-2000 and for yearwise pooled data, respectively. Mann *et al* (1978) also reported increase in wheat grain yield due to zinc application. Reddy *et al* (1994) observed that graded dose of phosphorus and zinc increased grain and straw yield of wheat.

Application of FYM alone to supply 100% RD<sub>NPK</sub> failed to increase grain, straw and total DM yields of wheat over control during both the years and also for yearwise pooled data. Math and Trivedi (1998) also noted increase in wheat straw yields due to farmyard manure application.

Different combinations of chemical fertilizers (RD<sub>NPKZn</sub>) and FYM together also significantly increased grain, straw and total DM yields of wheat over control, except for the increase in grain yield recorded at 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub>. Among different combinations, the highest grain yield was recorded in the treatment receiving 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>; the magnitude of increase in grain yield over control was 31.7, 138.4 and 69.3 percent during 1998-99 and 1999-2000 and for yearwise pooled data. The highest straw and total DM yields during 1998-99 was recorded in treatment receiving 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub>. However, the highest straw and total DM yields during 1999-2000 and also for yearwise pooled data was recorded under 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> treatment. An increase in grain and straw yields of wheat due to residual effect of zinc and farmyard manure application has been reported by Gupta *et al* (1987); Maskina *et*

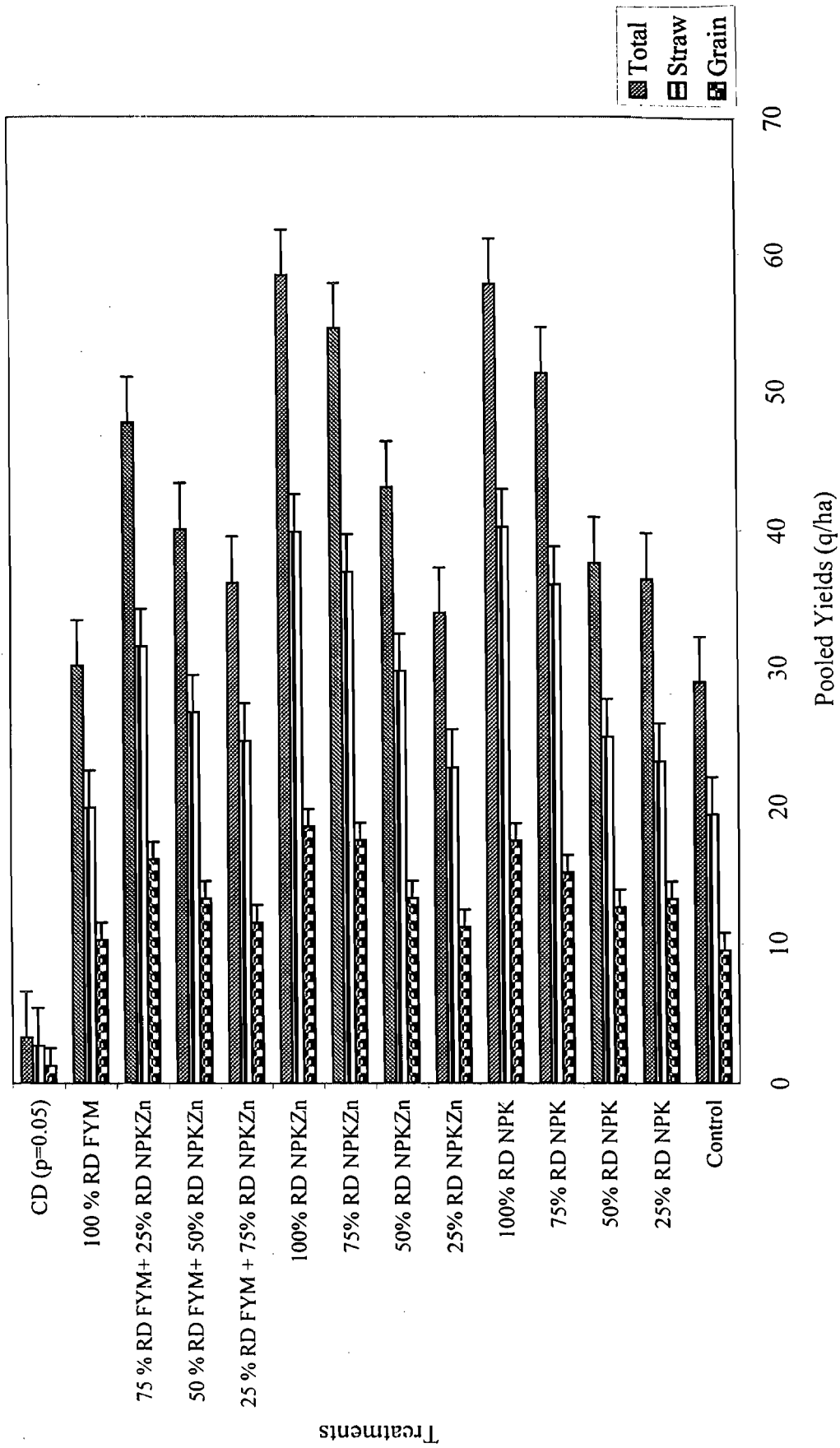


Figure 1b: Effect of chemical fertilizer, FYM and their conjunctive use on the pooled wheat yields (q/ha)

*al* (1984); Rajput *et al* (1997). Das *et al* (1996) have reported highest grain yield of wheat with conjoint use of farmyard manure and zinc.

As far as grain yield of wheat is concerned, among all treatments, the highest grain yield of wheat (18.80 q/ha during 1998-99, 18.28 q/ha during 1999-2000 and 18.54 q/ha receiving for yearwise pooled data) was noted in the treatment receiving 100% RD<sub>NPKZn</sub>; the yield under this treatment was *at par* with that of 100% RD<sub>NPK</sub> in both the years, but it was significantly higher over 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>. This signified that subsequent wheat crop was not much benefited by the residual effect of zinc applied to main rice crop.

On the basis of yearwise pooled grain yield data, the total productivity of aromatic rice – wheat rotation was highest (35.98 q grain/ha) under 75% RD<sub>NPKZn</sub> treatment for rice and 100% RD<sub>NPKZn</sub> treatment for wheat.

## **4.2 Effect of chemical fertilizers, FYM and their conjoint use on the quality parameters of aromatic rice**

### **4.2.1 Aroma**

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on aroma characteristics of aromatic rice are shown in table 3. It is evident from the data that application of chemical fertilizers did not adversely affect aroma score of rice in comparison to control. In both the years, the best aroma score (5.0) was recorded under 100% FYM application followed by 75% RD<sub>NPKZn</sub> (4.5 in 1998-99 and 4.63 in 1999-2000) and the score under both these treatments was significantly higher in comparison to control. Other treatments having combinations of 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> and 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> resulted significantly higher score in comparison to control during second year only and also for the pooled data. Suwanarit *et al* (1996) reported that aroma of *Khaw Dauk Mali-105* milled rice was inversely related to percentage N and application of chemical fertilizers, particularly urea, reduced the quality of aromatic rice. Dutta *et al* (1999) observed that aroma intensity was higher with N application at 25 kg N/ha and application of 50 kg N/ha gave no additional benefits regarding aroma synthesis over 25 kg N/ha.

**Table 3: Effect Of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Aroma content of Aromatic Rice**

Treatment	Aroma content		
	1998 – 99	1999 – 2000	Pooled
Control	3.25	3.25	3.25
25% RD <sub>NPK</sub>	3.50	4.00	3.75
50% RD <sub>NPK</sub>	4.00	4.13	4.13
75% RD <sub>NPK</sub>	3.25	3.13	3.13
100% RD <sub>NPK</sub>	3.25	2.88	2.88
25% RD <sub>NPKZn</sub>	3.50	3.50	3.50
50% RD <sub>NPKZn</sub>	2.75	2.75	2.75
75% RD <sub>NPKZn</sub>	4.50	4.63	4.63
100% RD <sub>NPKZn</sub>	3.50	3.50	3.50
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	3.50	4.50	4.00
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	3.75	4.25	4.00
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	3.25	3.25	3.25
100 % RD <sub>FYM</sub>	5.00	5.00	5.00
CD (p=0.05)	0.94	0.93	0.65

**Table 4: Effect Of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Alkali Score of Aromatic Rice**

Treatment	Alkali Score		
	1998 – 99	1999 – 2000	Pooled
Control	2.91	3.01	2.96
25% RD <sub>NPK</sub>	3.17	3.84	3.51
50% RD <sub>NPK</sub>	3.83	4.66	4.25
75% RD <sub>NPK</sub>	2.84	2.76	2.80
100% RD <sub>NPK</sub>	3.50	3.68	3.59
25% RD <sub>NPKZn</sub>	3.99	4.41	4.20
50% RD <sub>NPKZn</sub>	2.76	2.93	2.84
75% RD <sub>NPKZn</sub>	3.25	3.33	3.29
100% RD <sub>NPKZn</sub>	4.00	4.34	4.17
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	4.00	4.08	4.04
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	3.74	4.16	3.95
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	2.91	3.08	3.00
100 % RD <sub>FYM</sub>	3.74	3.83	3.79
CD (p=0.05)	0.73	0.89	0.57

### 4.2.2 Alkali Score

The data on grain alkali score, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 4.

It is apparent from the data that the application of 50%  $RD_{NPK}$ , 25%  $RD_{NPKZn}$  and 100%  $RD_{NPKZn}$  significantly increased the alkali score over control, during first year, second year and for pooled data. The treatment with 100%  $RD_{FYM}$  significantly increased the alkali score over control during first year and also for pooled data. The combined application of NPKZn and FYM as 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  and 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  also significantly increased the alkali score over control during both the years and also for pooled data. Rao *et al* (1993) reported the application of N did not adversely affect different quality traits such as alkali value. Pandey *et al* (1999) reported that alkali value was higher with the application of 10 tonnes of farmyard manure or 80 or 120 kg N/ha as compared to other treatments.

### 4.2.3 Grain Length

The data on grain length, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 5.

It is evident from the data that the application of 50%  $RD_{NPK}$  significantly increased the grain length over control, during both the years and also for pooled data. However, the application of 100%  $RD_{NPKZn}$  significantly decreased the grain length over control during first year and for pooled data. The application of 100%  $RD_{FYM}$  significantly increased grain length over control during both the years and for the pooled data. Among all the treatments, the highest grain length (7.84 mm, average of two years) was recorded under application of FYM alone. The combined application of NPKZn and FYM at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  significantly decreased the grain length over control during both the years and also for pooled data. On the other hand, the application of 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased the grain length over control during first year only. Khalid and Chaudhry (1999) also reported that nitrogen, when used @ 80 kg ha<sup>-1</sup> resulted in longer kernels than rest of the nitrogen. Pandey *et al* (1999) reported that application of N fertilizer increased

**Table 5: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Grain Length of Aromatic Rice**

Treatment	Grain Length		
	1998 – 99	1999 – 2000	Pooled
Control	7.40	7.50	7.45
25% RD <sub>NPK</sub>	7.50	7.65	7.57
50% RD <sub>NPK</sub>	7.38	7.45	7.42
75% RD <sub>NPK</sub>	7.30	7.43	7.36
100% RD <sub>NPK</sub>	7.61	7.50	7.55
25% RD <sub>NPKZn</sub>	7.37	7.38	7.38
50% RD <sub>NPKZn</sub>	7.73	7.75	7.74
75% RD <sub>NPKZn</sub>	7.44	7.57	7.51
100% RD <sub>NPKZn</sub>	7.08	7.28	7.18
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	7.05	7.13	7.09
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	7.74	7.36	7.55
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	7.65	7.56	7.60
100 % RD <sub>FYM</sub>	7.85	7.83	7.84
CD (p=0.05)	0.22	0.23	0.16

**Table 6: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Grain Breadth of Aromatic Rice**

Treatment	Grain Breadth		
	1998 – 99	1999 – 2000	Pooled
Control	1.80	1.78	1.79
25% RD <sub>NPK</sub>	1.80	1.80	1.80
50% RD <sub>NPK</sub>	1.78	1.79	1.78
75% RD <sub>NPK</sub>	1.73	1.80	1.76
100% RD <sub>NPK</sub>	1.73	1.80	1.76
25% RD <sub>NPKZn</sub>	1.78	1.73	1.75
50% RD <sub>NPKZn</sub>	1.63	1.65	1.64
75% RD <sub>NPKZn</sub>	1.73	1.72	1.73
100% RD <sub>NPKZn</sub>	1.87	1.70	1.79
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.80	1.75	1.77
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.73	1.70	1.71
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	1.79	1.78	1.78
100 % RD <sub>FYM</sub>	1.63	1.64	1.63
CD (p=0.05)	0.067	0.063	0.050

kernel length. Dahiphale *et al* (2000) observed maximum kernel size in the highest yielding treatment, 120:60:30 kg NPK plus 10 t FYM/ha.

#### 4.2.4 Grain Breadth

The data on grain breadth, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 6.

It is evident from the data that the application of 75% and 100%  $RD_{NPK}$  significantly decreased the grain breadth over control, during first year only. Application of 50% and 75%  $RD_{NPKZn}$  significantly decreased grain breadth over control during both the years and also for the pooled data. However, the application of 100%  $RD_{NPKZn}$  significantly increased the grain breadth over control during first year, but significantly decreased it during the second year. Application of FYM alone (100%  $RD_{FYM}$ ) significantly decreased grain breadth of rice in comparison to control in both the years and also for pooled data. The grain breadth recorded under this treatment was the lowest (1.63mm, pooled average) among all treatments. The combined application of FYM and NPKZn as 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  significantly decreased grain breadth during both the years and also for pooled data.

#### 4.2.5 L:B Ratio

The data on grain length:breadth (L:B) ratio, a measure of fineness of aromatic rice, as affected by soil application of chemical fertilizers, FYM and their combinations are presented in table 7.

It is apparent from the data that the L:B ratio decreased significantly under the treatments with 100%  $RD_{NPKZn}$  and 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  in comparison to control, during 1998-99, 1999-2000 and also for yearwise pooled data. Kumar *et al* (1996) also noted that increase in N rate decreased the L:B ratio of aromatic rice. In general, among all treatments, the highest L:B ratio was recorded under 100%  $RD_{FYM}$  treatment. Application of FYM alone (100%  $RD_{FYM}$ ) significantly increased the L:B ratio over control in the first year and also for yearwise pooled data; the increase recorded in the second year was statistically not significant. In the first year (1998-99), the L:B ratio increased

**Table 7: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Length:Breadth Ratio of Aromatic Rice**

Treatment	Length:Breadth Ratio		
	1998 - 99	1999 - 2000	Pooled
Control	4.60	4.64	4.62
25% RD <sub>NPK</sub>	4.65	4.72	4.69
50% RD <sub>NPK</sub>	4.58	4.62	4.60
75% RD <sub>NPK</sub>	4.51	4.62	4.56
100% RD <sub>NPK</sub>	4.67	4.65	4.66
25% RD <sub>NPKZn</sub>	4.58	4.55	4.56
50% RD <sub>NPKZn</sub>	4.68	4.70	4.69
75% RD <sub>NPKZn</sub>	4.59	4.65	4.62
100% RD <sub>NPKZn</sub>	4.48	4.49	4.48
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	4.42	4.44	4.43
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	4.74	4.53	4.63
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	4.72	4.67	4.69
100 % RD <sub>FYM</sub>	4.75	4.73	4.74
CD (p=0.05)	0.117	0.127	0.086

**Table 8: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the % Broken Kernels of Aromatic Rice**

Treatment	% Broken Kernels		
	1998 - 99	1999 - 2000	Pooled
Control	30.96	31.83	31.39
25% RD <sub>NPK</sub>	30.99	28.41	29.70
50% RD <sub>NPK</sub>	32.35	30.58	31.46
75% RD <sub>NPK</sub>	29.57	23.65	26.61
100% RD <sub>NPK</sub>	30.83	29.22	30.02
25% RD <sub>NPKZn</sub>	28.28	26.43	27.35
50% RD <sub>NPKZn</sub>	31.10	31.73	31.42
75% RD <sub>NPKZn</sub>	35.08	30.81	32.94
100% RD <sub>NPKZn</sub>	31.53	28.13	29.83
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	30.43	33.09	31.76
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	28.11	29.85	28.98
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	30.32	28.72	29.52
100 % RD <sub>FYM</sub>	31.86	30.69	31.27
CD (p=0.05)	2.86	4.61	2.71

significantly over the control under 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>. In pooled data, 100% RD<sub>FYM</sub> significantly affected the L:B ratio or fineness of the aromatic rice. Kumar *et al* (1996) reported that with increase in N rate, the breadth of kernel increased marginally which caused the L/B ratio to decrease slightly. Khalid and Chaudhry (1999) observed the maximum length-width ratio in control followed by nitrogen levels 80 and 120 kg ha<sup>-1</sup>. However, Pandey *et al* (1999) reported that application of N fertilizer increased length:breadth ratio.

#### 4.2.6 Percent Broken Kernels

The data on percent broken kernels, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 8.

The data on the percent broken kernels in the table show that the percent broken kernels under 75% RD<sub>NPKZn</sub> was significantly higher over control but no significant effect was recorded for rest of the treatments in the first year. Application of 75% RD<sub>NPK</sub> and 25% RD<sub>NPKZn</sub> significantly decreased the percent broken kernels over control in the second year and also for pooled data. Application of 75% RD<sub>NPKZn</sub>, however, significantly increased percent broken kernels over control during the first year only. Application of FYM alone (100% RD<sub>FYM</sub>) or combinations of chemical fertilizers and FYM failed to influence the percent broken kernels of aromatic rice. Andrade *et al* (1995) reported that N tended to increase the percentage of whole and unbroken grains.

#### 4.2.7 Percent Milling Yield

The data on percent milling yield, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 9.

The data on the percent milling yield reveal no effect of any treatment on the percent milling yield of aromatic rice in the first year. However, in the second year, the percent milling yield was significantly increased over control with the application of 25 and 75% RD<sub>NPK</sub>; the maximum percent milling yield (49.04%) was recorded under the latter treatment. At 50% RD<sub>NPK</sub>, the percent milling yield decreased significantly in comparison to control. Application of 25 and 100%

**Table 9: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the % Milling Yield of Aromatic Rice**

Treatment	% Milling Yield		
	1998 – 99	1999 – 2000	Pooled
Control	40.48	41.59	41.04
25% RD <sub>NPK</sub>	41.47	45.85	43.66
50% RD <sub>NPK</sub>	43.04	36.43	39.73
75% RD <sub>NPK</sub>	44.28	49.07	46.68
100% RD <sub>NPK</sub>	41.78	45.30	43.54
25% RD <sub>NPKZn</sub>	41.70	46.72	44.21
50% RD <sub>NPKZn</sub>	40.91	40.92	40.91
75% RD <sub>NPKZn</sub>	42.12	40.57	41.34
100% RD <sub>NPKZn</sub>	40.05	46.34	43.19
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	40.19	42.05	41.12
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	45.70	44.41	45.06
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	42.67	41.30	41.98
100 % RD <sub>FYM</sub>	41.13	44.40	42.76
CD (p=0.05)	NS	3.85	2.78

**Table 10: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the % Hull of Aromatic Rice**

Treatment	% Hull		
	1998 – 99	1999 – 2000	Pooled
Control	30.72	27.66	29.19
25% RD <sub>NPK</sub>	26.91	25.86	26.39
50% RD <sub>NPK</sub>	27.92	25.61	26.76
75% RD <sub>NPK</sub>	26.40	27.14	26.77
100% RD <sub>NPK</sub>	28.18	26.12	27.15
25% RD <sub>NPKZn</sub>	30.72	26.12	28.42
50% RD <sub>NPKZn</sub>	25.89	25.09	25.49
75% RD <sub>NPKZn</sub>	25.89	25.35	25.62
100% RD <sub>NPKZn</sub>	29.96	25.61	27.78
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	27.92	26.12	27.02
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	27.42	24.07	25.74
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	26.91	26.63	26.77
100 % RD <sub>FYM</sub>	26.91	26.38	26.64
CD (p=0.05)	2.29	1.65	1.41

$RD_{NPKZn}$  significantly increased the percent milling yield over control during second year. Application of FYM alone had no significant affect on the percent milling yield of rice. Combined application of chemical fertilizers and FYM also did not significantly influence the percent milling yield of aromatic rice. However, the yearwise pooled data showed that the combined application at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  level significantly increased the percent milling yield over control. Andrade *et al* (1995) reported that N tended to increase the percentage of whole, unbroken grains and 1000-grain weight.

#### 4.2.8 Percent Hull Content

The data on percent hull content, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 10.

As is evident from the data that percent hull content in the aromatic rice decreased significantly with the application of various treatments in both the years. Application of all levels of  $RD_{NPK}$  decreased the percent hull content over control in both the years and also for pooled data. However, in the second year, the percent hull content at 100%  $RD_{NPK}$  did not decrease significantly in comparison to control, although, the pooled was significant. Application of 50, 75 and 100%  $RD_{NPKZn}$  significantly decreased the percent hull content over control in both the years except for the decrease noted under 100%  $RD_{NPKZn}$  in the first year. Application of FYM alone (100%  $RD_{FYM}$ ) significantly decreased the percent hull content of rice in comparison to control during the first year and also pooled data. All combinations of NPKZn and FYM significantly decreased percent hull content of aromatic rice during the first year and for pooled data, however, the decrease noted at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  was only significant in the second year. Paliwal *et al* (1992) also found that rice/husk ratio increased significantly with increasing levels of nitrogen and sulphur applied singly and in combination.

#### 4.2.9 Percent Head Rice Yield Based On Brown Rice

The data on percent head rice yield based on brown rice, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 11.

The data depicted almost no effect of the application of  $RD_{NPK}$  levels on the percent head rice yield based on brown rice. Application of 50 and 75%  $RD_{NPKZn}$  significantly decreased percent head rice yield based on brown rice over control in both the years and yearwise pooled data, however, the decrease recorded under 50%  $RD_{NPKZn}$  treatment during first year was statistically non significant. Application of FYM alone or in combination with chemical fertilizers failed to influence this parameter significantly. Sajwan *et al* (1990) also observed a significant improvement in head rice yield from N applications up to 90 kg N/ha during the wet season and up to 120 kg N/ha during the dry season.

#### 4.2.10 Percent Head Rice Yield Based On Paddy

The data on percent head rice yield based on paddy, as affected by the soil application of chemical fertilizers, FYM and their combinations are presented in table 12.

It is evident from the data that the increasing levels of  $RD_{NPK}$  significantly increased percent head rice yield based on paddy over control during both the years and also for pooled data, however, no significant increase was noted under 50%  $RD_{NPK}$  level.

Application of 50 and 75%  $RD_{NPKZn}$  significantly increased percent head rice yield based on paddy over control in the first year, while in the second year and also for yearwise pooled data, significant increase was recorded under 100%  $RD_{NPKZn}$  treatment. Sajwan *et al* (1990) also reported improvement in head rice yield with N application up to 90 kg/ha during the wet season and up to 120 kg/ha during the dry season.

Application of FYM alone (100%  $RD_{FYM}$ ) brought significant increase in the percent head rice yield based on paddy over control in both the years and also for yearwise pooled data.

**Table 11: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the % Head Rice Yield of Aromatic Rice based on Brown Rice**

Treatment	% Head Rice Yield of Aromatic Rice based on Brown Rice		
	1998 – 99	1999 – 2000	Pooled
Control	91.08	91.44	91.26
25% RD <sub>NPK</sub>	91.40	92.69	92.04
50% RD <sub>NPK</sub>	90.97	92.03	91.50
75% RD <sub>NPK</sub>	91.08	93.68	92.38
100% RD <sub>NPK</sub>	92.14	92.64	92.39
25% RD <sub>NPKZn</sub>	89.31	91.29	90.30
50% RD <sub>NPKZn</sub>	89.72	86.57	88.15
75% RD <sub>NPKZn</sub>	86.67	86.95	86.81
100% RD <sub>NPKZn</sub>	91.94	92.71	92.33
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	89.05	93.31	91.18
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	91.97	91.57	91.77
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	90.66	89.81	90.24
100 % RD <sub>FYM</sub>	92.05	93.30	92.67
CD (p=0.05)	3.01	3.54	2.32

**Table 12: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the % Head Rice Yield of Aromatic Rice based on Paddy**

Treatment	% Head Rice Yield of Aromatic Rice based on Paddy		
	1998 – 99	1999 – 2000	Pooled
Control	63.06	68.02	65.54
25% RD <sub>NPK</sub>	66.59	70.63	68.61
50% RD <sub>NPK</sub>	63.06	66.20	64.63
75% RD <sub>NPK</sub>	66.84	70.11	68.48
100% RD <sub>NPK</sub>	66.09	70.37	68.23
25% RD <sub>NPKZn</sub>	61.80	69.33	65.56
50% RD <sub>NPKZn</sub>	66.59	66.46	66.53
75% RD <sub>NPKZn</sub>	66.59	66.72	66.66
100% RD <sub>NPKZn</sub>	63.06	70.89	66.98
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	64.07	70.89	67.48
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	66.59	71.41	69.00
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	66.09	67.24	66.66
100 % RD <sub>FYM</sub>	65.58	70.63	68.11
CD (p=0.05)	1.41	2.07	1.25

The combination of 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> significantly increased percent head rice yield based on paddy in both the years and also for pooled data. The increase noted over control under 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> was significant in second and first year, respectively. The pooled analysis of data revealed significant increase in percent head rice yield based on paddy under 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> and 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> treatments only. Zhang *et al* (1999) also noted that head rice yield was higher with N than with no N. Pandey *et al* (1999) reported that head rice recovery and alkali value were higher with the application of 10 tonnes of farmyard manure or 80 or 120 kg N/ha.

### **4.3 Effect of chemical fertilizers, FYM and their conjoint use on the nutrient content of aromatic rice and wheat**

The status of nutrient contents in different plant parts was influenced by several factors. One of the important factors was the supply of nutrients from fertilizers sources and native soil, which contributed towards the concentration of nutrients in plant tissues. The decrease in the nutrient contents was mainly due to the dilution effect caused by the enhanced dry matter production and thereby, distributing the nutrient in various plant parts, as the total uptake by crop increased. However, the decrease in the nutrient contents, where dry matter and total uptake also decreased, might have resulted from some imbalance or interference at metabolic sites. The other important factor playing a key role in the concentration of nutrient contents was the interaction among the nutrients. There were different types of synergistic, antagonistic, positive and negative interaction effects of nutrients on each other. The description, hereunder, is about the contents of nutrients in different plant parts as influenced by the application of chemical fertilizers, FYM and their conjunctive use.

#### **4.3.1 Nitrogen Content**

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on nitrogen contents of index leaf, grain and straw of aromatic rice and subsequent wheat crops are presented in table 13.

**Table 13: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Nitrogen Content (%) of Aromatic Rice – Wheat**

Treatment	Nitrogen Content (%) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	1.431	0.866	1.628	1.405	0.701	2.047
25% RD <sub>NPK</sub>	1.425	0.914	2.090	1.366	0.582	1.929
50% RD <sub>NPK</sub>	1.850	0.749	2.148	1.371	0.727	1.998
75% RD <sub>NPK</sub>	1.990	0.821	2.570	1.431	0.655	2.131
100% RD <sub>NPK</sub>	1.630	0.849	2.730	1.510	0.672	1.932
25% RD <sub>NPKZn</sub>	2.142	1.000	2.650	1.437	0.849	2.023
50% RD <sub>NPKZn</sub>	1.736	0.900	2.468	1.385	0.768	2.708
75% RD <sub>NPKZn</sub>	1.838	0.768	1.865	1.428	0.799	2.829
100% RD <sub>NPKZn</sub>	1.620	0.813	1.885	1.418	0.648	2.063
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.998	0.804	2.500	1.794	1.030	2.300
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.978	0.884	2.539	1.579	0.654	1.957
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	2.345	0.960	1.745	1.451	0.593	2.086
100 % RD <sub>FYM</sub>	2.233	0.875	2.118	1.369	0.549	1.943
CD (p=0.05)	0.66	0.141	0.311	0.057	0.053	0.099
	Nitrogen Content (%) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	1.753	0.649	2.340	0.985	0.553	2.178
25% RD <sub>NPK</sub>	1.748	0.703	2.904	1.040	0.543	2.836
50% RD <sub>NPK</sub>	1.663	0.656	5.296	1.586	0.418	2.664
75% RD <sub>NPK</sub>	1.695	0.680	2.984	1.093	0.760	2.694
100% RD <sub>NPK</sub>	1.535	0.700	2.880	2.069	0.365	3.458
25% RD <sub>NPKZn</sub>	1.510	0.650	2.580	3.114	0.723	3.047
50% RD <sub>NPKZn</sub>	1.693	0.677	3.580	1.832	0.718	3.372
75% RD <sub>NPKZn</sub>	1.685	0.697	2.268	1.269	0.262	5.017
100% RD <sub>NPKZn</sub>	1.653	0.706	2.576	3.033	0.197	3.184
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.793	0.741	2.786	2.651	0.241	2.911
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.748	0.760	2.270	2.927	0.313	2.996
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	1.842	0.850	3.006	2.550	0.326	2.708
100 % RD <sub>FYM</sub>	1.457	0.650	3.196	3.043	0.649	1.292
CD (p=0.05)	NS	0.097	0.486	0.111	0.127	0.109

It is evident from the data that the application of all levels of  $RD_{NPK}$  significantly increased N content in index leaf of rice over control in the first year i.e. 1998-99, but during the second year i.e. 1999-2000, no such effect was evident; rather N content in index leaf at 25 and 100% levels of  $RD_{NPK}$  was significantly lower than control. Application of 100%  $RD_{NPK}$  also significantly increased N content in grain over control during 1999-2000. These results are in conformity with those observed by Marr *et al* (1999) and Gangiah and Prasad (1999). Such outcome is obvious, since increasing supply of plant nutrients would apparently result in the increase in the nitrogen content of plant parts (Mengel and Kirkby, 1996).

Application of 25%  $RD_{NPKZn}$  significantly increased N content in index leaf and grain during 1998-99 and straw during 1999-2000 over control, while 50%  $RD_{NPKZn}$  was effective in significantly increasing N content in index leaf in both the years and in straw during 1999-2000 over control. Use of 75%  $RD_{NPKZn}$  also significantly increased N content in index leaf and straw during 1999-2000 over control. This might probably be due to a significant role of zinc in the N metabolism of plants.

Application of FYM equivalent to 100% recommended level of NPK significantly increased N content in index leaf and rice grain during first year only, but it decreased index leaf N during second year in comparison to control. Brar *et al* (1995) and Sadana *et al* (1995) also observed similar results. A combination of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  significantly increased index leaf N in both the years and grain and straw N during 1999-2000 in comparison to control. Application of 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  significantly increased N content in index leaf during 1998-99 and in grain during 1999-2000 over control. Application of 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased grain N over control during 1998-99 only. The mineralization of FYM and its conjoint application with chemical fertilizers could have resulted in the increased availability of N in soil, thereby, promoting the accumulation of nitrogen in different plant tissues.

In wheat, application of all levels of  $RD_{NPK}$  significantly increased N content in index leaf over control in both the years. Application of 50 and 100%  $RD_{NPK}$  was effective in increasing grain N content, but decreased straw N content in comparison

to control during 1999-2000. Application of 75%  $RD_{NPK}$  significantly increased straw N over control during 1999-2000.

Application of all levels of  $RD_{NPKZn}$  significantly increased N content in index leaf and grain of wheat over control during 1999-2000. Application of 25%  $RD_{NPKZn}$  increased N content in straw over control during 1999-2000, while 50%  $RD_{NPK}$  significantly increased index leaf N during 1998-99 and straw N during 1999-2000 in comparison to control. Application of 75 and 100% levels of  $RD_{NPKZn}$  resulted a significant decrease in N content of straw in comparison to control during 1999-2000.

Application of FYM alone increased index leaf N during 1998-99 and grain N during 1999-2000, but decreased leaf N during the latter year in comparison to control.

Application of all combinations of FYM and chemical fertilizers significantly increased N content in index leaf and grain, but decreased straw N content during 1999-2000 in comparison to control. Application of 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  significantly increased straw N content in comparison to control, while application of 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination significantly increased N in both index leaf and straw over control during 1998-99.

### 4.3.2 Phosphorus Content

The data on the effect of chemical fertilizers, FYM and their combinations on phosphorus content of index leaf, grain and straw of aromatic rice and wheat crops are presented in table 14.

It is clear from the data contained in table that all levels of  $RD_{NPK}$  significantly increased P content in rice straw during 1998-99 and in index leaf during 1998-99 but decreased straw P in the second year in comparison to control. Application of 25%  $RD_{NPK}$  decreased grain P, but application of higher level (50%  $RD_{NPK}$ ) significantly increased it in comparison to control during second year. Application of 75% and 100%  $RD_{NPK}$  significantly increased grain P over control during the first year; the latter dose was effective to increase P in index leaf, as well.

Application of all levels of  $RD_{NPKZn}$  also significantly increased straw P during the first year and leaf P during the second year in comparison to control.

Table 14: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Phosphorus Content (%) of Aromatic Rice – Wheat

Treatment	Phosphorus Content (%) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.330	0.122	0.207	0.354	0.165	0.266
25% RD <sub>NPK</sub>	0.329	0.146	0.195	0.317	0.139	0.325
50% RD <sub>NPK</sub>	0.324	0.233	0.217	0.394	0.157	0.288
75% RD <sub>NPK</sub>	0.390	0.233	0.212	0.377	0.137	0.279
100% RD <sub>NPK</sub>	0.378	0.210	0.233	0.367	0.144	0.273
25% RD <sub>NPKZn</sub>	0.274	0.153	0.210	0.333	0.164	0.278
50% RD <sub>NPKZn</sub>	0.281	0.158	0.233	0.427	0.154	0.285
75% RD <sub>NPKZn</sub>	0.387	0.205	0.219	0.342	0.146	0.280
100% RD <sub>NPKZn</sub>	0.264	0.166	0.221	0.357	0.187	0.304
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.359	0.170	0.226	0.342	0.178	0.341
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.362	0.160	0.223	0.340	0.142	0.318
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.316	0.166	0.199	0.359	0.165	0.249
100 % RD <sub>FYM</sub>	0.330	0.182	0.191	0.319	0.132	0.300
CD (p=0.05)	0.036	0.014	0.018	0.024	0.008	0.006
	Phosphorus Content (%) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.704	0.150	0.653	0.671	0.164	0.571
25% RD <sub>NPK</sub>	0.683	0.158	0.597	0.845	0.180	0.626
50% RD <sub>NPK</sub>	0.673	0.165	0.542	0.849	0.148	0.599
75% RD <sub>NPK</sub>	0.724	0.155	0.599	0.672	0.163	0.625
100% RD <sub>NPK</sub>	0.727	0.208	0.549	0.696	0.075	0.599
25% RD <sub>NPKZn</sub>	0.782	0.221	0.607	0.933	0.126	0.597
50% RD <sub>NPKZn</sub>	0.691	0.143	0.614	0.891	0.188	0.626
75% RD <sub>NPKZn</sub>	0.666	0.141	0.614	0.848	0.092	0.516
100% RD <sub>NPKZn</sub>	0.697	0.146	0.566	0.736	0.101	0.571
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.753	0.193	0.689	0.802	0.180	0.533
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.677	0.190	0.566	0.763	0.119	0.611
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.683	0.150	0.638	0.638	0.130	0.598
100 % RD <sub>FYM</sub>	0.664	0.237	0.589	0.894	0.166	0.663
CD (p=0.05)	0.057	0.029	0.099	0.086	0.011	0.017

Application of 25 and 50%  $RD_{NPKZn}$  decreased grain P during the first year and the latter dose decreased grain P during the second year. But the latter dose significantly increased leaf P in the first year and grain P in the second year in comparison to control. Application of 75%  $RD_{NPKZn}$  significantly increased grain and straw P in the first year but decreased straw P in the second year over control. Application of 100%  $RD_{NPK}$  increased the straw P in both the years but decreased grain P in the first year in comparison to control.

Application of FYM alone was effective in increasing straw P in the first year and leaf P in the second year, but decreased grain and straw P in the second year in comparison to control. Brar *et al* (1995) also observed increase in P content of rice due to FYM application.

All combinations of chemical fertilizers with FYM increased straw P in the first year and leaf P except at 75%  $RD_{FYM} + 25\% RD_{NPKZn}$ , in the second year in comparison to control. Application of 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  significantly increased leaf P in the first year and straw P in the second year in comparison to control. The combination of 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  and 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  decreased straw P and leaf P, respectively in comparison to control during the second year.

In wheat crop, application of all levels of  $RD_{NPK}$  significantly increased leaf P in comparison to control during second year. Application of 25%  $RD_{NPK}$  increased P content in grain and straw in comparison to control during second year, while 50%  $RD_{NPK}$  decreased leaf P in the first year and straw P in the second year, but increased grain P in the second year over control. Use of 100%  $RD_{NPK}$  increased straw P but decreased leaf P in the first year and straw P in the second year.

Application of 25%  $RD_{NPKZn}$  significantly increased grain and straw P in the first year and grain and leaf P in the second year but decreased straw P in the second year in comparison to control. Application of 50%  $RD_{NPKZn}$  was effective in significantly increasing P content in leaf, grain and straw in comparison to control in the second year. Use of 75%  $RD_{NPKZn}$  significantly increased grain P but decreased leaf and straw P in comparison to control in the second year. Application of 100%  $RD_{NPKZn}$  significantly decreased straw P in comparison to control in the second year.

Application of FYM alone significantly increased straw P in the first year, but both leaf and grain P in the second year in comparison to control.

Application of 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> significantly increased straw P in both the years, grain P in the second year but decreased leaf P in the latter year in comparison to control. Use of 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> significantly increased straw P in the first year, but leaf and grain P in second year but decreased straw P in the second year in comparison to control. Application of 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> significantly increased leaf P but decreased straw P in comparison to control in the second year.

### 4.3.3 Potassium Content

The data on the effect of chemical fertilizers, FYM and their combined application on K content of index leaf, grain and straw parts of aromatic rice and wheat crops are presented in table 15.

It is evident from the data that K content in different plant parts of aromatic rice was significantly influenced by different treatments in both the years except for K content of grain in the first year.

The lowest K content in index leaf was noted in 75% RD<sub>NPK</sub> treatment (1.18% K) in the first year and in 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> treatment (1.258% K) in the second year. The highest K content in index leaf was recorded in 75% RD<sub>NPKZn</sub> treatment in first year and in 25% RD<sub>NPKZn</sub> treatment in the second year. Gangiah *et al* (1999) and Qayyum and Akhtar (1981) observed increase in K contents due to NPK application.

Application of higher levels of RD<sub>NPK</sub> significantly increased K content in straw of aromatic rice in the first year and in grain and straw in the second year over control. Lower (25%) level of RD<sub>NPK</sub> was effective in increasing K content of straw in the first year.

Application of lower levels of RD<sub>NPKZn</sub> increased K content in straw during second year only in comparison to control. Application of higher (75%) level of RD<sub>NPKZn</sub> significantly decreased K content in straw during second year in comparison to control. Application of 100% RD<sub>NPKZn</sub> decreased K content in straw during first year but increased it in grain parts in the second year in comparison to control.

**Table 15: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Potassium Content (%) of Aromatic Rice – Wheat**

Treatment	Potassium Content (%) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.480	1.031	1.288	0.391	1.182	1.557
25% RD <sub>NPK</sub>	0.472	1.492	1.282	0.341	1.262	1.840
50% RD <sub>NPK</sub>	0.519	0.899	1.219	0.378	1.315	1.625
75% RD <sub>NPK</sub>	0.416	1.547	1.180	0.431	1.317	1.925
100% RD <sub>NPK</sub>	0.447	1.672	1.320	0.400	1.111	1.736
25% RD <sub>NPKZn</sub>	0.481	0.867	1.336	0.350	1.558	1.988
50% RD <sub>NPKZn</sub>	0.369	0.730	1.227	0.406	1.139	1.875
75% RD <sub>NPKZn</sub>	0.445	1.117	1.352	0.391	0.969	1.778
100% RD <sub>NPKZn</sub>	0.388	0.738	1.235	0.419	1.264	1.859
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.478	1.367	1.266	0.409	1.529	1.231
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.436	0.830	1.336	0.400	1.233	1.888
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.291	0.669	1.250	0.422	1.216	1.258
100 % RD <sub>FYM</sub>	0.474	0.711	1.313	0.366	1.361	1.997
CD (p=0.05)	NS	0.218	0.109	0.021	0.086	0.463
	Potassium Content (%) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.497	1.013	1.669	0.474	0.883	1.648
25% RD <sub>NPK</sub>	0.497	0.919	1.585	0.622	0.920	1.925
50% RD <sub>NPK</sub>	0.675	1.042	1.575	0.770	0.813	2.080
75% RD <sub>NPK</sub>	0.516	1.000	1.482	0.556	0.973	2.054
100% RD <sub>NPK</sub>	0.509	1.025	1.641	0.482	0.871	1.786
25% RD <sub>NPKZn</sub>	0.624	0.925	1.557	0.703	0.886	1.790
50% RD <sub>NPKZn</sub>	0.486	0.900	1.604	0.688	1.084	1.510
75% RD <sub>NPKZn</sub>	0.578	0.950	1.603	0.686	0.919	2.084
100% RD <sub>NPKZn</sub>	0.805	1.031	1.500	0.627	0.895	2.097
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.544	0.988	1.556	0.831	1.050	1.874
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.536	0.850	1.388	0.552	0.945	1.898
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.520	0.963	1.678	0.555	0.953	1.550
100 % RD <sub>FYM</sub>	0.509	0.875	1.641	0.659	1.043	2.223
CD (p=0.05)	NS	0.096	NS	0.058	0.061	0.194

Application of FYM alone significantly increased K content in straw part in the second year but decreased it in straw part in first year and grain part in the second year in comparison to control.

A combined application of 25% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> increase K content in straw in both the years over control. The application of 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> significantly decreased K content in straw during the first year but increased it in grain during second year in comparison to control.

In wheat crop, K content of straw during first year and of all plant parts during second year was significantly affected by different treatments.

Application of increasing levels of RD<sub>NPK</sub> except for 100% RD<sub>NPK</sub> significantly increased K content in index leaf and grain of wheat in comparison to control during second year. Potassium content of straw during second year was significantly increased over control under 75% RD<sub>NPK</sub> treatment only.

Potassium content of index leaf of wheat was significantly increased over control at 75 and 100% RD<sub>NPKZn</sub>. Application of increasing levels of RD<sub>NPKZn</sub> significantly increased K content of wheat grain over control during second year, while K content of straw part was significantly increased over control under 50% RD<sub>NPKZn</sub> treatment during second year.

Application of FYM alone significantly decreased K content in wheat straw during first year but increased it in all plant parts during second year in comparison to control.

Use of all combinations of FYM and chemical fertilizers significantly increased K content in all plant in second year over control except for the K content in index leaf under 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> treatment. Potassium content of wheat straw in the first year was significantly lower than control under 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> treatment.

#### **4.3.4 Calcium Content**

The data on the effect of chemical fertilizers, FYM and their combined application on Ca content of index leaf, grain and straw parts of aromatic rice and wheat crops are presented in table 16.

**Table 16: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Calcium Content (%) of Aromatic Rice – Wheat**

Treatment	Calcium Content (%) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.191	0.772	1.428	0.071	0.664	0.792
25% RD <sub>NPK</sub>	0.189	0.788	1.372	0.094	0.706	1.132
50% RD <sub>NPK</sub>	0.200	0.892	1.348	0.145	0.626	1.151
75% RD <sub>NPK</sub>	0.189	0.794	1.375	0.165	0.716	0.746
100% RD <sub>NPK</sub>	0.207	0.831	1.328	0.135	0.822	0.838
25% RD <sub>NPKZn</sub>	0.190	0.840	1.376	0.139	0.700	1.180
50% RD <sub>NPKZn</sub>	0.189	0.816	1.468	0.195	0.802	0.872
75% RD <sub>NPKZn</sub>	0.190	0.809	1.464	0.158	0.719	0.889
100% RD <sub>NPKZn</sub>	0.190	0.782	1.347	0.176	0.672	1.156
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.196	0.814	1.380	0.221	0.759	0.849
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.189	0.786	1.330	0.182	0.696	0.779
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.201	0.717	1.370	0.160	0.706	1.448
100 % RD <sub>FYM</sub>	0.191	0.817	1.369	0.182	0.703	0.853
CD (p=0.05)	NS	0.043	NS	0.006	0.045	0.057
	Calcium Content (%) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.030	0.045	0.135	0.023	0.038	0.174
25% RD <sub>NPK</sub>	0.030	0.044	0.135	0.026	0.042	0.184
50% RD <sub>NPK</sub>	0.030	0.047	0.137	0.024	0.044	0.164
75% RD <sub>NPK</sub>	0.030	0.047	0.138	0.016	0.045	0.159
100% RD <sub>NPK</sub>	0.029	0.046	0.138	0.020	0.037	0.188
25% RD <sub>NPKZn</sub>	0.031	0.046	0.138	0.026	0.032	0.180
50% RD <sub>NPKZn</sub>	0.031	0.047	0.141	0.031	0.063	0.180
75% RD <sub>NPKZn</sub>	0.031	0.045	0.137	0.046	0.046	0.206
100% RD <sub>NPKZn</sub>	0.030	0.046	0.144	0.032	0.064	0.224
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.031	0.046	0.135	0.042	0.067	0.185
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.030	0.044	0.142	0.031	0.043	0.213
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.030	0.046	0.137	0.021	0.043	0.199
100 % RD <sub>FYM</sub>	0.030	0.045	0.134	0.047	0.035	0.230
CD (p=0.05)	NS	NS	NS	0.001	0.002	0.014

It is evident from the data that different treatments influenced Ca content in all plant parts of both the crops in second year (1999-2000) and Ca content in straw of aromatic rice during the first year.

Application of 50 and 100%  $RD_{NPK}$  levels significantly increased Ca content in rice straw over control in the first year, while all levels of  $RD_{NPK}$  increased Ca content in rice grain over control in the second year. Lower levels of  $RD_{NPK}$  (25 and 50%) increased Ca in index leaf of rice and higher levels of  $RD_{NPK}$  (75 and 100%) increased the content of Ca in straw part over control in the second year. Marr *et al* (1999) also observed increase in Ca contents due to NPK application.

Application of all levels of  $RD_{NPKZn}$  significantly increased Ca content in rice index leaf and grain over control during second year only while lower levels were effective in increasing Ca content in straw part in both the years.

Application of FYM alone significantly increased Ca content in rice straw over control during first year and in index leaf and grain during second year.

All combinations of FYM and chemical fertilizers together increased Ca content in index leaf and grain of rice crop over control during second year, however, the increase noted in index leaf at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  was statistically not significant. The content of Ca in rice straw was significantly increased over control for treatment receiving 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  during second year. Use of 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly decreased Ca content in rice straw in comparison to control during first year.

In wheat crop of second year, lower levels (25 and 50 %) of  $RD_{NPK}$  increased Ca content in grain and straw parts over control. Higher levels of  $RD_{NPK}$  decreased Ca content in grain and index leaf especially at 75%  $RD_{NPK}$  or increased it in straw part of wheat.

Application of all levels of  $RD_{NPKZn}$  significantly increased Ca content in wheat grain and straw over control during second year, however, Ca content in straw at 25%  $RD_{NPKZn}$  was lower than control. Use of 75 and 100%  $RD_{NPKZn}$  resulted in a significant increase in Ca content of index leaf over control during second year. Use of FYM alone significantly increased Ca content in index leaf and grain of wheat during second year.

All combinations of FYM and chemical fertilizer significantly increased Ca contents in all plant parts of wheat crop in the second year, however, grain Ca under 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>, significantly decreased in comparison to control. Under combination of 25 % RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub>, the increase recorded in index leaf of wheat was statistically not significant in comparison to control.

#### 4.3.5 Magnesium Content

The data on the effect of chemical fertilizers, FYM and their combination on Mg content of index leaf, grain and straw parts of aromatic rice and wheat crops are presented in table 17.

It is clear from the data that application of all RD<sub>NPK</sub> levels increased Mg content of rice grain over control in both the years and of index leaf in the second year, however, the increase recorded at 25% RD<sub>NPK</sub> in grain was not significant in the second year and Mg content in grain was in the first year actually decreased in comparison to control. The content of Mg in straw was decreased at lower levels of RD<sub>NPK</sub> in comparison to control.

Application of all levels of RD<sub>NPKZn</sub> increased Mg content in index leaf and rice grain in comparison to control during second year. In the first year, Mg content in rice index leaf decreased in comparison to control at 100% RD<sub>NPKZn</sub> level, while during second year Mg content in straw was significantly decreased only in 25% RD<sub>NPKZn</sub> treatment.

Application of FYM alone significantly increased Mg content in rice grain in both the years and index leaf in the second year. In the first year, Mg content of index leaf was significantly decreased in comparison to control.

All combinations of FYM and chemical fertilizers increased Mg content in index leaf of rice in comparison to control during second year. In both the years, Mg content of rice grain was significantly increased over control by these treatment except for 75% RD<sub>FYM</sub> + 25% RD<sub>NPK</sub> in the first year and 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> in the second year. The Mg content in rice straw during first year was also significantly decreased in comparison to control under treatments receiving 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>.

In wheat crop, application of all levels of RD<sub>NPK</sub> significantly increased Mg content over control in wheat index leaf, grain and straw except for 25 and 50%

Table 17: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Magnesium Content (%) of Aromatic Rice – Wheat

Treatment	Magnesium Content (%) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.037	0.160	0.420	0.036	0.138	0.217
25% RD <sub>NPK</sub>	0.034	0.125	0.451	0.036	0.141	0.424
50% RD <sub>NPK</sub>	0.046	0.148	0.429	0.038	0.130	0.401
75% RD <sub>NPK</sub>	0.046	0.148	0.421	0.038	0.140	0.423
100% RD <sub>NPK</sub>	0.039	0.215	0.407	0.037	0.140	0.227
25% RD <sub>NPKZn</sub>	0.038	0.164	0.425	0.037	0.126	0.226
50% RD <sub>NPKZn</sub>	0.037	0.158	0.402	0.038	0.140	0.227
75% RD <sub>NPKZn</sub>	0.037	0.166	0.405	0.037	0.134	0.233
100% RD <sub>NPKZn</sub>	0.037	0.162	0.377	0.038	0.138	0.439
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.056	0.158	0.411	0.038	0.140	0.452
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.039	0.147	0.402	0.035	0.139	0.417
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.035	0.131	0.430	0.037	0.140	0.440
100 % RD <sub>FYM</sub>	0.039	0.155	0.384	0.037	0.137	0.403
CD (p=0.05)	0.002	0.007	0.028	0.001	0.007	0.008
	Magnesium Content (%) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.122	0.405	1.098	0.120	0.338	0.958
25% RD <sub>NPK</sub>	0.128	0.418	1.180	0.122	0.336	0.944
50% RD <sub>NPK</sub>	0.132	0.427	1.220	0.117	0.346	0.922
75% RD <sub>NPK</sub>	0.130	0.439	1.221	0.120	0.341	0.905
100% RD <sub>NPK</sub>	0.120	0.469	1.205	0.116	0.336	0.909
25% RD <sub>NPKZn</sub>	0.122	0.413	1.308	0.120	0.338	0.930
50% RD <sub>NPKZn</sub>	0.121	0.468	1.280	0.116	0.329	0.955
75% RD <sub>NPKZn</sub>	0.125	0.403	1.209	0.116	0.339	1.216
100% RD <sub>NPKZn</sub>	0.133	0.464	1.337	0.112	0.327	0.928
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.125	0.387	1.130	0.117	0.332	1.209
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.130	0.422	1.393	0.118	0.335	0.974
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.128	0.460	1.145	0.120	0.337	0.953
100 % RD <sub>FYM</sub>	0.124	0.377	1.114	0.120	0.330	1.014
CD (p=0.05)	0.005	0.027	0.055	NS	NS	0.035

$RD_{NPK}$  for straw and 100%  $RD_{NPK}$  for grain during first year. The Mg content in index leaf was significantly decreased in comparison to control at levels higher than 25%  $RD_{NPK}$ .

Application all levels of  $RD_{NPKZn}$  significantly increased Mg content in index leaf of wheat in comparison to control during first year but during the second year such increase was significant only at 75%  $RD_{NPKZn}$ . In the first year, Mg content of wheat grain and straw was also significantly increased over control under 100%  $RD_{NPKZn}$  and 50 and 100%  $RD_{NPKZn}$  treatments, respectively.

Application of FYM alone significantly decreased Mg content in straw during first year but increased it in index leaf during second year in comparison to control.

Application of a combination of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  significantly increased Mg content in wheat leaf over control during second year, while 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  increased it in index leaf, grain and straw parts, respectively.

#### 4.3.6 Sulphur Content

The data on the effect of chemical fertilizers, FYM and their combinations on S content of index leaf, grain and straw parts are presented in table 18.

It is clear from the data that application of all levels  $RD_{NPK}$  significantly increased S content over control in rice grain and straw parts during first year and in index leaf and straw parts during second year. The S content of index leaf was significantly increased over control under 50%  $RD_{NPK}$  treatment in the first year while of grain under 50 and 75%  $RD_{NPK}$  treatments in the second year.

Application of all levels of  $RD_{NPKZn}$  significantly increased S content of rice straw over control in both the years, except for 75%  $RD_{NPKZn}$  during second year. All levels of  $RD_{NPKZn}$  were also effective in significantly increasing S content of index leaf over control in the second year. Sulphur content of grain in the first year was significantly increased over control at 75%  $RD_{NPKZn}$  application but it was decreased in the second year at both 50% and 75%  $RD_{NPKZn}$  levels.

Application of FYM alone significantly increased S content of index leaf, grain and straw of rice over control during second year only. Sadana *et al* (1995)

**Table 18: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Sulphur Content (%) of Aromatic Rice – Wheat**

Treatment	Sulphur Content (%) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.057	0.162	0.376	0.075	0.213	0.162
25% RD <sub>NPK</sub>	0.073	0.212	0.412	0.078	0.282	0.237
50% RD <sub>NPK</sub>	0.081	0.241	0.455	0.094	0.229	0.236
75% RD <sub>NPK</sub>	0.096	0.212	0.363	0.078	0.238	0.192
100% RD <sub>NPK</sub>	0.083	0.235	0.433	0.082	0.232	0.196
25% RD <sub>NPKZn</sub>	0.066	0.206	0.386	0.073	0.370	0.201
50% RD <sub>NPKZn</sub>	0.060	0.248	0.410	0.057	0.238	0.336
75% RD <sub>NPKZn</sub>	0.073	0.246	0.341	0.066	0.215	0.179
100% RD <sub>NPKZn</sub>	0.067	0.248	0.253	0.075	0.249	0.281
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.109	0.237	0.340	0.071	0.282	0.334
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.100	0.146	0.401	0.072	0.244	0.171
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.078	0.151	0.447	0.070	0.274	0.255
100 % RD <sub>FYM</sub>	0.066	0.198	0.399	0.083	0.247	0.383
CD (p=0.05)	0.013	0.039	0.070	0.004	0.016	0.013
	Sulphur Content (%) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.125	0.077	0.210	0.144	0.085	0.285
25% RD <sub>NPK</sub>	0.079	0.119	0.210	0.189	0.073	0.309
50% RD <sub>NPK</sub>	0.114	0.092	0.194	0.167	0.095	0.384
75% RD <sub>NPK</sub>	0.111	0.086	0.232	0.136	0.086	0.269
100% RD <sub>NPK</sub>	0.117	0.123	0.206	0.139	0.106	0.320
25% RD <sub>NPKZn</sub>	0.126	0.077	0.237	0.182	0.106	0.320
50% RD <sub>NPKZn</sub>	0.116	0.088	0.250	0.190	0.112	0.361
75% RD <sub>NPKZn</sub>	0.046	0.143	0.231	0.124	0.079	0.247
100% RD <sub>NPKZn</sub>	0.071	0.083	0.250	0.127	0.096	0.225
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.090	0.113	0.288	0.211	0.084	0.360
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.121	0.118	0.226	0.134	0.107	0.343
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.143	0.108	0.225	0.122	0.102	0.333
100 % RD <sub>FYM</sub>	0.092	0.144	0.247	0.190	0.112	0.337
CD (p=0.05)	0.018	0.022	0.030	0.004	0.006	0.052

and Lal and Huda (1993) also observed increase in S uptake due to organic manure application.

All combinations of FYM and chemical fertilizers significantly increased S content in grain during first year and in index leaf and straw parts during second year over control. A significant increase in S content in index leaf and straw over control during first year was recorded in 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  treatments, respectively. Sulphur content in rice grain during second year was significantly lower than control in both 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  +  $RD_{NPKZn}$  treatments.

In wheat crop, application of 25%  $RD_{NPK}$  significantly decreased S content of grain over control in the first year but increased it in the second year, while *vice-versa* was true for straw content. Application of 50%  $RD_{NPK}$  significantly increased S content of index leaf, grain and straw of wheat in the second year. Application of 100%  $RD_{NPK}$  significantly increased S content of straw over control in both the years but decreased S content of grain during second year.

Application of 25%  $RD_{NPKZn}$  significantly increased S content in grain and straw of wheat over control during second year. Use of 50%  $RD_{NPKZn}$  increased S content in index leaf over control in both the years and in grain and straw parts during second year only. Application of 75%  $RD_{NPKZn}$  significantly decreased S content of wheat grain in comparison to control in both the years and of wheat straw in second year but increased it in straw in first year.

Application of FYM alone significantly increased S content in straw during first year and in index leaf, grain and straw parts over control during second year over control. During first year, S content in grain was significantly decreased in comparison to control.

Application of FYM and chemical fertilizers together significantly increased S content in index leaf specially at higher levels of  $RD_{NPKZn}$  and also in straw part in both the years. The increase in S content of grain over control was significant under 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  treatment during first year and under 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  treatment in the second year. With other combinations, the content of S in wheat grain remained either unaffected or decreased in comparison to control.

### 4.3.7 Zinc Content

The data on the effect of chemical fertilizers, FYM and their joint application on Zn concentration in index leaf, grain and straw parts of aromatic rice and wheat crops are presented in table 19.

It is evident from the data that application of 50 and 75%  $RD_{NPK}$  significantly increased Zn concentration in index leaf of aromatic rice over control in the second year only. Choudhary *et al* (1995) observed increase in foliar Zn content due to NPK application. These levels were also effective in increasing Zn concentration in grain and straw parts over control in the first and second year experiments, respectively. Application of 100%  $RD_{NPK}$  also significantly increased Zn concentration in rice grain over control during first year but at 25%  $RD_{NPK}$  level Zn concentration in rice grain was significantly lower than control in the first year.

Application of 100%  $RD_{NPKZn}$  significantly increased Zn concentration in index leaf of rice over control but lower levels (25 and 75%) of  $RD_{NPKZn}$  decreased Zn concentration in index leaf in comparison to control. Application of 100%  $RD_{NPKZn}$  also resulted a significant increase in Zn concentration in straw part in comparison to control in both the years. Lower levels of  $RD_{NPKZn}$  increased Zn concentration in straw part during first year but decreased Zn concentration in grains during second year in comparison to control. Several workers (Bhardwaj and Prasad, 1981; Reddy and Yadav, 1994; Singh and Singh, 1979; Brar and Sekhon, 1978; Gupta *et al*, 1987; Khan *et al*, 1992; Kumar *et al*, 1999 and Duraisamy *et al*, 1988) observed increase in foliar Zn content due to Zn application. Maharana *et al* (1993) reported that zinc application increased the concentration of zinc in both grain and straw and the concentration of zinc in straw was more than in grain.

Application of FYM alone significantly increased Zn concentration in index leaf of rice but decreased it in grain and straw parts during second year and also in grain part during first year in comparison to control.

All combinations of FYM with chemical fertilizers especially under 50%  $RD_{FYM} + RD_{NPKZn}$  and 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  increased Zn concentration in flag and straw during both the years and also in grain during second year in comparison to control. Zinc concentration in rice grain during first and second years

**Table 19: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Zinc Content (ppm) of Aromatic Rice – Wheat**

Treatment	Zinc Content (ppm) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	51.88	62.75	52.50	41.19	66.00	54.41
25% RD <sub>NPK</sub>	31.06	59.06	60.88	38.53	69.89	55.35
50% RD <sub>NPK</sub>	64.75	62.88	49.03	38.22	74.09	57.38
75% RD <sub>NPK</sub>	64.50	63.00	54.25	40.24	77.50	66.05
100% RD <sub>NPK</sub>	63.19	63.44	50.38	39.57	68.82	55.10
25% RD <sub>NPKZn</sub>	56.56	70.44	61.88	38.68	71.14	49.33
50% RD <sub>NPKZn</sub>	36.56	79.81	57.75	39.15	69.11	55.37
75% RD <sub>NPKZn</sub>	61.30	90.00	60.63	36.51	69.02	51.96
100% RD <sub>NPKZn</sub>	48.25	99.94	46.13	39.80	80.41	65.52
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	57.79	81.69	59.75	36.71	70.61	56.37
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	52.81	100.56	68.38	44.19	76.85	62.17
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	34.88	89.50	83.75	46.76	78.20	65.88
100 % RD <sub>FYM</sub>	39.50	71.56	55.48	34.83	58.57	57.79
CD (p=0.05)	9.70	9.91	10.06	3.03	6.77	2.43
	Zinc Content (ppm) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	69.50	22.38	86.88	72.58	30.94	83.63
25% RD <sub>NPK</sub>	58.44	23.75	83.75	68.75	29.84	82.68
50% RD <sub>NPK</sub>	53.88	20.25	82.31	70.86	23.50	89.13
75% RD <sub>NPK</sub>	52.25	23.00	82.81	65.21	34.67	95.27
100% RD <sub>NPK</sub>	70.13	21.19	90.63	65.86	27.37	101.63
25% RD <sub>NPKZn</sub>	69.13	20.38	89.69	75.13	30.27	104.12
50% RD <sub>NPKZn</sub>	66.69	21.56	96.88	92.45	40.77	107.56
75% RD <sub>NPKZn</sub>	67.25	21.13	88.44	57.87	18.88	131.55
100% RD <sub>NPKZn</sub>	56.69	23.81	93.13	57.87	26.51	104.97
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	61.81	21.38	89.94	84.82	24.72	94.77
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	51.69	21.59	101.25	53.76	21.25	104.59
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	56.75	25.56	95.06	61.10	25.24	87.24
100 % RD <sub>FYM</sub>	54.56	22.44	94.00	55.54	20.40	101.08
CD (p=0.05)	7.23	2.79	11.50	3.03	1.11	11.65

were significantly lower than control under 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> treatments, respectively.

In wheat, application of 100% RD<sub>NPK</sub> significantly increased Zn concentration in index leaf and also in grain and straw over control during second year only. Lower levels of RD<sub>NPK</sub> significantly decreased Zn concentration in grain during both the years in comparison to control except for 75% RD<sub>NPK</sub> level at which Zn concentration in straw part was significantly increased over control during second year.

Application of increasing level of RD<sub>NPKZn</sub> significantly increased Zn concentration in index leaf of wheat during second year only. The increase noted in grain and straw parts during second year over control was significant only at 50% RD<sub>NPKZn</sub> level. Higher level of RD<sub>NPKZn</sub> decreased Zn concentration in grain and straw during second year and in grain during first year in comparison to control.

Application of FYM alone, significantly increased Zn concentration in index leaf of wheat but decreased Zn concentration in grain and straw parts during second year and in grain during first year in comparison to control.

Application of 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> significantly increased Zn concentration in index leaf of wheat in both the years in comparison to control. The increase in Zn concentration in straw part during first year and in grain part during second year in comparison to control was statistically significant under 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> and 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> treatments. All combinations of FYM with chemical fertilizers invariably decreased Zn concentration in grain during first year and in straw part during second year in comparison to control. Increasing proportion of FYM resulted in a significant decrease in Zn concentration in grain during second year in comparison to control.

#### 4.3.8 Copper Content

The data on the effect soil application of chemical fertilizers, FYM and their combinations on Cu content of index leaf, grain and straw of aromatic rice and wheat crop are presented in table 20.

It is evident from the data that application of higher (75 and 100%) RD<sub>NPK</sub> significantly increased Cu content in index leaf, grain and straw of aromatic rice in

**Table 20: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Copper Content (ppm) of Aromatic Rice – Wheat**

Treatment	Copper Content (ppm) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	2.74	3.90	4.43	3.29	4.39	3.72
25% RD <sub>NPK</sub>	2.65	3.80	6.47	2.23	3.59	3.62
50% RD <sub>NPK</sub>	2.88	4.70	4.50	3.39	2.85	2.85
75% RD <sub>NPK</sub>	3.70	4.60	6.75	2.43	3.88	4.43
100% RD <sub>NPK</sub>	3.29	5.05	4.59	3.84	3.08	8.24
25% RD <sub>NPKZn</sub>	2.85	4.65	4.77	2.30	5.20	7.04
50% RD <sub>NPKZn</sub>	2.20	4.04	4.30	4.19	3.50	7.22
75% RD <sub>NPKZn</sub>	2.92	4.46	5.38	3.64	3.50	6.26
100% RD <sub>NPKZn</sub>	2.30	4.30	3.83	3.31	4.05	3.97
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	2.63	4.23	5.53	4.10	5.72	5.95
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	3.24	5.00	6.17	3.30	3.48	7.91
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	2.98	4.76	4.88	2.08	4.03	4.50
100 % RD <sub>FYM</sub>	2.63	4.90	5.53	4.00	4.16	3.85
CD (p=0.05)	0.50	0.27	0.74	1.17	0.37	0.30
	Copper Content (ppm) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	5.00	3.17	10.25	4.42	2.10	12.37
25% RD <sub>NPK</sub>	5.00	3.13	8.44	5.67	2.24	11.20
50% RD <sub>NPK</sub>	5.28	3.36	11.00	5.74	1.98	11.11
75% RD <sub>NPK</sub>	4.73	3.45	10.63	4.99	3.79	12.89
100% RD <sub>NPK</sub>	5.50	3.27	10.06	5.62	2.91	12.01
25% RD <sub>NPKZn</sub>	4.88	3.29	10.81	5.77	2.02	13.01
50% RD <sub>NPKZn</sub>	5.33	3.38	10.19	7.29	4.49	13.50
75% RD <sub>NPKZn</sub>	5.35	3.55	10.13	7.15	3.24	14.31
100% RD <sub>NPKZn</sub>	5.43	3.35	10.31	4.88	2.32	11.62
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	4.71	3.19	10.75	5.17	1.59	13.34
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	4.70	3.40	10.44	3.35	1.69	11.75
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	4.68	3.06	10.44	4.20	1.35	10.25
100 % RD <sub>FYM</sub>	4.68	3.30	10.06	6.30	1.88	12.37
CD (p=0.05)	0.18	0.18	0.60	0.42	1.02	1.16

the first year and in index leaf of aromatic rice during second year in comparison to control. All levels of  $RD_{NPK}$  significantly decreased Cu content in straw part during second year. Application of 25 and 50% levels of  $RD_{NPK}$  significantly increased Cu content in index leaf and straw, respectively in comparison to control during first year. The latter level (50%) of  $RD_{NPK}$  decreased Cu content in the index leaf in comparison to control in the second year.

Application of 25%  $RD_{NPKZn}$  significantly increased Cu content in straw in both years and in index leaf in the second year in comparison to control. Use of 50%  $RD_{NPKZn}$  increased Cu content in index leaf during second year, but decreased it in grain during first year and in straw during second year in comparison to control. Application of 75%  $RD_{NPKZn}$  significantly increased Cu content in both grain and straw in the first year and in index leaf during second year, but decreased it in straw part in second year in comparison to control. Application of 100%  $RD_{NPKZn}$  significantly increased Cu content in straw part during first year in comparison to control.

Application of FYM alone significantly increased Cu content in index leaf and straw parts in comparison to control during first year only. Gupta *et al* (1987) also reported an increase in copper concentration of pigeon pea shoots due to applications of organic manures.

All combinations of FYM and chemical fertilizers significantly increased Cu content in straw during first year and in index leaf in both the years in comparison to control except for 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  treatment in case of index leaf during the first year. Application of 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  increased Cu content in grain during first year but decreased it in straw part in the second year in comparison to control. Application of 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  also decreased the content of Cu in grain in comparison to control during second year. The observed effect of chemical fertilizers levels and farmyard manure alone or in combination on Cu content appeared to be due to zinc response induced increase in the requirement of crop for copper and supply of organic acids from farmyard manure to improve mobilization of copper to plants.

In wheat crop, application of lower levels (25 and 50%) of  $RD_{NPKZn}$  significantly decreased Cu content in index leaf in both the years in comparison to

control, however, the latter level was found to be effective in increasing Cu concentration in index leaf during first year. Application of 50 and 75% RD<sub>NPK</sub> significantly increased the content of Cu in grain and straw in comparison to control with an exception for grain content in the first year and straw content during second year. Application of 100% RD<sub>NPK</sub> significantly increased Cu content in grain as compared to control in both the years.

Application of 25% RD<sub>NPKZn</sub> significantly increased Cu content in wheat grain during second year in comparison to control while 50, 75 and 100% RD<sub>NPKZn</sub> were effective in increasing Cu concentration in both grain and straw parts over control during both the years. The increase noted in straw at 100% RD<sub>NPK</sub> during second year was statistically non-significant. Application of 75% RD<sub>NPKZn</sub> also significantly increased Cu content in index leaf during second year in comparison to control. These findings are not in conformity with those of Gupta *et al* (1987) who reported that application of zinc decreased the concentration of copper in pigeon pea shoots.

Application of FYM alone decreased Cu content in grain during first year but increased it significantly in the second year in comparison to control. Gupta *et al* (1987) also recorded a decrease in copper concentration in wheat straw under manure treatment.

The combined application of 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> significantly decreased Cu content in wheat grain during first year but increased it in the second year in comparison to control. Application of 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> decreased Cu content in grain in both the years but increased it significantly in straw part during first year in comparison to control. Application of 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> decreased Cu content in grain during first year and also in index leaf during second year in comparison to control.

#### 4.3.9 Iron Content

The data on the effect of chemical fertilizers, FYM and their combinations on Fe content of index leaf, grain and straw parts of aromatic rice and wheat crop are presented in table 21.

It is evident from the data that Fe content of index leaf was significantly decreased under 100% RD<sub>NPK</sub> treatment in comparison to control during first year

**Table 21: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Iron Content (ppm) of Aromatic Rice – Wheat**

Treatment	Iron Content (ppm) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	135	482	478	159	623	407
25% RD <sub>NPK</sub>	159	554	450	168	641	419
50% RD <sub>NPK</sub>	165	519	452	168	688	524
75% RD <sub>NPK</sub>	170	782	454	187	656	485
100% RD <sub>NPK</sub>	159	659	427	179	926	383
25% RD <sub>NPKZn</sub>	163	667	454	146	639	497
50% RD <sub>NPKZn</sub>	166	629	395	172	754	328
75% RD <sub>NPKZn</sub>	165	602	516	141	878	365
100% RD <sub>NPKZn</sub>	162	496	470	157	746	435
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	154	725	476	153	997	407
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	166	657	457	227	599	383
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	166	676	481	276	778	382
100 % RD <sub>FYM</sub>	164	627	468	174	672	397
CD (p=0.05)	12	45	29	11	46	54
	Iron Content (ppm) (ppm) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	137	491	384	111	447	263
25% RD <sub>NPK</sub>	104	475	372	118	476	335
50% RD <sub>NPK</sub>	126	515	418	117	461	274
75% RD <sub>NPK</sub>	118	529	424	155	527	241
100% RD <sub>NPK</sub>	116	507	429	111	476	288
25% RD <sub>NPKZn</sub>	160	505	420	158	508	335
50% RD <sub>NPKZn</sub>	115	578	423	163	462	333
75% RD <sub>NPKZn</sub>	147	458	388	173	338	356
100% RD <sub>NPKZn</sub>	119	503	430	132	691	420
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	105	492	408	115	599	383
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	133	477	422	110	456	306
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	126	488	459	94	493	308
100 % RD <sub>FYM</sub>	122	477	428	165	465	331
CD (p=0.05)	12	35	21	5	24	36

but in the second year it was increased under 50 and 75%  $RD_{NPK}$  treatments. Application of higher levels of  $RD_{NPK}$  significantly increased Fe content in grain and straw parts of aromatic rice in comparison to control in both years.

Iron content of index leaf of rice was significantly lower than control under 50%  $RD_{NPKZn}$  treatment in both the years but it was higher than control in 75%  $RD_{NPKZn}$  and 25%  $RD_{NPKZn}$  treatments during first and second year, respectively. Application of all levels of  $RD_{NPKZn}$  significantly increased Fe content of grain and straw of rice in comparison control in the first year except for Fe content in straw under 100%  $RD_{NPKZn}$ . In the second year, significantly increase in Fe content of rice grain over control was noted under 50%  $RD_{NPKZn}$  treatment but at 25 and 75%  $RD_{NPKZn}$  levels Fe content of grain significantly decreased in comparison to control. Application of higher levels of  $RD_{NPKZn}$  also significantly increased Fe content of rice straw over control during second year. Application of FYM alone significantly increased Fe content of rice grain and straw over control in both the years. Swarup (1985) noted an increase in iron concentration of rice crop due to farmyard manure application.

All combinations of FYM and chemical fertilizers significantly increased Fe content of rice grain and straw over control in both the years expect for Fe content in grain and straw observed under 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  and 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  treatments, respectively during second year.

In wheat crop, application of 100%  $RD_{NPK}$  significantly increased Fe content in index leaf in comparison to control in the first year. In the second year Fe content in index leaf was increased over control under 25%  $RD_{NPK}$  treatment. Application of increasing levels of  $RD_{NPK}$  decreased Fe content in grain part in comparison to control in the first year but increased it in the second year. In the case of straw, Fe concentration increased with increasing level of  $RD_{NPK}$  in both the years.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased Fe concentration in index leaf of wheat in comparison to control in both the years; however, the increase noted at 75%  $RD_{NPKZn}$  in the first year was statistically not significant. Application of 25%  $RD_{NPKZn}$  significantly increased Fe concentration in grain in both the years and in straw in the second year. Application 50%  $RD_{NPKZn}$  decreased Fe content in grain over control in the first year but increased it in second

year. Application of 75%  $RD_{NPK}$  increased Fe content in grain but decreased it in straw in comparison to control in the second year. Highest (100%) level of  $RD_{NPKZn}$  decreased it in both grain and straw in the second year in comparison to control. The decrease in Fe content at 100%  $RD_{NPKZn}$  could be attributed to the antagonistic effect of Zn on Fe. Khan and Zende (1976) observed that application of zinc at 10 and 200 ppm significantly reduced the content of iron in wheat and maize. Sakal and Singh (1977) reported that application of calcium carbonate and zinc progressively decreased the iron content of different plant parts of wheat

Application of FYM alone significantly increased Fe concentration in index leaf in both the years and also in grain during second year but decreased it in the first year in comparison to control. Nemeth *et al* (1987) also reported that Fe content in wheat cv MV-8 was significantly increased with application of 34.7-69.4 ton FYM/ha.

All combinations of FYM and chemical fertilizers also significantly increased Fe concentration in index leaf over control in both the years. Application of 25%  $RD_{FYM} + RD_{NPKZn}$  and 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  significantly decreased Fe concentration in wheat grain as compared to control in the first and second year, respectively. Application of 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  and 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  significantly increased Fe concentration in wheat straw as compared to control in the second year.

#### 4.3.10 Manganese Content

The data on the effect of chemical fertilizers, FYM and their combinations on Mn content of index leaf, grain and straw of aromatic rice and wheat are presented in table 22.

It is evident from the data that application of increasing levels of  $RD_{NPK}$  significantly increased Mn content in straw part in both the years and in grain only during second year in comparison to control. Higher levels of  $RD_{NPK}$  decreased Mn content in grain during first year in comparison to control. Lower levels of  $RD_{NPK}$  significantly increased Mn content of index leaf over control.

Application of higher levels of  $RD_{NPKZn}$  significantly increased Mn content in straw parts in both the year and in grain during second year in comparison to

**Table 22: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Manganese Content (ppm) of Aromatic Rice – Wheat**

Treatment	Manganese Content (ppm) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	46.8	448.2	311.4	45.2	470.3	330.2
25% RD <sub>NPK</sub>	38.6	461.8	378.3	70.3	503.1	450.6
50% RD <sub>NPK</sub>	42.9	549.8	278.6	55.3	553.9	379.7
75% RD <sub>NPK</sub>	41.1	510.1	333.3	61.3	515.9	176.5
100% RD <sub>NPK</sub>	41.9	607.4	312.2	61.1	529.1	329.0
25% RD <sub>NPKZn</sub>	44.0	513.1	295.1	48.3	569.6	377.9
50% RD <sub>NPKZn</sub>	38.7	518.3	296.5	69.8	483.5	309.0
75% RD <sub>NPKZn</sub>	43.0	559.9	373.0	60.6	490.4	305.8
100% RD <sub>NPKZn</sub>	41.5	554.1	390.7	69.2	509.1	245.2
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	38.4	556.1	344.9	58.0	511.1	231.9
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	37.0	513.5	290.1	64.6	475.1	188.6
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	38.0	483.9	428.4	55.2	471.3	255.4
100 % RD <sub>FYM</sub>	41.6	445.1	257.3	56.1	383.9	252.4
CD (p=0.05)	4.4	43.3	38.0	3.9	45.2	7.1
	Manganese Content (ppm) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	50.8	70.7	60.6	53.0	62.2	52.2
25% RD <sub>NPK</sub>	50.8	76.4	66.0	65.6	80.1	52.7
50% RD <sub>NPK</sub>	47.3	67.7	59.9	53.7	61.1	55.2
75% RD <sub>NPK</sub>	42.5	66.7	59.7	61.4	65.6	63.1
100% RD <sub>NPK</sub>	53.8	70.4	62.9	67.8	56.3	55.1
25% RD <sub>NPKZn</sub>	54.6	69.1	62.0	73.0	56.6	51.9
50% RD <sub>NPKZn</sub>	48.6	74.3	65.9	36.7	60.6	56.9
75% RD <sub>NPKZn</sub>	48.1	69.8	61.8	41.0	55.1	59.0
100% RD <sub>NPKZn</sub>	46.6	72.9	62.1	61.4	57.0	55.1
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	54.9	69.6	62.0	38.1	55.5	60.5
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	47.6	64.8	63.4	46.0	53.8	51.3
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	47.2	76.4	64.2	50.5	57.1	50.1
100 % RD <sub>FYM</sub>	49.3	63.6	56.9	36.6	56.6	50.4
CD (p=0.05)	4.0	NS	NS	2.7	1.0	1.4

control. In the first year, higher levels of  $RD_{NPKZn}$  significantly decreased Mn content in grain in comparison to control due to the antagonistic effect of Zn applied in first year on Mn content. Other workers (Ishizuka and Ando, 1968; Khan and Zende, 1976 and Sakal *et al*, 1993) also observed that application of zinc decreased the content of manganese in rice cop. Lower level of  $RD_{NPKZn}$  significantly increased Mn content of index leaf over control during first year and in second year similar increase was noted at higher levels of  $RD_{NPKZn}$ .

Application of FYM alone decreased Mn content in index leaf in both the years, in grain during first year and in straw during second year in comparison to control but increased it in grain in the second year. Swarup (1985) noted an increase in manganese concentration of rice crop due to farmyard manure application. All combinations of FYM with chemical fertilizers decreased Mn in grain during first year and index leaf during second year but increased it during second year in comparison to control. Application of 25%  $RD_{FYM} + RD_{NPKZn}$  and 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  significantly increased Mn content in straw during first year while application of 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  significantly increased it in index leaf during first year in comparison to control.

In wheat crop, the content of Mn in grain during first year and in all plant parts during second year was significantly influenced by the treatments. Application of increasing levels of  $RD_{NPK}$  significantly increased Mn content in all plant parts during second year in comparison to control except for straw at 100%  $RD_{NPK}$  level in the second year.

Application of higher levels of  $RD_{NPKZn}$  significantly increased Mn content in index leaf of wheat as compared to control but decreased it in straw part during the second year. Application of 100%  $RD_{NPKZn}$  decreased Mn concentration in wheat grain as compared to control in the first year but increased it in the second year. Sakal and Singh (1977) and Sakal (1981) reported that zinc application decreased manganese concentration in grain and straw of wheat indicating some inhibitory effect on manganese nutrition.

Application of FYM alone significantly decreased Mn content in all plant parts of wheat in comparison to control during second year. Gupta *et al* (1987) also

reported that application of manures decreased manganese concentration in wheat straw.

Increasing proportion of FYM in combined treatments of FYM and chemical fertilizers together was conducive to decrease Mn concentration in all plant parts of wheat as compared to control during the second year.

#### 4.3.11 Boron Content

The data on the effect of chemical fertilizers, FYM and their combinations on B content of index leaf, grain and straw parts of aromatic rice and wheat crop are presented in table 23.

It is evident from the data that application of all levels of  $RD_{NPK}$  increased B content in index leaf over control in both years, the increase being significant at 75%  $RD_{NPK}$  in the first year and at 25, 50 and 75%  $RD_{NPK}$  levels in the second year. Boron content in index leaf at 50%  $RD_{NPK}$  level during first year was statistically lower than B content under control. Boron content in rice grain was significantly decreased in comparison to control at 25%  $RD_{NPK}$  level during first year but during the second year reverse was true. The increasing levels of  $RD_{NPK}$  significantly increased B content in straw part over control during both years except at 75%  $RD_{NPK}$  where the content was lower than control during first year.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased B concentration in index leaf of rice over control during second year except at 75%  $RD_{NPKZn}$  level while during the first year, the concentration of B in index leaf decreased in comparison to control especially at the responsive levels of  $RD_{NPKZn}$ . The concentration of B in rice grain increased significantly over control at higher levels of  $RD_{NPKZn}$  in both years, while in straw it was significantly increased at 75%  $RD_{NPKZn}$  level in the first year and at all levels of  $RD_{NPKZn}$  in the second year.

Application of FYM alone (100% FYM) significantly increased B concentration in index leaf in comparison to control in both the years and also in grain and straw parts during the second year.

All combinations of chemical fertilizers and FYM significantly increased B concentration in index leaf, grain and straw parts of rice over control during second year while in the first year such increase was limited only to 50%  $RD_{FYM}$  + 50%

**Table 23: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Boron Content (ppm) of Aromatic Rice – Wheat**

Treatment	Boron Content (ppm) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	9.86	8.20	13.02	6.70	8.84	11.64
25% RD <sub>NPK</sub>	6.82	10.78	13.70	8.66	14.80	17.70
50% RD <sub>NPK</sub>	11.38	10.84	10.40	6.58	13.44	18.72
75% RD <sub>NPK</sub>	9.38	6.96	15.30	6.24	14.00	17.74
100% RD <sub>NPK</sub>	11.14	9.54	13.60	6.26	18.18	12.40
25% RD <sub>NPKZn</sub>	6.38	8.60	14.26	6.78	15.18	14.66
50% RD <sub>NPKZn</sub>	13.52	9.00	10.68	6.98	13.90	17.94
75% RD <sub>NPKZn</sub>	13.24	9.30	7.10	8.56	17.32	10.38
100% RD <sub>NPKZn</sub>	11.30	7.58	13.84	9.22	14.52	16.04
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	11.40	10.18	13.36	7.42	14.40	18.94
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	18.02	7.98	13.84	9.46	14.64	14.28
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	16.46	9.68	13.28	11.22	16.86	19.12
100 % RD <sub>FYM</sub>	10.90	9.00	18.08	8.46	17.10	18.90
CD (p=0.05)	1.71	1.09	1.73	0.50	1.16	1.37
	Boron Content (ppm) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	9.70	7.54	11.78	11.38	9.96	12.78
25% RD <sub>NPK</sub>	7.00	13.62	12.78	12.14	8.84	9.80
50% RD <sub>NPK</sub>	8.64	11.14	15.16	16.86	8.14	10.56
75% RD <sub>NPK</sub>	6.32	9.74	15.52	8.40	10.78	16.62
100% RD <sub>NPK</sub>	5.68	7.38	15.96	7.04	13.46	14.82
25% RD <sub>NPKZn</sub>	8.62	9.36	14.66	4.76	9.80	12.64
50% RD <sub>NPKZn</sub>	7.22	12.54	10.30	7.10	7.50	8.98
75% RD <sub>NPKZn</sub>	7.22	7.12	9.64	9.42	9.08	16.96
100% RD <sub>NPKZn</sub>	8.96	7.24	17.72	8.72	14.42	10.78
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	6.94	9.80	15.20	16.56	8.94	10.50
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	5.32	10.42	16.32	16.06	8.06	13.64
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	6.56	9.68	10.54	9.82	8.16	9.26
100 % RD <sub>FYM</sub>	5.94	9.76	12.38	15.44	8.12	13.62
CD (p=0.05)	1.43	1.90	2.04	0.48	0.45	0.79

$RD_{NPKZn}$  and  $75\% RD_{FYM} + 25\% RD_{NPKZn}$  in the case of grain and to  $25\% RD_{FYM} + 75\% RD_{NPKZn}$  and  $75\% RD_{FYM} + 25\% RD_{NPKZn}$  in the case of straw.

In wheat crop, B concentration in index leaf was significantly increased over control at higher levels of  $RD_{NPK}$  in both years. Boron content in wheat grain decreased at increasing levels of  $RD_{NPK}$  in comparison to control in the first year but during second year it was significantly increased over control especially at lower levels of  $RD_{NPK}$ . Boron concentration in wheat straw was significantly increased over control at all levels of  $RD_{NPK}$  except at  $100\% RD_{NPK}$  level during the first year, but in the second year, such increase was significant especially at higher level of  $RD_{NPK}$ . Nemeth *et al* (1987) reported that in wheat cv. MV-8, application of inorganic fertilizers favoured B content.

Application of  $RD_{NPKZn}$  significantly increased B concentration in index leaf over control at 25% and 100% levels in the first year and also at 75% level during second year. Boron concentration in index leaf was significantly lower than control at 75%  $RD_{NPKZn}$  level during first year and also at 50 and 100%  $RD_{NPKZn}$  levels during second year. Boron concentration in wheat grain was significantly lower than control at all  $RD_{NPKZn}$  levels in both the years. Boron concentration in wheat straw was significantly increased over control at lower levels of  $RD_{NPKZn}$  in the first year but during second year such increase was recorded only at  $100\% RD_{NPKZn}$  level.

Application of FYM alone significantly increased B concentration in index leaf over control during second year only. Boron concentration in wheat grain under FYM alone was significantly lower than control during first year, but reverse was true with second year; while in straw it was increased during first year but decreased in the second year. Similar trend was noted with various combinations of chemical fertilizer and FYM.

#### 4.3.12 Molybdenum Content

The data on the effect of chemical fertilizers, FYM and their combination on Mo content of index leaf, grain and straw of aromatic rice and wheat crops are presented in table 24.

It is evident from the data that application of all levels of  $RD_{NPK}$  significantly increased Mo content of index leaf of rice in comparison to control during second year. In the first year, however, such increase was only significant at  $100\% RD_{NPK}$

**Table 24: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Molybdenum Content (ppm) of Aromatic Rice – Wheat**

Treatment	Molybdenum Content (ppm) in Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.862	0.341	0.947	0.430	0.158	0.433
25% RD <sub>NPK</sub>	0.863	0.351	0.384	0.467	0.360	0.380
50% RD <sub>NPK</sub>	0.962	0.531	0.865	0.351	0.435	0.720
75% RD <sub>NPK</sub>	0.964	0.456	0.772	0.262	0.365	0.638
100% RD <sub>NPK</sub>	0.962	0.776	1.117	0.361	0.563	0.828
25% RD <sub>NPKZn</sub>	0.963	0.576	1.315	0.603	0.340	0.743
50% RD <sub>NPKZn</sub>	0.979	0.481	1.140	0.372	0.381	1.000
75% RD <sub>NPKZn</sub>	0.967	0.526	0.943	0.752	0.475	0.873
100% RD <sub>NPKZn</sub>	0.908	0.386	0.417	0.718	0.726	0.802
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.918	0.356	0.396	0.930	0.700	0.775
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.856	0.291	0.796	0.331	0.277	0.647
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.816	0.230	0.694	0.334	0.226	0.715
100 % RD <sub>FYM</sub>	0.961	0.356	0.710	0.413	0.320	0.658
CD (p=0.05)	0.008	0.003	0.050	0.025	0.033	0.029
	Molybdenum Content (ppm) in Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Leaf	Grain	Straw	Leaf
Control	0.414	0.721	1.049	0.189	0.330	0.479
25% RD <sub>NPK</sub>	0.209	0.233	0.375	0.207	0.231	0.371
50% RD <sub>NPK</sub>	0.304	0.388	0.947	0.253	0.323	0.789
75% RD <sub>NPK</sub>	0.504	0.402	0.619	0.416	0.332	0.512
100% RD <sub>NPK</sub>	0.641	0.658	0.579	0.475	0.488	0.429
25% RD <sub>NPKZn</sub>	0.711	0.631	0.757	0.402	0.357	0.428
50% RD <sub>NPKZn</sub>	0.480	0.336	0.439	0.421	0.295	0.385
75% RD <sub>NPKZn</sub>	1.528	0.632	0.573	1.564	0.585	0.530
100% RD <sub>NPKZn</sub>	1.297	0.359	0.351	1.552	0.690	0.674
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.216	0.335	0.362	1.344	0.657	0.711
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.674	0.530	1.081	1.613	0.431	0.879
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	1.365	0.419	0.421	1.499	0.432	0.434
100 % RD <sub>FYM</sub>	1.526	0.440	0.398	1.654	0.408	0.369
CD (p=0.05)	0.824	0.039	0.058	0.213	0.042	0.052

level and at lower levels the content of Mo in index leaf was decreased in comparison to control. Application of higher levels of  $RD_{NPK}$  also significantly increased Mo content in grain and straw parts over control during first year and in straw part in the second year; however, in rice grain the Mo content registered a decreased in comparison to control during second year.

Application of all levels of  $RD_{NPKZn}$  increased Mo content in index leaf over control in both the years and increasing levels diluted the content of Mo in index leaf. However, Mo content of index leaf during first year under 100%  $RD_{NPKZn}$  treatment was significantly lower than control. All levels of  $RD_{NPKZn}$  also increased Mo content in grain and straw parts over control in both the year except for grain under 50%  $RD_{NPKZn}$  during second year where the content was significantly lower than control.

Application of FYM alone (100%  $RD_{FYM}$ ) significantly increased Mo content of index leaf over control during second year but in the first year the reverse was true. The Mo content of grain and straw parts was significantly higher than control in both the years. Nemeth *et al* (1987) reported that in wheat cv. MV-8, Mo contents were greater in crop manured with FYM.

All combinations of FYM and chemical fertilizers significantly increased Mo content of index leaf over control during second year but the reverse was true during first year. Decreasing proportion of chemical fertilizer decreased Mo content in both grain and straw during both the years.

In wheat crop, all levels of  $RD_{NPK}$  decreased Mo content in index leaf in comparison to control during first year, however, during second year Mo content of index leaf under 50%  $RD_{NPK}$  was significantly higher than control. All levels of  $RD_{NPK}$  decreased Mo content in straw in comparison to control during first year but in grain part it was significantly increased over control under 75%  $RD_{NPK}$  during second year.

All levels of  $RD_{NPKZn}$  significantly decreased Mo content in index leaf and straw parts of wheat in comparison to control during first year, however, in the second year especially higher levels of  $RD_{NPKZn}$  tended to increase Mo content of these parts over control. The Mo content of grain part was significantly increased over control especially under higher  $RD_{NPKZn}$  levels.

Application of FYM alone (100%  $RD_{FYM}$ ) decreased Mo content of index leaf, in comparison to control in both the years and also of straw in the first year alone. The content of Mo in grain part was significantly increased over control in both the years but in straw part it was significantly decreased during the first year.

All combination of FYM and chemical fertilizers significantly increased Mo content of grain over control in both the years except for increase registered under 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  in the first year. The Mo content of index leaf was significantly increased over control in the first year but mostly decreased during the first year. The Mo content in straw part was significantly increased over control in the second year but decreased significantly in the first year.

#### 4.4 Effect of Chemical Fertilizers, FYM and their Conjoint Use on Nutrient Uptake of Aromatic Rice – Wheat Sequence

##### 4.4.1 Nitrogen Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combination on the nitrogen uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 25.

##### RICE:

The data show that increasing levels of  $RD_{NPK}$  significantly increased the nitrogen uptake by grain, straw and total crop over control in both the years, except for the uptake noted at 25%  $RD_{NPK}$  by grain, straw and total crop during first year and by grain during second year, and at 50%  $RD_{NPK}$  by straw and total crop during first year. These results are in conformity with those observed by Marr *et al* (1999) and Gangiah and Prasad (1999).

Application of increasing levels of  $RD_{NPKZn}$  significantly increased the nitrogen uptake by grain, straw and total crop over control during both the years, except for the uptake recorded at 50%  $RD_{NPKZn}$  by grain and straw in the first year; and at 75% and 100%  $RD_{NPKZn}$  by straw during first year. The addition of zinc to soil has been reported to increase N contents and uptake of many crops (Singh and Tripathi, 1974; Kene and Deshpande, 1980; Singh and Singh, 1981; Hualagur and Dangarwala, 1983).

Application of 100%  $RD_{FYM}$  significantly increased N uptake by grain and total crop over control during first year only. Brar *et al* (1995) and Sadana *et al* (1995) also observed similar results.

All combination of FYM and NPKZn significantly increased nitrogen uptake by grain, straw and total crop over control during both the years, except for the uptake noted at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  by straw during first year.

##### WHEAT

It is evident from the data of wheat crop that application of increasing levels of  $RD_{NPK}$  significantly increased the nitrogen uptake by grain, straw and total crop over control during both the years. However, the uptakes recorded at 25%  $RD_{NPK}$  by grain and straw during first year and by straw during second year; at 50%  $RD_{NPK}$  by grain, straw and total crop during first year and by straw during

**Table 25: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Nitrogen Uptake (kg/ha) of Aromatic Rice – Wheat**

Treatment	Nitrogen Uptake (kg/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	15.86	22.23	38.10	14.13	16.26	30.38
25% RD <sub>NPK</sub>	20.46	24.75	45.21	15.28	26.10	41.38
50% RD <sub>NPK</sub>	28.69	18.55	47.23	18.71	26.26	44.97
75% RD <sub>NPK</sub>	32.83	28.28	61.11	18.54	35.66	54.20
100% RD <sub>NPK</sub>	23.95	31.82	55.77	26.36	38.40	64.76
25% RD <sub>NPKZn</sub>	28.87	32.59	61.46	22.56	26.96	49.53
50% RD <sub>NPKZn</sub>	22.31	27.56	49.87	19.87	25.86	45.73
75% RD <sub>NPKZn</sub>	33.45	26.68	60.13	23.86	36.51	60.37
100% RD <sub>NPKZn</sub>	27.97	27.41	55.38	20.41	35.70	56.10
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	26.84	26.36	53.20	22.04	43.95	65.99
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	27.78	29.20	56.98	20.17	26.41	46.58
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	40.63	31.65	72.28	23.07	34.49	57.56
100 % RD <sub>FYM</sub>	28.87	25.04	53.90	14.44	19.37	33.81
CD (p=0.05)	7.33	5.82	9.52	2.98	3.53	4.08
	Nitrogen Uptake (kg/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	21.61	13.43	35.04	6.62	10.08	16.70
25% RD <sub>NPK</sub>	25.12	17.00	42.11	12.61	12.13	24.73
50% RD <sub>NPK</sub>	23.49	16.95	40.44	17.88	10.15	28.03
75% RD <sub>NPK</sub>	26.13	18.43	44.57	16.87	34.36	51.23
100% RD <sub>NPK</sub>	27.66	22.85	50.51	35.07	17.49	52.56
25% RD <sub>NPKZn</sub>	19.60	14.74	34.34	29.42	16.43	45.85
50% RD <sub>NPKZn</sub>	27.64	19.05	46.69	18.85	22.63	41.48
75% RD <sub>NPKZn</sub>	30.62	20.48	51.10	21.39	11.67	33.06
100% RD <sub>NPKZn</sub>	30.93	23.51	54.43	55.44	9.07	64.51
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	23.60	18.47	42.07	26.42	5.92	32.35
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	28.40	20.35	48.74	30.54	8.38	38.92
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	29.95	22.71	52.66	40.91	11.95	52.86
100 % RD <sub>FYM</sub>	18.43	14.60	33.03	24.01	11.11	35.12
CD (p=0.05)	4.79	3.72	5.75	4.53	5.97	5.99

second year; and at 75%  $RD_{NPK}$  by grain during first year were statistically not significant over control.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased N uptake by grain, straw and total crop over control during both the years, except for the uptake noted at 25%  $RD_{NPKZn}$  by grain, straw and total crop during first year; and at 75% and 100%  $RD_{NPKZn}$  by straw during second year. Singh and Tripathi (1974) reported an increase in N contents and uptake by wheat crop due to zinc application.

Application of 100%  $RD_{FYM}$  significantly increased N uptake by grain and total crop over control during second year.

All combinations of FYM and  $NPKZn$  significantly increased N uptake by grain, straw and total crop over control during both the years, except for the uptake recorded at 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  by grain during first year and uptake by straw under all combinations during second year.

#### **TOTAL UPTAKE BY RICE-WHEAT SEQUENCE**

As shown in figure 2, application of all levels of  $RD_{NPK}$ , especially higher levels significantly increased total N uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in N uptake at 25, 50, 75 and 100 %  $RD_{NPK}$  was 30.8, 37.3, 73.5 and 107.3 percent over control, respectively.

Application of  $RD_{NPKZn}$  also significantly increased total N uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total N uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 61.6, 68.4, 70.3 and 156.7 percent over control, respectively.

Application of 100% FYM significantly increased total N uptake of rotation over control in the second year. For yearwise pooled data, application of FYM increased the total N uptake of rotation by 38.3 percent over control.

All combinations of FYM and  $NPKZn$  significantly increased total N uptake of rice-wheat sequence over control in both the years, except under with 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  during first year. For yearwise pooled data, the magnitude of increase in total N uptake of rotation at 25%  $RD_{FYM} + 75\%$

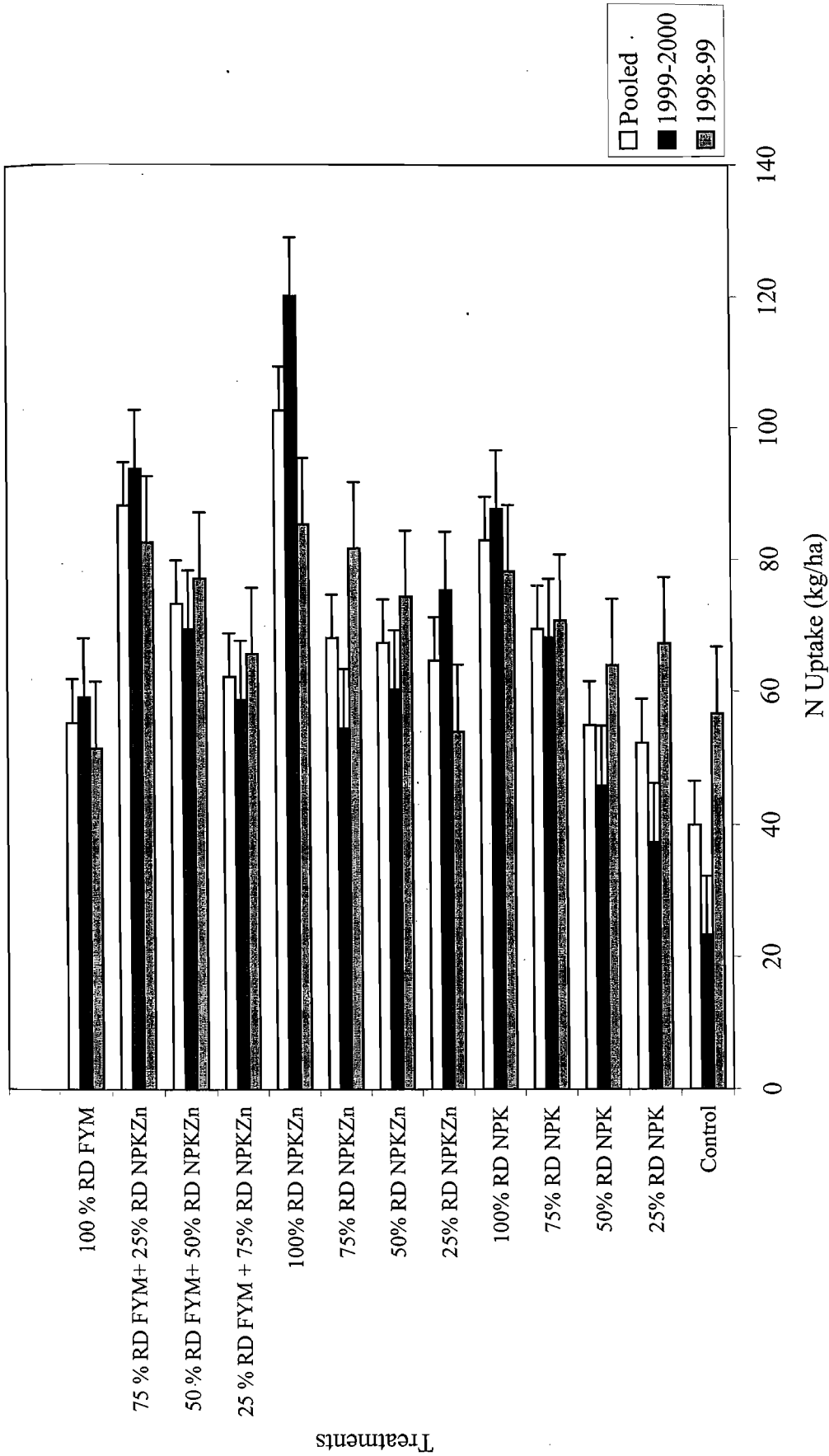


Figure 2: Effect of Chemical Fertilizer, FYM and their conjunctive use on N uptake (kg/ha) of aromatic rice-wheat sequence

$RD_{NPKZn}$ ,  $50\% RD_{FYM} + 50\% RD_{NPKZn}$  and  $75\% RD_{FYM} + 25\% RD_{NPKZn}$  was 55.6, 83.3 and 120.5 percent over control, respectively.

A comparison of pooled data of total N uptake recorded at various combinations of FYM and NPKZn with their corresponding values noted at NPKZn levels revealed that the role of FYM in significantly increasing total N uptake over chemical fertilizer source was noted at  $75\% RD_{FYM} + 25\% RD_{NPKZn}$ .

#### 4.4.2 Phosphorus Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the phosphorus uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 26.

##### RICE

It is evident from the data that increasing levels of  $RD_{NPK}$  significantly increased the phosphorus uptake by grain, straw and total rice crop over control in both the years, except for the increase in uptake noted at  $25\% RD_{NPK}$  for rice grain in the second year. In the first year, no significant increase in total P uptake by rice crop was noted beyond  $75\% RD_{NPK}$  level.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased the phosphorus uptake by grain and straw parts and total P uptake of rice crop over control in both the years, except for the increase in P uptake noted at 25 and  $50\% RD_{NPK}$  level for rice grain in the first year. During first year, no significant successive increase in total P uptake of rice was noted beyond  $75\% RD_{NPKZn}$  level. In general, no detrimental effect of Zn addition on total P uptake of rice was noted at any  $RD_{NPK}$  level in both the years except at 50 and  $100\% RD_{NPKZn}$  levels in the first year only.

Application of FYM alone ( $100\% RD_{FYM}$ ) significantly increased phosphorus uptake by rice grain, straw and their total in comparison to control during the first year. But during the second year, the increase recorded in P uptake by rice grain and also in total P uptake by crop was statistically not significant.

All combinations of FYM and chemical fertilizers significantly increased P uptake by rice grain, straw and their total uptake over control in both the years.

**Table 26: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Phosphorus Uptake (kg/ha) of Aromatic Rice – Wheat**

Treatment	Phosphorus Uptake (kg/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	3.65	3.14	6.79	3.57	3.83	7.39
25% RD <sub>NPK</sub>	4.64	3.95	8.58	3.56	6.30	9.86
50% RD <sub>NPK</sub>	4.99	5.76	10.75	5.37	5.69	11.06
75% RD <sub>NPK</sub>	6.38	8.00	14.38	4.90	7.49	12.39
100% RD <sub>NPK</sub>	5.57	7.83	13.40	6.41	8.22	14.63
25% RD <sub>NPKZn</sub>	3.72	5.00	8.72	5.22	5.21	10.43
50% RD <sub>NPKZn</sub>	3.62	4.79	8.41	6.13	5.20	11.33
75% RD <sub>NPKZn</sub>	7.04	7.13	14.17	5.72	6.70	12.42
100% RD <sub>NPKZn</sub>	4.55	5.59	10.13	5.14	10.27	15.41
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	4.86	5.55	10.41	4.20	7.59	11.79
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	5.14	5.28	10.42	4.36	5.73	10.09
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	5.54	5.47	11.01	5.70	9.61	15.31
100 % RD <sub>FYM</sub>	4.27	5.20	9.47	3.36	4.67	8.03
CD (p=0.05)	0.74	0.62	1.02	0.81	0.74	1.12
	Phosphorus Uptake (kg/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	8.69	3.12	11.81	4.51	2.98	7.48
25% RD <sub>NPK</sub>	9.86	3.81	13.67	10.25	4.02	14.26
50% RD <sub>NPK</sub>	9.49	4.27	13.76	9.63	3.59	13.22
75% RD <sub>NPK</sub>	11.16	4.19	15.36	10.27	7.40	17.67
100% RD <sub>NPK</sub>	13.14	6.78	19.92	11.77	3.58	15.35
25% RD <sub>NPKZn</sub>	10.15	5.04	15.19	8.81	2.87	11.68
50% RD <sub>NPKZn</sub>	11.30	4.00	15.29	9.16	5.90	15.06
75% RD <sub>NPKZn</sub>	12.09	4.23	16.31	14.33	4.10	18.43
100% RD <sub>NPKZn</sub>	13.10	4.88	17.98	13.44	4.71	18.15
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	9.89	4.79	14.68	7.98	4.41	12.38
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	10.93	5.11	16.04	7.93	3.19	11.12
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	11.23	3.98	15.21	10.22	4.79	15.01
100 % RD <sub>FYM</sub>	8.40	5.30	13.69	7.05	2.85	9.90
CD (p=0.05)	1.57	1.00	1.97	2.12	0.68	2.31

except for the increase in P uptake by rice grain in the second year under 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  and 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  levels. In the first year, total P uptake under various combinations of FYM and chemical fertilizers was at par with total P uptake under 100%  $RD_{NPKZn}$  while in the second year, total P uptake under 75%  $RD_{FYM} + RD_{NPKZn}$  was *at par* with total P uptake under 100%  $RD_{NPKZn}$  which was significantly higher than total P uptake under 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  or 50%  $RD_{FYM} + 50\% RD_{NPKZn}$ . Nazir *et al* (1998) also observed increase in P uptake in basmati rice due to application of organic matter and phosphatic fertilizers.

#### WHEAT

In wheat crop, the increasing levels of  $RD_{NPK}$  significantly increased phosphorus uptake by grain, straw and their total over control in both the years, except at lower  $RD_{NPK}$  level during first year and at 50% and 100%  $RD_{NPK}$  levels for straw during second year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased phosphorus uptake by grain, straw and their total over control during both the years, however, the increase noted at 25%  $RD_{NPKZn}$  for wheat grain during first year and for straw during second year; and at 50%  $RD_{NPKZn}$  for straw during first year was statistically not significant. Use of different levels of  $RD_{NPKZn}$  did not substantially increase P uptake over corresponding  $RD_{NPK}$  level possibly due to lack of Zn response in wheat in the experiment. Kuligod *et al* (1994), however, observed increase in P uptake due to zinc application.

Application of FYM alone (100%  $RD_{FYM}$ ) could not significantly affect phosphorus uptake by grain and total uptake by crop during first year, but increased significantly over control during second year. Phosphorus uptake by straw due to 100% application of FYM was significantly higher over control during first year, but no significant increase over control was noted during second year.

All combinations of FYM and  $NPKZn$  significantly increased phosphorus uptake by grain, straw and their total over control during both the years, except for 25%  $FYM + 75\% RD_{NPKZn}$  in the case of grain and 75%  $RD_{FYM} + 25\%$

$RD_{NPKZn}$  in the case of straw during first year; and 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  in the case of straw during second year.

#### **TOTAL UPTAKE BY RICE-WHEAT SEQUENCE**

As depicted in figure 3, application of all levels of  $RD_{NPK}$  significantly increased total P uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total P uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 38.5, 45.7, 78.6 and 89.1 percent over control, respectively.

Application of all levels of  $RD_{NPKZn}$  also significantly increased total P uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total P uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPKZn}$  was 37.4, 49.6, 83.2 and 84.2 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) significantly increased total P uptake of rotation in comparison to control in both the years. For yearwise pooled data, the application of 100%  $RD_{FYM}$  significantly increased the total P uptake of rotation by 22.7 percent over control.

Various combinations of FYM and NPKZn also significantly increased total P uptake of rice-wheat sequence over control, in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total P uptake of rotation by 47.1, 42.4 and 68.1 percent over control, respectively.

A comparison of pooled P uptake data recorded for various combinations of FYM and NPKZn with their corresponding values noted at  $RD_{NPKZn}$  levels revealed that significant effect of FYM in promoting total P uptake of rotation was noted only with 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination. However, at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , application of FYM significantly decreased total P uptake of rotation in comparison to P uptake recorded at 75%  $RD_{NPK}$  alone.

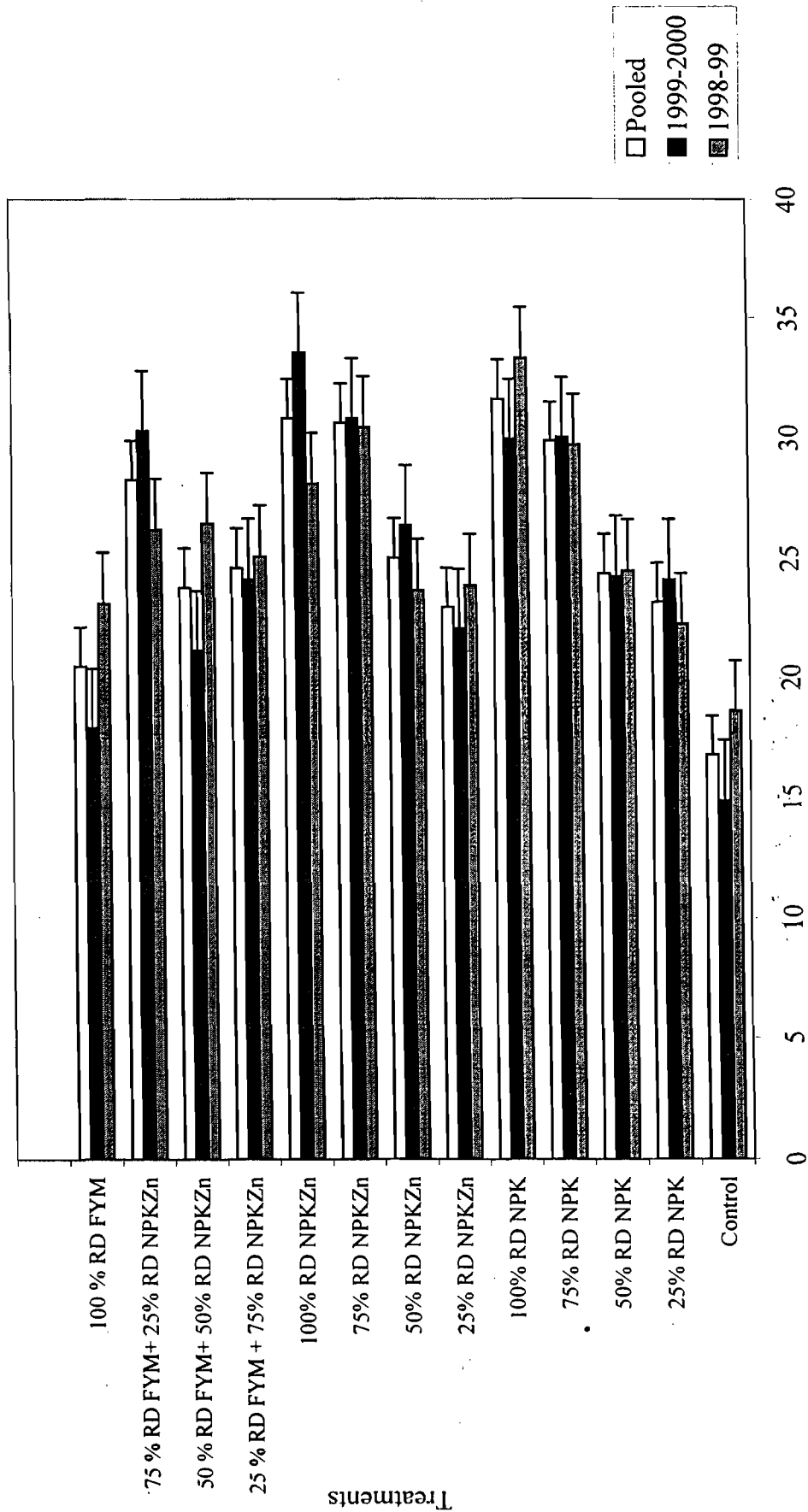


Figure 3: Effect of Chemical Fertilizer, FYM and their conjunctive use on P uptake (kg/ha) of aromatic rice-wheat sequence

### 4.4.3 Potassium Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the potassium uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 27.

#### RICE

The data show that potassium uptake by rice grain did not change significantly over control at any level of  $RD_{NPK}$  during first year, while during second year, application of increasing levels of  $RD_{NPK}$  significantly increased the potassium uptake by grain in comparison to 25%  $RD_{NPK}$ . The potassium uptake by straw and total rice crop increased significantly over control at all levels of  $RD_{NPK}$  in both the years, however, the increase at 50%  $RD_{NPK}$  during first year was statistically not significant.

Application of  $RD_{NPKZn}$  levels could not significantly affect potassium uptake by grain, straw and total crop except at 75%  $RD_{NPKZn}$  during first year, where potassium uptake was significantly increased over control. During second year, the application of  $RD_{NPKZn}$  levels significantly increased potassium uptake by grain, straw and total crop over control at all levels.

Application of 100%  $RD_{FYM}$  could not significantly affect potassium uptake by grain, straw and total potassium uptake by crop during both years, however, increase in potassium uptake by straw and total uptake of rice due to FYM in second year was statistically significant.

The combined application of FYM and NPKZn did not significantly affect potassium uptake by grain, straw and total crop over control during first year, except for 25%  $RD_{FYM}$  + 75%  $RD_{FYM} RD_{NPKZn}$ , which increased significantly potassium uptake by straw and total crop uptake significantly over control. During second year, all combinations significantly increased potassium uptake over control, by grain, straw and total crop. Total potassium uptake by rice at 75%  $RD_{NPKZn}$  was at par with total potassium uptake recorded at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  in the first year and at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  during second year.

**Table 27: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Potassium Uptake (kg/ha) of Aromatic Rice – Wheat**

Treatment	Potassium Uptake (kg/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	5.29	26.48	31.77	3.93	27.40	31.33
25% RD <sub>NPK</sub>	6.56	40.45	47.01	3.82	57.21	61.03
50% RD <sub>NPK</sub>	8.03	22.29	30.33	5.15	47.51	52.66
75% RD <sub>NPK</sub>	6.73	53.26	59.99	5.58	71.64	77.21
100% RD <sub>NPK</sub>	6.58	62.53	69.11	6.97	63.31	70.29
25% RD <sub>NPKZn</sub>	6.53	28.33	34.85	5.50	49.52	55.01
50% RD <sub>NPKZn</sub>	4.75	22.10	26.85	5.83	38.38	44.22
75% RD <sub>NPKZn</sub>	8.14	38.95	47.08	6.54	44.34	50.88
100% RD <sub>NPKZn</sub>	6.70	24.76	31.46	6.00	69.61	75.61
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	6.36	44.63	50.98	5.02	65.26	70.28
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	6.21	27.45	33.66	5.12	49.93	55.05
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	5.04	22.02	27.06	6.71	71.25	77.96
100 % RD <sub>FYM</sub>	6.13	20.41	26.54	3.85	47.97	51.82
CD (p=0.05)	NS	8.36	9.16	0.78	7.51	7.57
	Potassium Uptake (kg/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	6.16	20.86	27.02	3.20	16.11	19.31
25% RD <sub>NPK</sub>	7.18	22.12	29.30	7.55	20.51	28.05
50% RD <sub>NPK</sub>	9.51	26.91	36.43	8.68	19.70	28.38
75% RD <sub>NPK</sub>	7.95	27.09	35.04	8.31	44.02	52.33
100% RD <sub>NPK</sub>	9.19	33.48	42.66	8.16	41.75	49.90
25% RD <sub>NPKZn</sub>	8.10	21.26	29.36	6.64	20.16	26.80
50% RD <sub>NPKZn</sub>	7.93	25.23	33.16	7.08	34.08	41.16
75% RD <sub>NPKZn</sub>	10.55	27.84	38.39	11.56	41.07	52.63
100% RD <sub>NPKZn</sub>	14.91	34.34	49.24	11.50	41.57	53.07
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	7.16	24.52	31.68	8.24	25.70	33.94
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	8.68	22.80	31.48	5.76	25.27	31.03
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	8.45	25.54	33.98	8.84	34.91	43.75
100 % RD <sub>FYM</sub>	6.43	19.91	26.33	5.19	17.84	23.03
CD (p=0.05)	3.54	4.15	5.53	1.22	4.53	4.70

## WHEAT

In wheat crop, application of higher levels of  $RD_{NPK}$  significantly increased potassium uptake by straw and total crop over control, during first year. During second year, application of increasing levels of  $RD_{NPK}$  significantly increased potassium uptake by grain, straw and total crop over control except for the increase noted in potassium uptake by straw at 25% and 50%  $RD_{NPK}$ , which was statistically not significant. Bajwa and Paul (1978) and Brar *et al* (1995) also observed increase in K uptake of crop due to NPK application.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased potassium uptake by grain, straw and total crop over control during both the years, except at 25%  $RD_{NPKZn}$  for grain, straw and total crop and 50%  $RD_{NPKZn}$  for grain during first year; and 25%  $RD_{NPKZn}$  for straw during second year.

Application of 100%  $RD_{FYM}$  did not significantly affect potassium uptake by wheat crop during both the years, except for potassium uptake by grain during second year, which was significantly higher over control.

The effect of combined application of FYM and NPKZn on increasing potassium uptake by grain, straw and total crop was different during first and second year. In the first year, application of 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased potassium uptake by straw and total crop over control. During second year, all combinations significantly increased potassium uptake by grain, straw and total crop over control. Total potassium uptake noted under any combination of FYM and NPKZn was significantly lower than total potassium uptake at 100%  $RD_{NPKZn}$ .

## TOTAL UPTAKE BY RICE-WHEAT SEQUENCE

As shown in figure 4, application of  $RD_{NPK}$ , especially at lower and higher levels significantly increased total K uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total K uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 51.1, 35.1, 105.2 and 112.0 percent over control, respectively.

Application of  $RD_{NPKZn}$  especially at higher levels significantly increased total K uptake of rotation over control in both the years. For the yearwise pooled

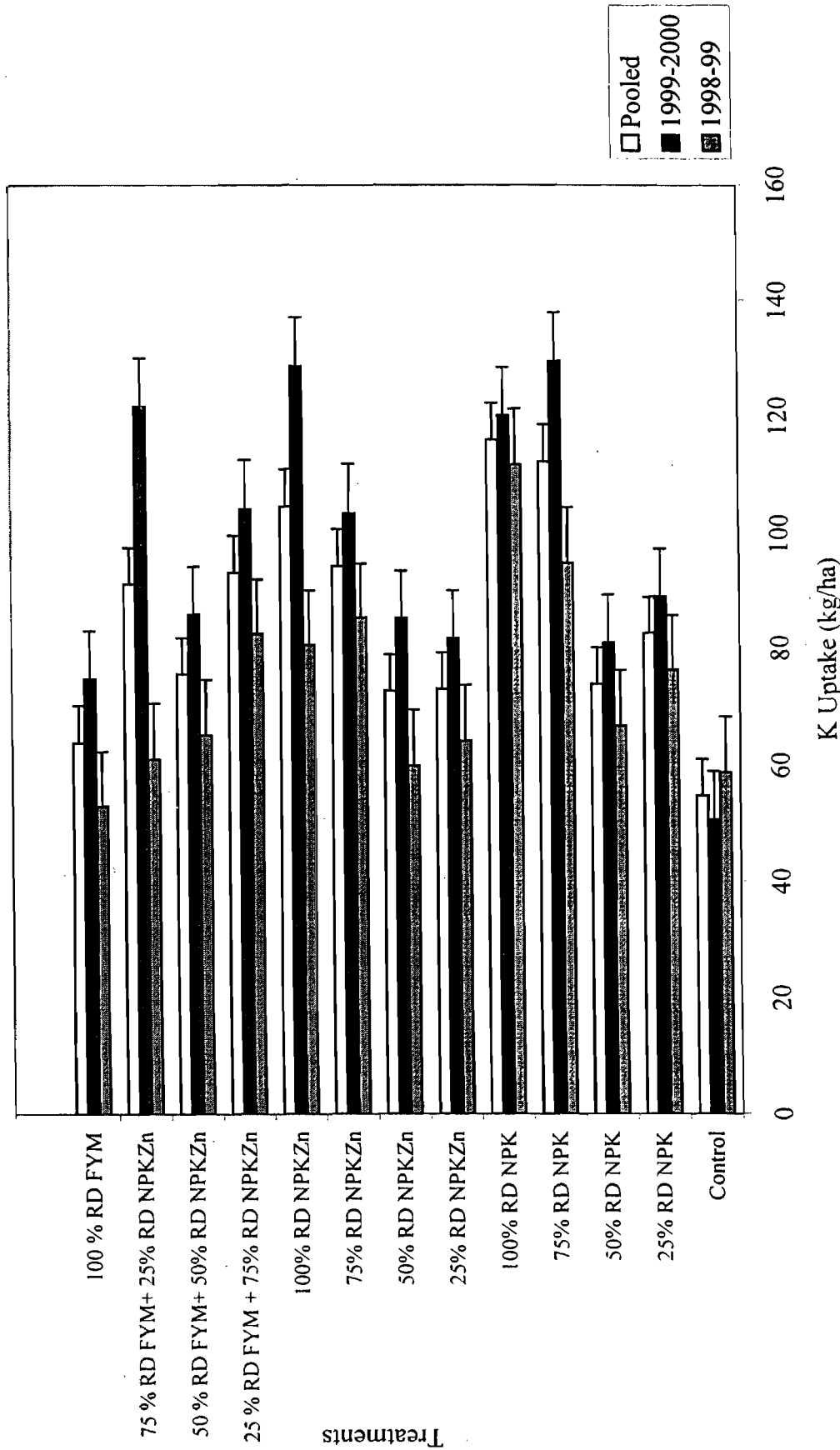


Figure 4: Effect of Chemical Fertilizer, FYM and their conjunctive use on K uptake (kg/ha) of aromatic rice-wheat sequence

data, the magnitude of increase in total K uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 33.4, 32.9, 72.7 and 91.4 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) also increased total K uptake of rotation in comparison to control in the second year. For yearwise pooled data, the application of 100% FYM significantly increased the total K uptake of rotation by 16.7 percent over control.

Various combinations of FYM and NPKZn also significantly increased total K uptake of rice-wheat sequence over control in second year. For yearwise pooled data, the application of 25%  $RD_{FYM}$  +75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  +50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total K uptake of rotation by 70.8, 38.2 and 67.0 percent over control, respectively.

A comparison of pooled K uptake data recorded for various combinations of FYM and NPKZn with their corresponding values noted at  $RD_{NPKZn}$  levels revealed that significant effect of FYM in promoting total K uptake of rotation was noted only at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination.

#### 4.4.4 Calcium Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the calcium uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 28.

##### RICE

Application of all levels of  $RD_{NPK}$  significantly increased the calcium uptake by grain over control in both the years, while in straw Ca uptake was significantly increased over control at 75% and 100%  $RD_{NPK}$  during first year; and at all levels during second year. Application of NPK at all levels significantly increased total Ca uptake by crop over control during both the years, except at 25%  $RD_{NPK}$  during first year. Marr *et al* (1999) observed an increase in Ca uptake due to NPK application.

Application of all levels of  $RD_{NPKZn}$  also significantly increased the calcium uptake by grain, straw and total crop over control during both the years.

**Table 28: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Calcium Uptake (kg/ha) of Aromatic Rice – Wheat**

Treatment	Calcium Uptake (kg/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	2.11	19.83	21.94	0.72	15.39	16.11
25% RD <sub>NPK</sub>	2.65	21.35	24.00	1.06	32.09	33.15
50% RD <sub>NPK</sub>	3.08	22.06	25.15	1.98	22.62	24.60
75% RD <sub>NPK</sub>	3.09	27.29	30.38	2.14	38.90	41.04
100% RD <sub>NPK</sub>	3.04	31.03	34.06	2.36	46.99	49.35
25% RD <sub>NPKZn</sub>	2.57	27.45	30.02	2.18	22.25	24.44
50% RD <sub>NPKZn</sub>	2.44	24.77	27.21	2.79	27.02	29.81
75% RD <sub>NPKZn</sub>	3.46	28.10	31.56	2.64	32.87	35.51
100% RD <sub>NPKZn</sub>	3.28	26.33	29.60	2.54	36.96	39.49
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	2.66	26.64	29.30	2.72	32.41	35.12
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	2.69	26.02	28.71	2.33	28.19	30.52
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	3.50	23.58	27.08	2.55	41.19	43.73
100 % RD <sub>FYM</sub>	2.48	23.38	25.86	1.92	24.79	26.71
CD (p=0.05)	0.33	2.53	2.58	0.33	4.29	4.32
	Calcium Uptake (kg/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	0.37	0.94	1.31	0.16	0.69	0.85
25% RD <sub>NPK</sub>	0.44	1.07	1.50	0.32	0.95	1.27
50% RD <sub>NPK</sub>	0.43	1.22	1.65	0.28	1.08	1.35
75% RD <sub>NPK</sub>	0.47	1.27	1.74	0.24	2.02	2.26
100% RD <sub>NPK</sub>	0.53	1.52	2.05	0.34	1.77	2.10
25% RD <sub>NPKZn</sub>	0.41	1.06	1.46	0.25	0.72	0.97
50% RD <sub>NPKZn</sub>	0.50	1.32	1.81	0.32	1.99	2.32
75% RD <sub>NPKZn</sub>	0.56	1.32	1.88	0.79	2.07	2.85
100% RD <sub>NPKZn</sub>	0.56	1.52	2.07	0.59	2.99	3.58
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.41	1.14	1.55	0.42	1.65	2.07
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.49	1.18	1.67	0.32	1.14	1.46
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.48	1.22	1.70	0.34	1.57	1.91
100 % RD <sub>FYM</sub>	0.39	1.03	1.42	0.37	0.60	0.98
CD (p=0.05)	0.067	0.183	0.203	0.052	0.195	0.203

Application of 100%  $RD_{FYM}$  and also different combinations of FYM and NPKZn significantly increased calcium uptake by grain, straw and total crop over control in both the years.

#### **WHEAT**

It is evident from the data pertaining to calcium uptake of wheat crop that application of increasing levels of  $RD_{NPK}$  significantly increased calcium uptake by grain, straw and total crop over control during both the years, except at 50%  $RD_{NPK}$  in grain and at 25%  $RD_{NPK}$  in straw and total crop during first year. Kuligod *et al* (1994) observed an increase in Ca contents due to NPK application.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased calcium uptake by grain, straw and total crop over control during both the years, except at 25%  $RD_{NPKZn}$  for grain, straw and total crop during second year.

Application of FYM alone (100%  $RD_{FYM}$ ) did not significantly increase calcium uptake by grain, straw and total crop during first year and by straw and total crop during second year. Application of 100%  $RD_{FYM}$ , however, significantly increased calcium uptake by grain over control during second year. Various combinations of FYM and NPKZn at different proportions significantly increased calcium uptake by grain, straw and total crop over control during both the years, except at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  for grain during first year.

#### **TOTAL UPTAKE BY RICE-WHEAT SEQUENCE**

As shown in figure 5, application of  $RD_{NPK}$  especially at higher levels significantly increased total Ca uptake by aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total Ca uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 49.1, 31.2, 87.6 and 117.8 percent over control, respectively.

Application of all levels of  $RD_{NPKZn}$  also significantly increased total Ca uptake by rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total Ca uptake by the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 41.5, 52.1, 78.6 and 86.0 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) significantly increased total Ca uptake of rotation in comparison to control in both the years. For yearwise pooled

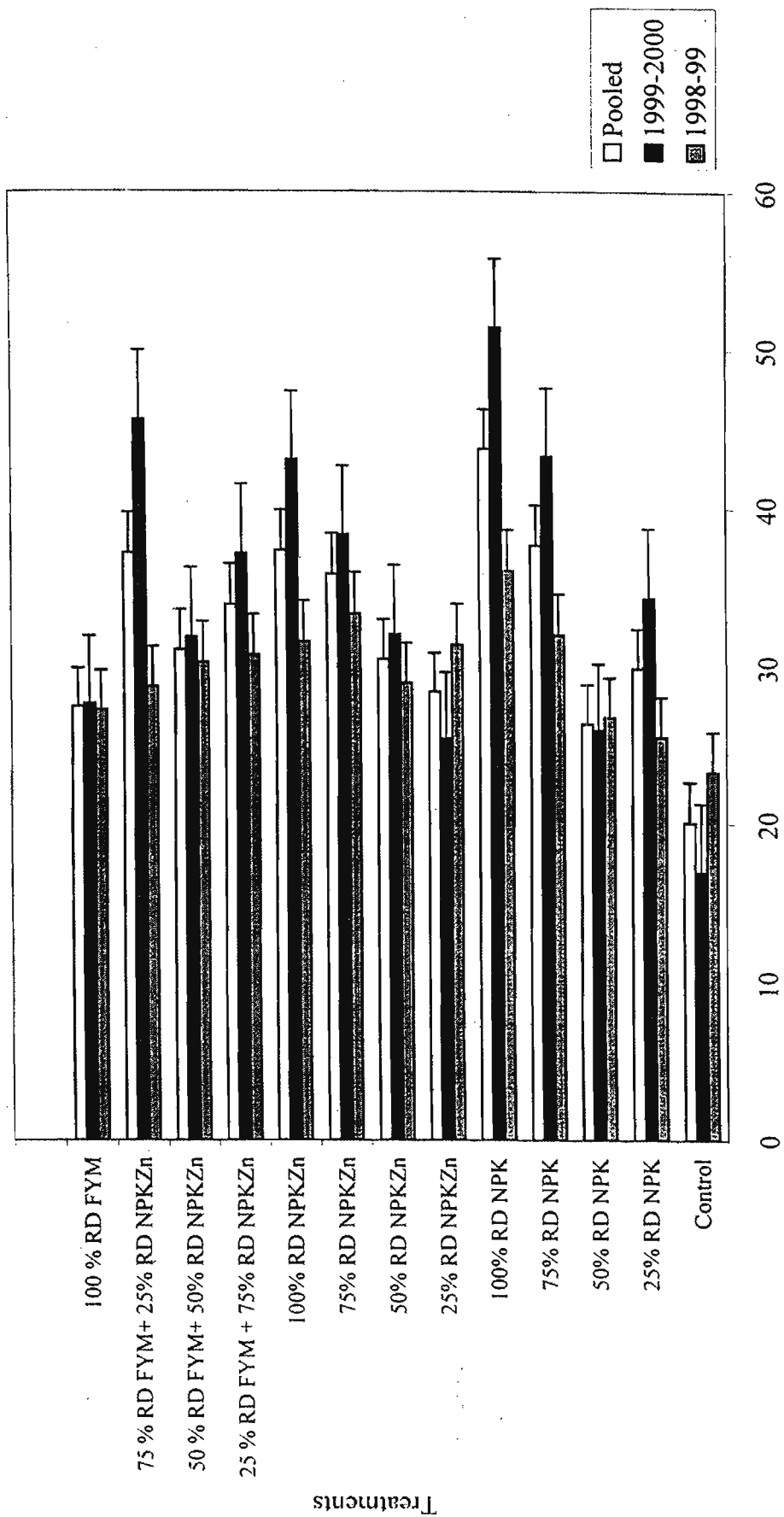


Figure 5: Effect of Chemical Fertilizer, FYM and their conjunctive use on Ca uptake (g/ha) of aromatic rice-wheat sequence

data, the application of 100% FYM significantly increased the total Ca uptake of rotation by 36.7 percent over control.

Various combinations of FYM and NPKZn also significantly increased total Ca uptake by rice-wheat sequence over control, in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total Ca uptake by rotation by 69.3, 55.1 and 85.1 percent over control, respectively.

A comparison of pooled Ca uptake data recorded for various combinations of FYM and NPKZn with their corresponding values noted at respective  $RD_{NPKZn}$  levels revealed that significant effect of FYM in promoting total Ca uptake by rotation was noted at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination. Application of 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  also increased total Ca uptake by rotation, as compared to total Ca uptake observed at 50%  $RD_{NPKZn}$  levels, but the magnitude of increase was statistically not significant. On the other hand, total Ca uptake by rotation at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  was non-significantly decreased as compared to 75%  $RD_{NPKZn}$  alone.

A comparison of pooled data of total Ca uptake by rotation observed at different  $RD_{NPKZn}$  levels with those observed at corresponding  $RD_{NPK}$  level revealed that application of 50%  $RD_{NPKZn}$  significantly increased total Ca uptake of rotation as compared to that noted at 50%  $RD_{NPK}$  level. Application of 25% and 75%  $RD_{NPKZn}$  non-significantly decreased total Ca uptake as compared to those noted at corresponding  $RD_{NPK}$  levels. Application of 100%  $RD_{NPKZn}$  significantly decreased total Ca uptake of rotation in comparison to that recorded at 100%  $RD_{NPK}$  level. The decrease in total Ca uptake at higher level of  $RD_{NPKZn}$  could be ascribed to the antagonistic effect of Zn on Ca in crops (Mann and Takkar, 1982, 1983; Nayyar and Chhibba, 1992).

#### 4.4.5 Magnesium Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the magnesium uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 29.

**Table 29: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Magnesium Uptake (kg/ha) of Aromatic Rice – Wheat**

Treatment	Magnesium Uptake (kg/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	0.41	4.10	4.51	0.36	3.20	3.56
25% RD <sub>NPK</sub>	0.48	3.38	3.86	0.41	6.36	6.77
50% RD <sub>NPK</sub>	0.70	3.66	4.37	0.51	4.73	5.24
75% RD <sub>NPK</sub>	0.75	5.07	5.82	0.50	7.65	8.14
100% RD <sub>NPK</sub>	0.58	8.01	8.59	0.65	7.97	8.63
25% RD <sub>NPKZn</sub>	0.52	5.33	5.85	0.58	3.99	4.57
50% RD <sub>NPKZn</sub>	0.47	4.81	5.29	0.54	4.72	5.27
75% RD <sub>NPKZn</sub>	0.67	5.77	6.43	0.62	6.15	6.77
100% RD <sub>NPKZn</sub>	0.63	5.45	6.08	0.55	7.61	8.16
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	0.76	5.19	5.95	0.46	5.99	6.45
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	0.55	4.86	5.41	0.45	5.60	6.05
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	0.60	4.32	4.92	0.58	8.16	8.74
100 % RD <sub>FYM</sub>	0.51	4.44	4.94	0.39	4.84	5.22
CD (p=0.05)	0.067	0.44	0.45	0.069	0.77	0.77
	Magnesium Uptake (kg/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	1.50	8.34	9.85	0.80	6.15	6.96
25% RD <sub>NPK</sub>	1.85	10.09	11.94	1.47	7.50	8.97
50% RD <sub>NPK</sub>	1.86	11.02	12.88	1.31	8.39	9.70
75% RD <sub>NPK</sub>	2.00	11.87	13.87	1.81	15.42	17.23
100% RD <sub>NPK</sub>	2.18	15.31	17.48	1.96	16.09	18.05
25% RD <sub>NPKZn</sub>	1.59	9.46	11.04	1.13	7.71	8.84
50% RD <sub>NPKZn</sub>	1.97	13.14	15.11	1.19	10.35	11.54
75% RD <sub>NPKZn</sub>	2.27	11.82	14.09	1.95	15.13	17.08
100% RD <sub>NPKZn</sub>	2.50	15.46	17.96	2.06	15.18	17.24
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.64	9.71	11.35	1.16	8.12	9.28
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	2.09	11.31	13.40	1.24	8.99	10.22
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	2.08	12.20	14.29	1.92	12.36	14.28
100 % RD <sub>FYM</sub>	1.57	8.64	10.21	0.95	5.64	6.58
CD (p=0.05)	0.20	1.73	1.78	0.25	1.33	1.45

## RICE

The data pertaining to magnesium uptake of rice show that application of increasing levels of  $RD_{NPK}$  significantly increased the calcium uptake by grain over control in both the years, except at 25%  $RD_{NPK}$  during second year and by straw and total crop during second year. Application of 25% and 50.5%  $RD_{NPK}$  significantly decreased the Mg uptake by straw over control during first year, while application of 75% and 100%  $RD_{NPK}$  significantly increased magnesium uptake by straw over control during first year. Application of 25%  $RD_{NPK}$  significantly decreased magnesium uptake by total crop over control during first year, while application of 75% and 100%  $RD_{NPK}$  significantly increased magnesium uptake by total crop.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased the magnesium uptake by grain, straw and total crop over control during both the years, except at 50%  $RD_{NPKZn}$  for magnesium uptake by grain during first year.

Application of 100% FYM significantly increased magnesium uptake by grain over control during first year and by straw and total crop during second year.

Various combinations of FYM and NPKZn significantly increased magnesium uptake by grain, straw and total crop over control during both the years except at 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  for straw and total crop during first year.

## WHEAT

Application of increasing levels of  $RD_{NPK}$  significantly increased magnesium uptake by grain, straw and total crop over control during both the years. Kuligod *et al* (1994) observed increase in Mg uptake due to NPK application.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased magnesium uptake by grain, straw and total crop over control during both the years, except at 25%  $RD_{NPKZn}$  for grain, straw and total crop during first year. Shukla (1986) also observed increase in Mg uptake by wheat crop with Zn addition to the soil.

Application of FYM alone (100%  $RD_{FYM}$ ) did not significantly alter magnesium uptake by grain, straw and total wheat crop during both the years.

Different combinations of FYM and NPKZn at different proportions significantly increased magnesium uptake by grain, straw and total crop over control during both the years, except at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  during first year.

#### TOTAL UPTAKE BY RICE-WHEAT SEQUENCE

As depicted in figure 6, application of  $RD_{NPK}$ , especially at higher levels significantly increased total Mg uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total Mg uptake of rotation at 25, 50, 75 and 100%  $RD_{NPK}$  was 26.8, 29.4, 81.1 and 112.1 percent over control, respectively.

Application of all levels of  $RD_{NPKZn}$  also significantly increased total Mg uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total Mg uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 21.8, 49.6, 78.4 and 98.7 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) increased total Mg uptake of rotation in comparison to control in both the years and also for yearwise pooled data, however, the increase was statistically not significant.

Various combinations of FYM and NPKZn also significantly increased total Mg uptake of rice-wheat sequence over control, in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  +75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  +50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total Mg uptake of rotation by 32.8, 41.0 and 69.8 percent over control, respectively.

A comparison of pooled Mg uptake data recorded for various combinations of FYM and  $RD_{NPKZn}$  with their corresponding values noted at  $RD_{NPKZn}$  levels revealed that significant role of FYM in promoting total Mg uptake of rotation was noted only at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination. However, application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  significantly decreased total Mg uptake of rotation over that noted at corresponding  $RD_{NPK}$  level. The

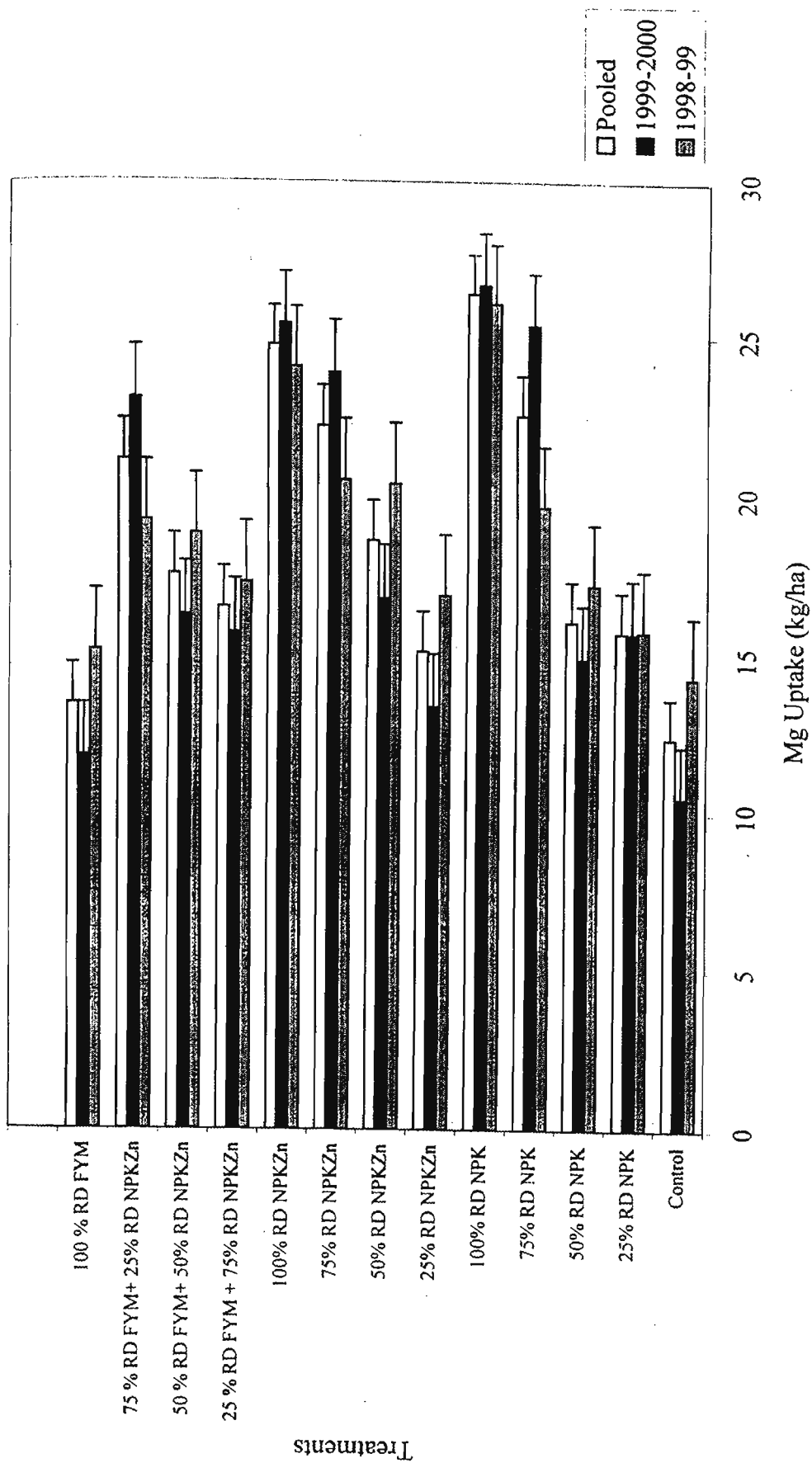


Figure 6: Effect of Chemical Fertilizer, FYM and their conjunctive use on Mg uptake (g/ha) of aromatic rice-wheat sequence

decrease noted at 50% RD<sub>FYM</sub> + 50% RD<sub>NPK</sub> was, however, statistically not significant.

Application of 50% and 100% RD<sub>NPKZn</sub> significantly increased total Mg uptake of rotation as compared to Mg uptake observed at corresponding RD<sub>NPK</sub> levels, thereby, indicating that application of zinc had a synergistic effect on Mg and enhanced total Mg uptake of rotation.

#### 4.4.6 Sulphur Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the sulphur uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 30.

##### RICE

It is evident from the data that increasing levels of RD<sub>NPK</sub> significantly increased the sulphur uptake by grain, straw and total rice crop over control in both the years, except at 25% RD<sub>NPK</sub> for grain during second year.

Application of increasing levels of RD<sub>NPKZn</sub> also significantly increased the sulphur uptake by grain, straw and total crop over control in both the years, except at 50% RD<sub>NPK</sub> by grain during both the years. Mukhi and Shukla (1991) observed an increase in S uptake due to Zn application.

Application of 100% RD<sub>FYM</sub> significantly increased sulphur uptake by straw and total crop over control during both the years. However, it had no significant effect on sulphur uptake by grain during both the years.

Various combinations of FYM and NPKZn significantly increased sulphur uptake by grain, straw and total crop over control during both the years, except at 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> for straw and total crop, respectively.

##### WHEAT

Application of 25% RD<sub>NPK</sub> significantly decreased sulphur uptake by grain over control during first year, while it significantly increased sulphur uptake by straw over control during first year and by grain and total crop during second year. Application of 50% and 75% RD<sub>NPK</sub> also significantly decreased sulphur uptake by grain, straw and total crop over control during second year.

**Table 30: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Sulphur Uptake (kg/ha) of Aromatic Rice – Wheat**

Treatment	Sulphur Uptake (kg/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	0.63	4.16	4.78	0.75	4.95	5.70
25% RD <sub>NPK</sub>	1.02	5.74	6.76	0.87	12.78	13.65
50% RD <sub>NPK</sub>	1.25	5.98	7.24	1.28	8.28	9.55
75% RD <sub>NPK</sub>	1.55	7.28	8.84	1.01	12.92	13.93
100% RD <sub>NPK</sub>	1.22	8.85	10.07	1.43	13.26	14.70
25% RD <sub>NPKZn</sub>	0.90	6.77	7.67	1.15	11.75	12.90
50% RD <sub>NPKZn</sub>	0.77	7.55	8.32	0.82	8.02	8.84
75% RD <sub>NPKZn</sub>	1.32	8.55	9.87	1.10	9.82	10.93
100% RD <sub>NPKZn</sub>	1.17	8.34	9.51	1.07	13.72	14.79
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.49	7.76	9.25	0.87	12.04	12.92
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.42	4.84	6.26	0.91	9.84	10.76
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	1.36	4.95	6.31	1.11	16.03	17.14
100 % RD <sub>FYM</sub>	0.85	5.66	6.51	0.88	8.72	9.60
CD (p=0.05)	0.25	1.49	1.54	0.15	1.45	1.48
	Sulphur Uptake (kg/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	1.54	1.60	3.14	0.97	1.55	2.52
25% RD <sub>NPK</sub>	1.14	2.89	4.03	2.29	1.64	3.92
50% RD <sub>NPK</sub>	1.60	2.39	4.00	1.88	2.30	4.18
75% RD <sub>NPK</sub>	1.71	2.33	4.04	2.04	3.89	5.92
100% RD <sub>NPK</sub>	2.11	4.03	6.15	2.36	5.09	7.45
25% RD <sub>NPKZn</sub>	1.65	1.75	3.40	1.72	2.41	4.13
50% RD <sub>NPKZn</sub>	1.90	2.45	4.35	1.95	3.51	5.46
75% RD <sub>NPKZn</sub>	0.82	4.23	5.05	2.09	3.50	5.59
100% RD <sub>NPKZn</sub>	1.34	2.77	4.11	2.32	4.48	6.79
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.19	2.82	4.01	2.10	2.04	4.14
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.94	3.16	5.10	1.39	2.85	4.25
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	2.32	2.87	5.19	1.96	3.73	5.69
100 % RD <sub>FYM</sub>	1.16	3.33	4.49	1.50	1.93	3.43
CD (p=0.05)	0.33	0.85	0.92	0.29	0.39	0.56

Application of 100%  $RD_{NPK}$  significantly increased sulphur uptake by grain, straw and total crop over control during both the years.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased sulphur uptake by grain, straw and total crop over control during both the years, except at 25%  $RD_{NPKZn}$  for grain, straw and total crop during first year; 75% and 100%  $RD_{NPKZn}$  for grain during first year. Application of 75%  $RD_{NPKZn}$  significantly decreased sulphur uptake in comparison to control by grain during first year. Kuligod *et al* (1994) observed increase in S uptake due to Zn and S application.

Application of 100%  $RD_{FYM}$  significantly decreased sulphur uptake by grain over control during first year, while, it significantly increased sulphur uptake by straw and total crop over control during first year and by grain and total crop during second year.

Various combinations of FYM and NPKZn significantly increased sulphur uptake by grain, straw and total crop over control during both the years, except at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  for grain during first year, which significantly decreased sulphur uptake by grain over control; and for total sulphur uptake by crop in first year, which was statistically similar to that of control.

#### **TOTAL UPTAKE BY RICE-WHEAT SEQUENCE**

As depicted in figure 7, application of all levels of  $RD_{NPK}$  significantly increased total S uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total S uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 75.7, 54.6, 102.8 and 137.7 percent over control, respectively.

Application of all levels of  $RD_{NPKZn}$  also significantly increased total S uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total S uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 74.1, 67.2, 94.8 and 118.1 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) also increased total S uptake of rotation in comparison to control in both the years. The magnitude of increase for the yearwise pooled data was 42.8 percent.

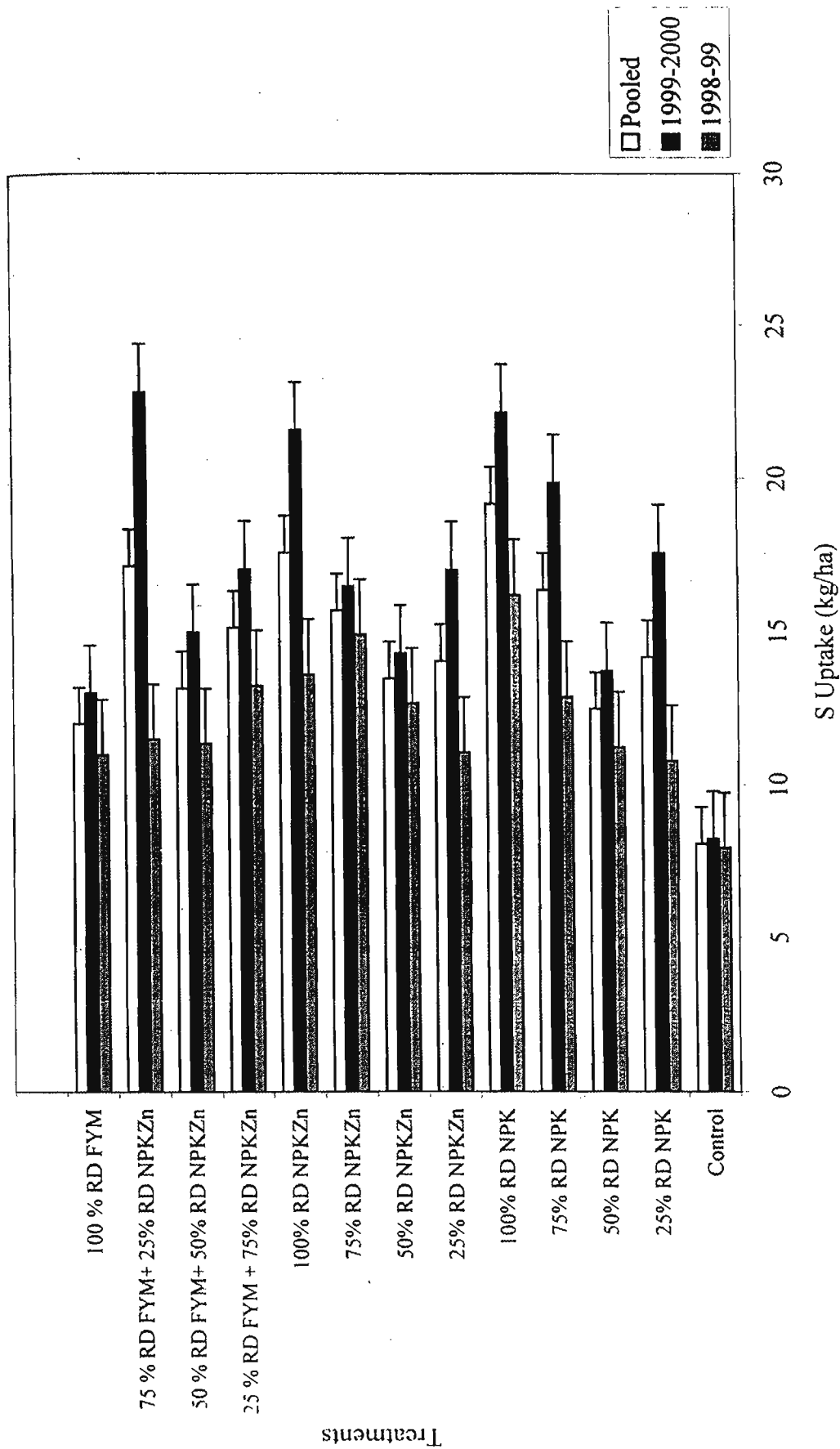


Figure 7: Effect of Chemical Fertilizer, FYM and their conjunctive use on S uptake (kg/ha) of aromatic rice-wheat sequence

Various combinations of FYM and NPKZn significantly increased total S uptake of rice-wheat sequence over control in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total S uptake of rotation by 87.9, 63.3 and 112.8 percent over control, respectively.

A comparison of pooled S uptake data recorded for various combinations of FYM and NPKZn with their corresponding  $RD_{NPKZn}$  level values revealed that significant effect of FYM in promoting total S uptake of rotation was noted only at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination.

#### 4.4.7 Zinc Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the zinc uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 31.

##### RICE

It is evident from the data that increasing levels of  $RD_{NPK}$  significantly increased the zinc uptake by grain, straw and total rice crop over control in both the years, however, the uptake noted at 25%  $RD_{NPK}$  by grain, straw and total crop and at 50%  $RD_{NPK}$  by straw during first year and by grain during second year were statistically not significantly higher over control.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased the zinc uptake by grain and straw parts and total Zn uptake of rice over control in both the years, except for the uptake noted at 50%  $RD_{NPKZn}$  by grain during first year. Duraisamy *et al* (1988) observed increase in Zn uptake due to Zn application.

Application of 100%  $RD_{FYM}$  significantly increased zinc uptake by straw over control during both the years. Sharma and Deb (1991) and Sadana *et al* (1995) also reported that uptake of zinc increased with the application of FYM.

All combinations of FYM and NPKZn significantly increased zinc uptake by grain, straw and total crop over control during both the years, except for the uptake by grain noted at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  during both the years. During second year, zinc uptake by grain at 25%

**Table 31: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Zinc Uptake (g/ha) of Aromatic Rice – Wheat**

Treatment	Zinc Uptake (g/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	57.1	161.5	218.6	41.4	153.0	194.4
25% RD <sub>NPK</sub>	43.6	160.0	203.5	43.1	318.1	361.3
50% RD <sub>NPK</sub>	99.8	155.7	255.5	52.4	268.9	321.3
75% RD <sub>NPK</sub>	106.7	216.5	323.2	52.1	419.3	471.4
100% RD <sub>NPK</sub>	92.9	235.4	328.2	69.1	391.7	460.8
25% RD <sub>NPKZn</sub>	76.6	230.8	307.4	60.8	225.9	286.8
50% RD <sub>NPKZn</sub>	46.9	242.6	289.6	56.2	232.8	289.0
75% RD <sub>NPKZn</sub>	111.7	312.3	424.0	60.9	316.0	377.0
100% RD <sub>NPKZn</sub>	83.2	336.7	419.9	56.9	442.6	499.4
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	78.4	268.1	346.5	45.1	301.3	346.4
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	75.2	332.4	407.6	56.5	310.9	367.4
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	60.6	294.5	355.1	74.7	456.8	531.6
100 % RD <sub>FYM</sub>	51.3	205.5	256.8	36.7	206.5	243.1
CD (p=0.05)	18.2	37.1	40.9	9.5	44.4	48.8
	Zinc Uptake (g/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	86.1	46.2	132.3	48.8	56.3	105.1
25% RD <sub>NPK</sub>	84.5	57.1	141.7	83.4	66.6	150.0
50% RD <sub>NPK</sub>	76.0	52.5	128.5	80.0	56.8	136.8
75% RD <sub>NPK</sub>	80.6	62.4	143.0	97.6	156.9	254.5
100% RD <sub>NPK</sub>	126.7	69.2	195.9	111.6	131.1	242.7
25% RD <sub>NPKZn</sub>	89.8	46.4	136.2	71.0	68.9	139.9
50% RD <sub>NPKZn</sub>	108.7	60.2	168.9	95.1	128.2	223.3
75% RD <sub>NPKZn</sub>	122.1	62.0	184.1	97.6	84.3	181.9
100% RD <sub>NPKZn</sub>	106.5	79.3	185.8	105.7	122.9	228.6
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	81.0	53.0	134.1	84.8	60.3	145.1
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	83.6	57.9	141.5	56.2	56.9	113.1
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	93.0	67.3	160.3	97.9	92.4	190.2
100 % RD <sub>FYM</sub>	68.9	50.8	119.7	43.8	34.9	78.7
CD (p=0.05)	14.9	10.6	21.1	14.1	11.6	21.5

$RD_{FYM} + 75\% RD_{NPKZn}$  was also not significantly different from control. Nand Ram and Ram (1996) reported that application of zinc and farmyard manure along with 100% NPK resulted in increased uptake of zinc in mollisol.

#### **WHEAT**

In wheat crop, application of 25%  $RD_{NPK}$  significantly increased zinc uptake by straw over control during first year and by grain and total crop over control during second year. Application of 50%  $RD_{NPK}$  also significantly increased zinc uptake by grain and total crop over control during second year. Application of 75%  $RD_{NPK}$  significantly increased zinc uptake by straw over control during first year and by grain, straw and total crop over control during second year. Application of 100%  $RD_{NPK}$  significantly increased zinc uptake by grain, straw and total crop over control in both the years.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased zinc uptake by grain, straw and total crop over control during both the years, except for the increase in uptake noted at 25%  $RD_{NPKZn}$  by grain, straw and total crop during first year.

Application of 100%  $RD_{FYM}$  significantly decreased zinc uptake by grain over control during first year and by straw and total crop over control during second year. A combination of 25%  $RD_{FYM}$  and 75%  $RD_{NPKZn}$  significantly increased zinc uptake by grain and total crop over control during second year. Application of 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  significantly increased zinc uptake by straw over control during first. Application of 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  significantly increased zinc uptake by grain over control during second year and by straw and total crop over control during both the years. The presence of FYM along with zinc applied to rice crop improved the availability of Zn to wheat crop (Naresh, 2001).

#### **TOTAL UPTAKE BY RICE-WHEAT SEQUENCE**

As shown in figure 8, application of  $RD_{NPK}$ , especially at higher levels significantly increased total Zn uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in Zn uptake at 25, 50, 75 and 100 %  $RD_{NPK}$  was 31.8, 29.5, 83.4 and 88.8 percent over control, respectively.

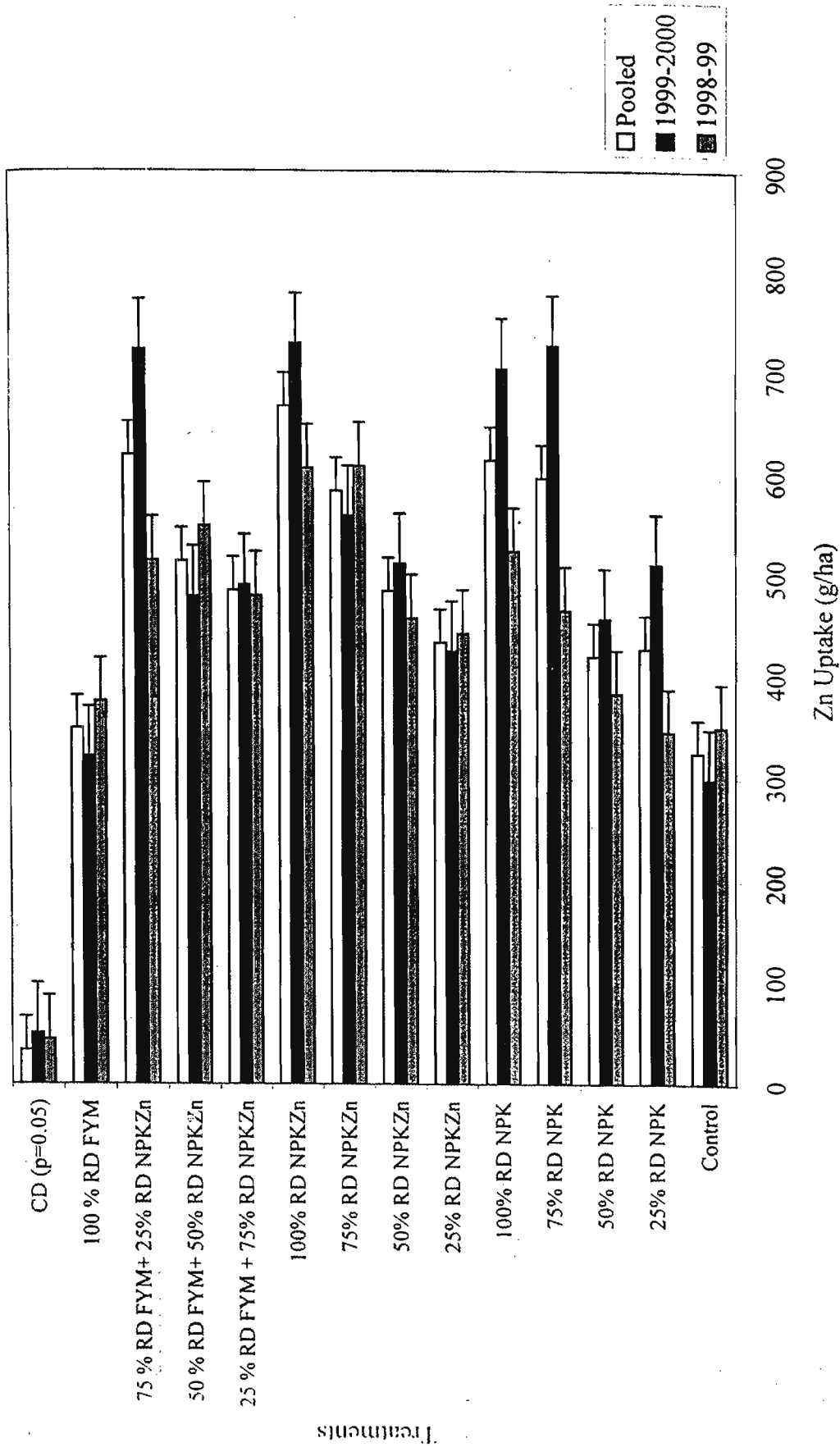


Figure 8: Effect of Chemical Fertilizer, FYM and their conjunctive use on Zn uptake (g/ha) of aromatic rice-wheat sequenc

Application of all levels of  $RD_{NPKZn}$  also significantly increased total Zn uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total Zn uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 33.8, 49.3, 79.5 and 105.2 percent over control, respectively. Similar observations were recorded by several other workers (Das *et al*, 1993; Sakal *et al*, 1993; Prasad and Umar, 1993).

Application of FYM alone (100%  $RD_{FYM}$ ) also increased total Zn uptake of rotation in comparison to control, but the magnitude of increase was statistically not significant in both the years.

Various combinations of  $RD_{FYM}$  and  $NPKZn$  significantly increased total Zn uptake of rice-wheat sequence over control in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total Zn uptake of rotation by 49.6, 58.3 and 90.3 percent over control, respectively.

A comparison of pooled Zn uptake data noted for various combinations of FYM and  $NPKZn$  with the values noted at corresponding  $RD_{NPKZn}$  levels revealed that significant role of FYM in promoting total Zn uptake of rotation was noted only at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination.

#### 4.4.8 Copper Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the copper uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 32.

##### RICE

It is evident from the data that application of 25%  $RD_{NPK}$  significantly increased the copper uptake by straw and total rice crop over control in second year only, while application of 50%  $RD_{NPK}$  significantly increased copper uptake by grain, straw and total crop during first year. Application of 75% and 100%  $RD_{NPK}$  significantly increased copper uptake by grain, straw and total crop over control during both the years, except for the uptake by grain recorded at 75%  $RD_{NPK}$  during second year.

**Table 32: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Copper Uptake (g/ha) of Aromatic Rice – Wheat**

Treatment	Copper Uptake (g/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	3.03	10.04	13.06	3.31	10.19	13.5
25% RD <sub>NPK</sub>	3.73	10.29	14.02	2.5	16.5	19
50% RD <sub>NPK</sub>	4.42	11.63	16.06	4.5	10.31	14.81
75% RD <sub>NPK</sub>	6.03	15.81	21.84	3.16	21.05	24.21
100% RD <sub>NPK</sub>	4.83	18.84	23.67	6.6	17.59	24.19
25% RD <sub>NPKZn</sub>	3.87	15.2	19.07	3.63	16.51	20.14
50% RD <sub>NPKZn</sub>	2.83	12.24	15.07	5.97	11.8	17.76
75% RD <sub>NPKZn</sub>	5.32	15.49	20.81	6.15	15.98	22.13
100% RD <sub>NPKZn</sub>	3.99	14.48	18.46	4.88	22.28	27.16
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	3.54	13.83	17.37	5.04	24.41	29.45
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	4.61	16.52	21.13	4.27	14.09	18.36
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	5.23	15.63	20.86	3.28	23.5	26.78
100 % RD <sub>FYM</sub>	3.41	14.04	17.45	4.21	14.66	18.87
CD (p=0.05)	0.97	1.45	1.76	1.89	2.64	3.15
	Copper Uptake (g/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	6.18	6.55	12.74	2.97	3.81	6.77
25% RD <sub>NPK</sub>	7.21	7.58	14.79	6.87	5	11.87
50% RD <sub>NPK</sub>	7.44	8.67	16.11	6.46	4.77	11.24
75% RD <sub>NPK</sub>	7.29	9.36	16.64	7.63	17.14	24.77
100% RD <sub>NPK</sub>	9.94	10.66	20.6	9.51	14.02	23.54
25% RD <sub>NPKZn</sub>	6.33	7.52	13.85	5.47	4.61	10.09
50% RD <sub>NPKZn</sub>	8.7	9.5	18.2	7.49	14.29	21.78
75% RD <sub>NPKZn</sub>	9.7	10.46	20.16	12	14.68	26.67
100% RD <sub>NPKZn</sub>	10.21	11.17	21.38	8.94	10.79	19.74
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	6.18	7.97	14.16	5.21	3.88	9.08
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	7.59	9.1	16.69	3.51	4.54	8.05
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	7.61	8.08	15.69	6.73	4.96	11.68
100 % RD <sub>FYM</sub>	5.92	7.5	13.42	4.97	3.2	8.16
CD (p=0.05)	0.8	1.32	1.69	1.33	4.61	4.84

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased the copper uptake by grain and straw parts and total Cu uptake of rice over control in both the years, except for the uptake noted at 25%, 50% and 100%  $RD_{NPKZn}$  by grain during first year; at 25% and 100%  $RD_{NPKZn}$  by grain during second year and at 50%  $RD_{NPKZn}$  by straw during second year.

Application of 100%  $RD_{FYM}$  significantly increased copper uptake by straw and total crop over control during both the years. Swarup (1985) also reported an increase in copper uptake of rice in farmyard manure treated soil.

All combinations of FYM and NPKZn significantly increased copper uptake by grain, straw and total crop over control during both the years, except for the uptake by grain noted at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  by grain during both the years; at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  by grain during second year.

#### **WHEAT**

In wheat crop, application of increasing levels of  $RD_{NPK}$  significantly increased copper uptake by grain, straw and total crop over control during both the years, except for the uptake noted at 25%  $RD_{NPK}$  by straw during both the years; and at 50%  $RD_{NPK}$  by straw during second year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased copper uptake by grain, straw and total crop over control during both the years, except for the uptake noted at 25%  $RD_{NPKZn}$  by grain, straw and total crop during first year.

Application of 100%  $RD_{FYM}$  significantly decreased copper uptake by grain over control during second year only possibly due to less release of Cu from FYM during winter season due to slow rate of decomposition and stronger binding of Cu with organic complexes present in FYM.

A combination of 25%  $RD_{FYM}$  and 75%  $RD_{NPKZn}$  significantly increased copper uptake by straw over control during first year and by grain over control during second year. Application of 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  significantly increased copper uptake by grain, straw and total crop over control during first year. Application of 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased copper

uptake by grain and total crop over control during first year and by grain and total crop over control during second year.

#### **TOTAL UPTAKE BY RICE-WHEAT SEQUENCE**

As shown in figure 9, application of  $RD_{NPK}$  especially at higher levels significantly increased total Cu uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total Cu uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 29.5, 26.3, 89.8 and 99.7 percent over control, respectively. This could be attributed to increased dry matter production and consequently increased demand of Cu by crop.

Application of all levels of  $RD_{NPKZn}$  significantly increased total Cu uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total Cu uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 37.1, 58.0, 94.8 and 88.2 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) significantly increased total Cu uptake of rotation in comparison to control in both the years. For yearwise pooled data, the application of 100%  $RD_{FYM}$  significantly increased the total Cu uptake of rotation by 25.7 percent over control.

Various combinations of FYM and NPKZn also significantly increased total Cu uptake of rice-wheat sequence over control, in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total Cu uptake of rotation by 52.0, 39.4 and 62.8 percent over control, respectively.

A comparison of pooled Cu uptake data recorded for various combinations of FYM and NPKZn with the values noted at corresponding  $RD_{NPKZn}$  levels revealed that significant effect of FYM in promoting total Cu uptake of rotation was noted at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination, while for other two combinations, total Cu uptake of rotation was significantly decreased as compared to the uptake values observed at corresponding  $RD_{NPKZn}$  levels.

A comparison of total Cu uptake of rotation observed at  $RD_{NPKZn}$  levels with the values observed at corresponding  $RD_{NPK}$  revealed that a significant

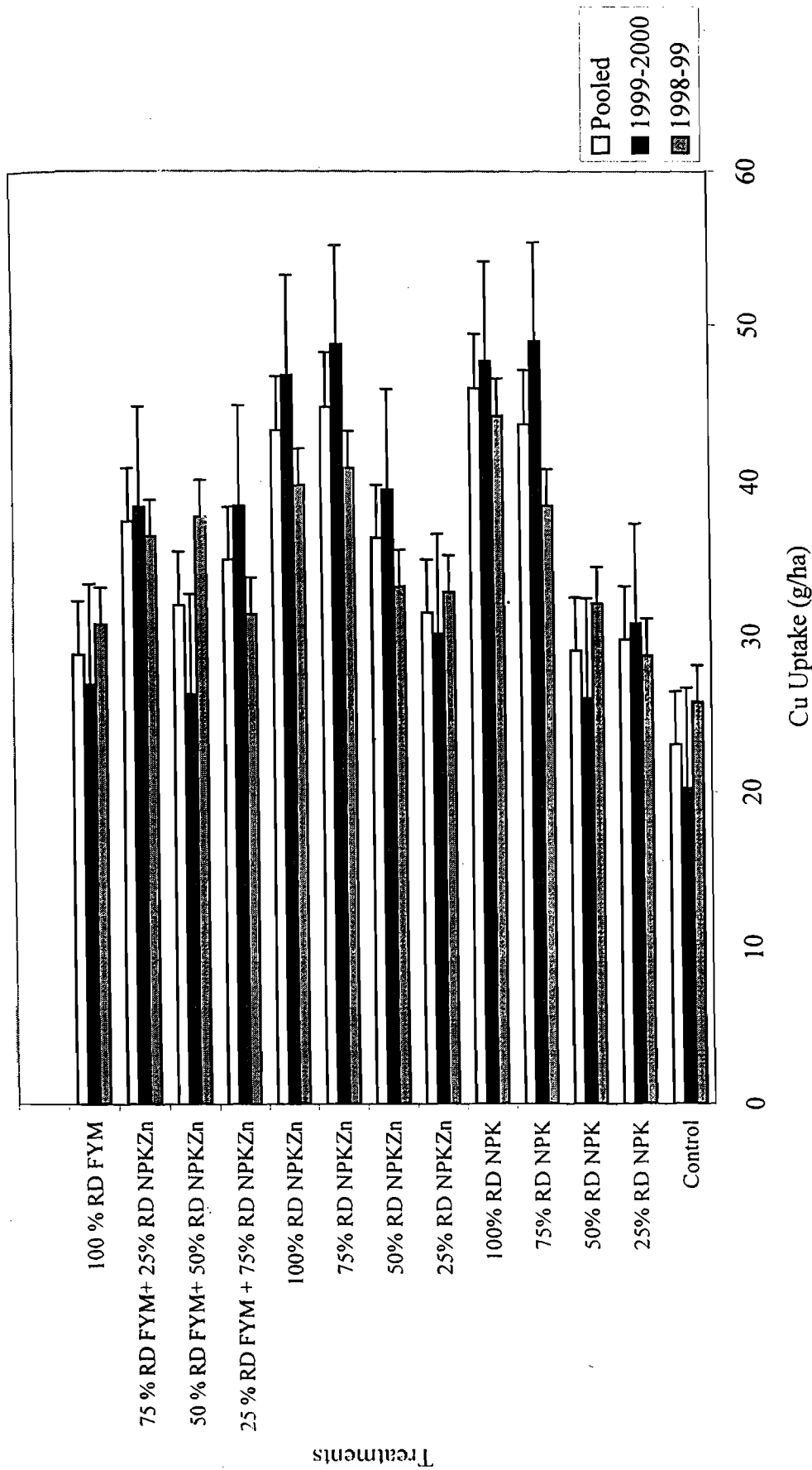


Figure 9: Effect of Chemical Fertilizer, FYM and their conjunctive use on Cu uptake (g/ha) of aromatic rice-wheat sequence

increase in total Cu uptake of rotation occurred at 50%  $RD_{NPKZn}$  as compared to 50%  $RD_{NPK}$ , while at 75 and 100%  $RD_{NPKZn}$  levels, there was a non-significant increase in total Cu uptake, as compared to the values at corresponding  $RD_{NPK}$  levels.

#### 4.4.9 Iron Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combination on the iron uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 33.

##### RICE

It is evident from the data that increasing levels of  $RD_{NPK}$  significantly increased the iron uptake by grain, straw and total crop over control in both the years, except for the increase in uptake noted at 25%  $RD_{NPK}$  by grain during second year and at 50%  $RD_{NPK}$  by straw and total crop during first year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased the iron uptake by grain, straw and total crop over control during both the years. The increase in Fe uptake at increasing levels of  $RD_{NPK}$  or  $RD_{NPKZn}$  could be ascribed to increased dry matter production and consequently increased demand of Fe by crop.

Application of 100%  $RD_{FYM}$  significantly increased iron uptake by grain, straw and total crop over control during both the years, except for the increase in uptake noted in case of grain during second year.

All combinations of FYM and NPKZn significantly increased iron uptake by grain, straw and total crop over control during both the years, except for the uptake noted at 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  by grain during second year.

##### WHEAT

In wheat crop, increasing levels of  $RD_{NPK}$  significantly increased the iron uptake by grain, straw and total crop over control, during both the years, except for the uptake recorded at 25%  $RD_{NPK}$  by grain, straw and total crop during first year and at 50%  $RD_{NPK}$  by grain during first year.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased iron uptake by grain, straw and total crop over control during both the years, except

**Table 33: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Iron Uptake (g/ha) of Aromatic Rice – Wheat**

Treatment	Iron Uptake (g/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	149	1237	1387	160	1443	1603
25% RD <sub>NPK</sub>	223	1500	1724	188	2932	3120
50% RD <sub>NPK</sub>	255	1280	1534	227	2492	2719
75% RD <sub>NPK</sub>	279	2687	2965	242	3577	3819
100% RD <sub>NPK</sub>	234	2455	2688	312	5285	5597
25% RD <sub>NPKZn</sub>	221	2181	2402	231	2031	2261
50% RD <sub>NPKZn</sub>	214	1910	2125	247	2538	2785
75% RD <sub>NPKZn</sub>	301	2092	2394	234	4017	4252
100% RD <sub>NPKZn</sub>	281	1672	1952	224	4112	4336
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	209	2368	2577	189	4254	4442
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	236	2172	2408	290	2432	2722
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	291	2224	2515	440	4541	4981
100 % RD <sub>FYM</sub>	212	1794	2007	184	2368	2552
CD (p=0.05)	33	192	199	36	449	450
	Iron Uptake (g/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	169	1009	1178	75	812	887
25% RD <sub>NPK</sub>	150	1144	1294	143	1063	1206
50% RD <sub>NPK</sub>	177	1328	1505	132	1114	1247
75% RD <sub>NPK</sub>	182	1433	1615	233	2385	2617
100% RD <sub>NPK</sub>	209	1654	1864	187	2280	2468
25% RD <sub>NPKZn</sub>	207	1149	1356	149	1155	1304
50% RD <sub>NPKZn</sub>	188	1627	1815	168	1453	1620
75% RD <sub>NPKZn</sub>	267	1348	1615	292	1508	1800
100% RD <sub>NPKZn</sub>	224	1675	1899	241	3216	3457
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	137	1230	1367	115	1463	1578
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	216	1278	1493	115	1222	1336
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	206	1289	1495	150	1807	1957
100 % RD <sub>FYM</sub>	154	1082	1236	130	797	928
CD (p=0.05)	30	171	176	30	216	222

for the increase in uptake noted at 25%  $RD_{NPKZn}$  by straw and at 50%  $RD_{NPKZn}$  by grain during first year only. Kuligod *et al* (1994) also observed that application of sulphur and zinc fertilizer increased uptake of iron by the wheat crop.

Application of 100%  $RD_{FYM}$  significantly increased iron uptake by grain over control during second year.

All combinations of FYM and  $NPKZn$  significantly increased iron uptake by grain, straw and total crop over control during both the years, except for the combination with 25%  $RD_{FYM}$  +75%  $RD_{NPKZn}$ , at which iron uptake by grain significantly decreased in comparison to control during second year.

#### TOTAL UPTAKE BY RICE-WHEAT SEQUENCE

As depicted in figure 10, application of all levels of  $RD_{NPK}$  significantly increased total Fe uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total Fe uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 45.3, 38.6, 118.0 and 149.7 percent over control, respectively.

Application of all levels of  $RD_{NPKZn}$  significantly increased total Fe uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total Fe uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPKZn}$  was 44.9, 65.1, 99.1 and 130.4 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) significantly increased total Fe uptake of rotation in comparison to control in both the years. For yearwise pooled data, the application of 100% FYM significantly increased the total Fe uptake of rotation by 33.0 percent over control.

Various combinations of FYM and  $NPKZn$  also significantly increased total Fe uptake of rice-wheat sequence over control in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total Fe uptake of rotation by 97.2, 57.5 and 116.6 percent over control, respectively.

A comparison of pooled Fe uptake data recorded for various combinations of FYM and  $NPKZn$  with the values noted at corresponding  $RD_{NPKZn}$  levels revealed that significant effect of FYM in promoting total Fe uptake of rotation was noted at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination, while at other two

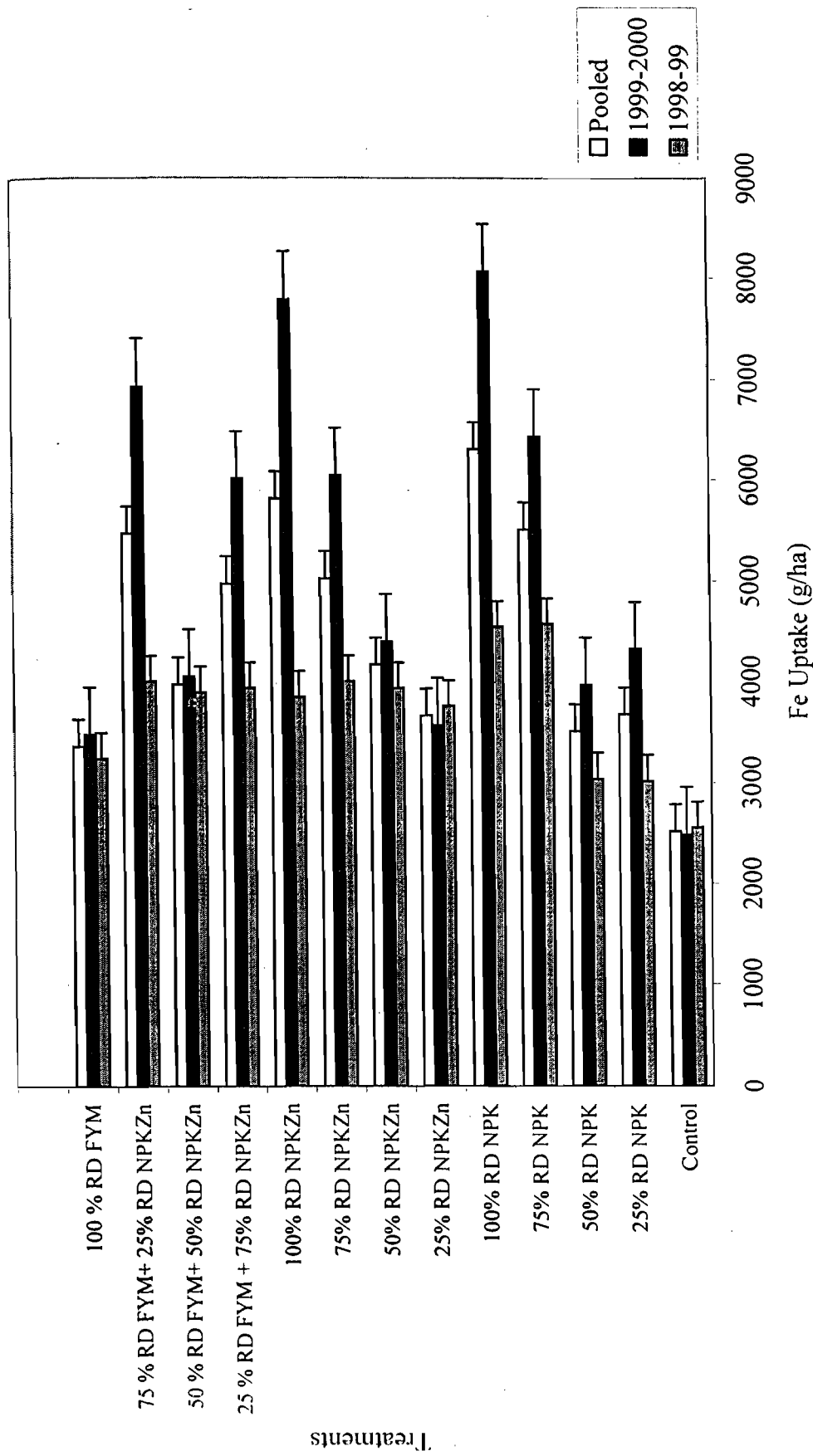


Figure 10: Effect of Chemical Fertilizer, FYM and their conjunctive use on Fe uptake (g/ha) of aromatic rice-wheat sequence

combinations, total Fe uptake of rotation was non-significantly decreased as compared to the uptake values observed at corresponding  $RD_{NPKZn}$  levels.

A comparison of total Fe uptake of rotation observed at 50%  $RD_{NPKZn}$  with that observed at corresponding  $RD_{NPK}$  revealed a significant increase in total Fe uptake of rotation due to application of zinc, but at higher (75 and 100%)  $RD_{NPKZn}$  levels the uptake of Fe by rotation was significantly reduced in comparison to uptake values observed at corresponding  $RD_{NPK}$  levels due to antagonistic effect of Zn on Fe uptake (Tiwari, 1976; Sinha and Sakal, 1983; Verma and Tripathi, 1983; Patel and Dangarwala, 1983; Prasad and Singh, 1985; Mukhi and Shukla, 1987; Sakal, 1980).

#### 4.4.10 Manganese Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combination on the manganese uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 34.

##### RICE

It is evident from the data that increasing levels of  $RD_{NPK}$  significantly increased the manganese uptake by grain, straw and total rice crop over control in both the years, except for the increase in uptake noted at 25%  $RD_{NPK}$  by grain, straw and total crop during first year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased the manganese uptake by grain, straw and total crop over control during both the years, except for the increase noted in manganese uptake at 25% and 50%  $RD_{NPKZn}$  by grain during first year.

Application of 100%  $RD_{FYM}$  significantly increased manganese uptake by grain over control during first year only. Swarup (1985) reported that use of farmyard manure and rice husk resulted in marked improvements in manganese uptake of the rice crop,

The combinations of FYM and  $NPKZn$  significantly increased manganese uptake by grain, straw and total crop over control during both the years, except for the increase noted in uptake by grain under 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  and 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  during first year.

**Table 34: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Manganese Uptake (g/ha) of Aromatic Rice – Wheat**

Treatment	Manganese Uptake (g/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	52	1151	1203	46	1092	1138
25% RD <sub>NPK</sub>	54	1249	1302	79	2249	2328
50% RD <sub>NPK</sub>	66	1361	1427	75	2023	2098
75% RD <sub>NPK</sub>	67	1753	1820	80	2827	2907
100% RD <sub>NPK</sub>	62	2275	2337	106	3015	3121
25% RD <sub>NPKZn</sub>	60	1676	1736	76	1809	1885
50% RD <sub>NPKZn</sub>	50	1571	1621	100	1629	1729
75% RD <sub>NPKZn</sub>	78	1942	2021	101	2245	2346
100% RD <sub>NPKZn</sub>	72	1867	1939	99	2808	2906
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	52	1817	1869	72	2180	2252
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	52	1698	1751	82	1911	1993
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	67	1591	1657	88	2761	2848
100 % RD <sub>FYM</sub>	54	1274	1328	59	1353	1412
CD (p=0.05)	10	206	206	11	295	297
	Manganese Uptake (g/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	63	145	208	35	113	148
25% RD <sub>NPK</sub>	73	184	258	80	179	259
50% RD <sub>NPK</sub>	67	175	241	60	148	209
75% RD <sub>NPK</sub>	66	180	246	93	297	389
100% RD <sub>NPK</sub>	97	230	327	115	270	385
25% RD <sub>NPKZn</sub>	71	157	228	69	129	198
50% RD <sub>NPKZn</sub>	79	209	288	38	191	228
75% RD <sub>NPKZn</sub>	88	207	294	69	246	315
100% RD <sub>NPKZn</sub>	88	243	330	112	265	377
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	72	174	246	38	136	174
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	77	174	251	48	144	192
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	77	202	279	81	210	290
100 % RD <sub>FYM</sub>	62	144	206	29	97	126
CD (p=0.05)	10	37	43	12	24	31

## WHEAT

It is evident from the data pertaining to manganese uptake of wheat crop that increasing levels of  $RD_{NPK}$  significantly increased the manganese uptake by grain, straw and total crop over control, during both the years, except for the increase in uptake noted at 50% and 75%  $RD_{NPK}$  by grain, straw and total crop during first year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased manganese uptake by grain, straw and total crop over control during both the years, except for the increase in uptake noted at 25%  $RD_{NPKZn}$  by grain, straw and total crop during first year; and at 50%  $RD_{NPKZn}$  by grain during second year.

Application of 100%  $RD_{FYM}$  did not significantly affect manganese uptake during both the years.

The combinations of FYM and NPKZn significantly increased manganese uptake by grain, straw and total crop over control during both the years, except with 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , which did not significantly affect manganese uptake during either year. The increase in uptake noted at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  by straw during first year was also statistically not significant.

## TOTAL UPTAKE BY RICE-WHEAT SEQUENCE

As depicted in figure 11, application of  $RD_{NPK}$ , especially at higher levels significantly increased the total Mn uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total Mn uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 53.7, 47.4, 98.7 and 128.7 percent over control, respectively.

Application of all levels of  $RD_{NPKZn}$  significantly increased the total Mn uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total Mn uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 50.0, 43.3, 84.4 and 105.9 percent over control, respectively.

Application of FYM alone (100%  $RD_{FYM}$ ) increased total Mn uptake of rotation in comparison to control in both the years, however, the increase was statistically not significant for any year. For yearwise pooled data, the application of 100% FYM significantly increased the total Mn uptake of rotation by 13.9 percent over control.

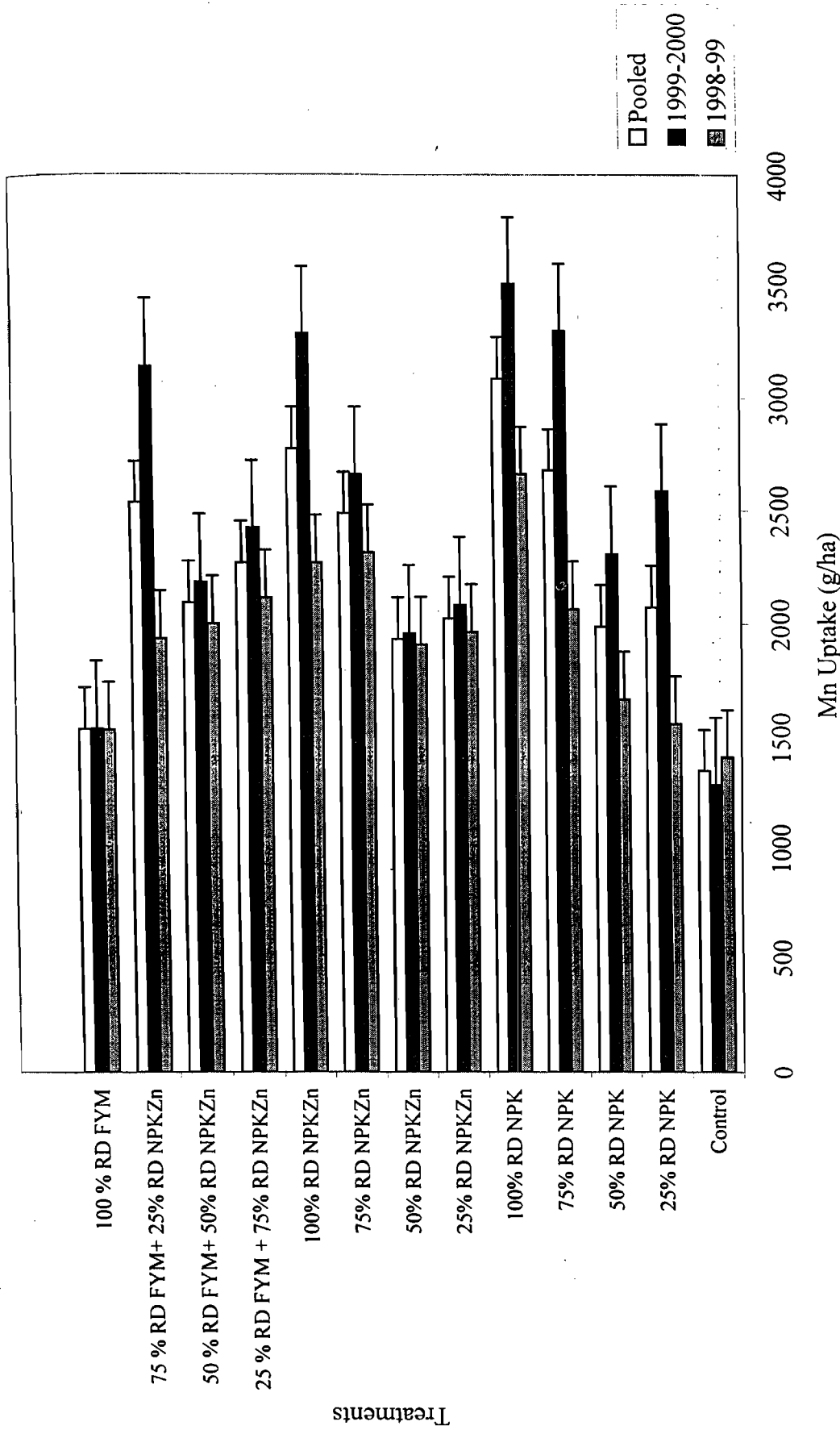


Figure 11: Effect of Chemical Fertilizer, FYM and their conjunctive use on Mn uptake (g/ha) of aromatic rice-wheat sequence

Various combinations of FYM and NPKZn also significantly increased total Mn uptake of rice-wheat sequence over control, in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total Mn uptake of rotation by 68.3, 55.2 and 88.1 percent over control, respectively.

A comparison of pooled Mn uptake data recorded for various combinations of FYM and NPKZn with the values noted at corresponding  $RD_{NPKZn}$  levels revealed that significant effect of FYM in promoting total Mn uptake of rotation was noted only at 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination. However, application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  significantly decreased total Mn uptake of rotation in comparison to the uptake noted at corresponding  $RD_{NPK}$  level. Application of 50%  $RD_{FYM}$  + 50%  $RD_{NPK}$  decreased total Mn uptake of rotation in comparison to the uptake observed at corresponding  $RD_{NPK}$  level, but, the decrease was statistically not significant.

A comparison of total Mn uptake of rotation observed at 100%  $RD_{NPKZn}$  with the uptake observed at corresponding  $RD_{NPK}$  revealed that application of zinc significantly decreased total Mn uptake of rotation. At lower levels of  $RD_{NPKZn}$ , the decrease recorded was statistically not significant. This could be ascribed to the antagonistic effect of higher Zn levels on the Mn uptake by crops (Gangwar and Mann, 1972; Khan and Zende, 1976; Safaya, 1976; Sakal, 1981; Hulagur and Dangarwala, 1982; Patel and Dangarwala, 1983). The decrease in Mn concentrations in plants may arise from the dilution effect resulting from marked increase in plant growth with Zn application as reflected by an increase in the total manganese uptake by plant (Sakal, 1981).

#### 4.4.11 Boron Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the boron uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 35.

**Table 35: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Boron Uptake (g/ha) of Aromatic Rice – Wheat**

Treatment	Boron Uptake (g/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	10.89	21.19	32.08	6.74	20.45	27.19
25% RD <sub>NPK</sub>	9.56	29.21	38.77	9.70	67.47	77.18
50% RD <sub>NPK</sub>	17.59	26.81	44.40	8.92	48.65	57.57
75% RD <sub>NPK</sub>	15.38	23.93	39.31	8.07	76.54	84.61
100% RD <sub>NPK</sub>	16.37	35.56	51.93	10.94	103.73	114.67
25% RD <sub>NPKZn</sub>	8.64	28.09	36.74	10.68	48.21	58.89
50% RD <sub>NPKZn</sub>	17.40	27.23	44.63	10.00	46.85	56.85
75% RD <sub>NPKZn</sub>	24.08	32.32	56.40	14.30	79.19	93.50
100% RD <sub>NPKZn</sub>	19.39	25.53	44.92	13.19	79.83	93.02
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	15.45	33.26	48.71	9.12	61.45	70.57
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	25.67	26.34	52.00	12.08	59.25	71.33
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	28.77	32.02	60.79	17.83	98.65	116.48
100 % RD <sub>FYM</sub>	14.09	25.77	39.85	8.91	60.27	69.18
CD (p=0.05)	3.18	4.37	5.37	1.48	10.64	10.84
	Boron Uptake (g/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	11.82	15.67	27.49	7.65	18.11	25.76
25% RD <sub>NPK</sub>	10.09	32.84	42.93	14.72	19.74	34.46
50% RD <sub>NPK</sub>	12.18	28.60	40.78	19.01	19.76	38.77
75% RD <sub>NPK</sub>	9.75	26.43	36.17	12.57	48.73	61.30
100% RD <sub>NPK</sub>	10.24	24.08	34.32	11.92	64.53	76.46
25% RD <sub>NPKZn</sub>	11.26	21.27	32.52	4.50	22.26	26.76
50% RD <sub>NPKZn</sub>	11.77	35.18	46.94	7.30	23.58	30.88
75% RD <sub>NPKZn</sub>	13.11	21.05	34.16	15.91	40.48	56.39
100% RD <sub>NPKZn</sub>	16.81	24.14	40.95	15.93	66.97	82.91
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	9.15	24.55	33.70	16.48	21.91	38.39
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	8.59	28.01	36.60	16.71	21.57	38.27
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	10.70	25.57	36.27	15.76	29.88	45.65
100 % RD <sub>FYM</sub>	7.50	22.29	29.79	12.18	13.87	26.05
CD (p=0.05)	2.00	5.96	6.46	2.25	4.17	5.18

## RICE

It is evident from the data that increasing level of  $RD_{NPK}$  significantly increased B uptake by grain, straw and total rice crop over control in both the years except at 25%  $RD_{NPK}$  by grain during first year and at 75%  $RD_{NPK}$  by straw in first year and by grain in second year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased B uptake by grain and straw parts and total B uptake of rice over control in both the years, except at 25%  $RD_{NPKZn}$  by grain and total crop in first year; and at 100%  $RD_{NPKZn}$  by straw in first year.

Application of 100%  $RD_{FYM}$  significantly increased B uptake by grain, straw and total crop over control during both the years.

All combinations of FYM and NPKZn significantly increased B uptake by grain, straw and total crop over control during both the years.

## WHEAT

In wheat crop, application of increasing levels of  $RD_{NPK}$  significantly increased B uptake by straw and total crop over control in first year and by grain, straw and total crop in second year except 25% and 50%  $RD_{NPK}$  by straw in second year. Application of 100%  $RD_{NPK}$  significantly decreased B uptake by grain in comparison to control in first year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased B uptake by grain, straw and total crop over control during both the years, however, the differences recorded over control at 25%  $RD_{NPKZn}$  for grain, straw and total crop in both the years; at 50%  $RD_{NPKZn}$  by grain in both the years and by total crop in second year; at 75%  $RD_{NPKZn}$  by grain and straw in first year which were statistically not significant. Application of 25%  $RD_{NPKZn}$  significantly decreased B uptake by grain in comparison to control during second year.

Application of 100%  $RD_{FYM}$  significantly increased B uptake by straw in first year and by grain in second year in comparison to control. In this treatment, B uptake by grain was significantly decreased as compared to control in first year.

All combinations of FYM and NPKZn significantly increased B uptake by straw and total crop during first year and by grain, straw and total crop during

second year in comparison to control. However, the increase in B uptake at 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  by total crop in first year and by straw in second year; at 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  by straw in second year over control was statistically not significant. Application of 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  and 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  significantly decreased B uptake by grain in comparison to control in first year.

### TOTAL UPTAKE BY RICE-WHEAT SEQUENCE

As shown in figure 12, application of increasing levels of  $RD_{NPK}$  significantly increased total B uptake of aromatic rice- wheat sequence over control in both the years. For pooled data, the magnitude of increase in B uptake at 25, 50, 75 and 100 %  $RD_{NPK}$  was 71.8, 61.3, 96.8 and 146.5 per cent over control, respectively.

Application of all levels of  $RD_{NPKZn}$  also significantly increased total B uptake by aromatic rice-wheat sequence over control in both the years. For pooled data, the magnitude of increase in B uptake at 25, 50, 75, 100 %  $RD_{NPK}$  was 37.7, 59.3, 113.7 and 132.7 per cent over control, respectively.

Application of 100%  $RD_{FYM}$  significantly increased total B uptake of rotation in comparison to control in both the years. For pooled data, the magnitude of increase in total B uptake due to FYM application was 46.5 per cent over control.

All combinations of FYM and  $NPKZn$  significantly increased total B uptake of rice-wheat sequence over control in both the years. For pooled data, the magnitude of increase in total B uptake at 25%  $RD_{FYM} + 75\% RD_{NPKZn}$ , 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  and 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  was 70.1, 76.1 and 130.4 per cent over control, respectively.

A comparison of pooled data noted for various combinations of FYM and  $NPKZn$  with the values noted at corresponding  $RD_{NPKZn}$  levels revealed that application of FYM significantly increased total B uptake of the rice-wheat sequence under all combinations except for the one with 25%  $RD_{FYM} + 75\% RD_{NPKZn}$ , where total B uptake was significantly decreased with the application of FYM in comparison to 75%  $RD_{NPKZn}$ .

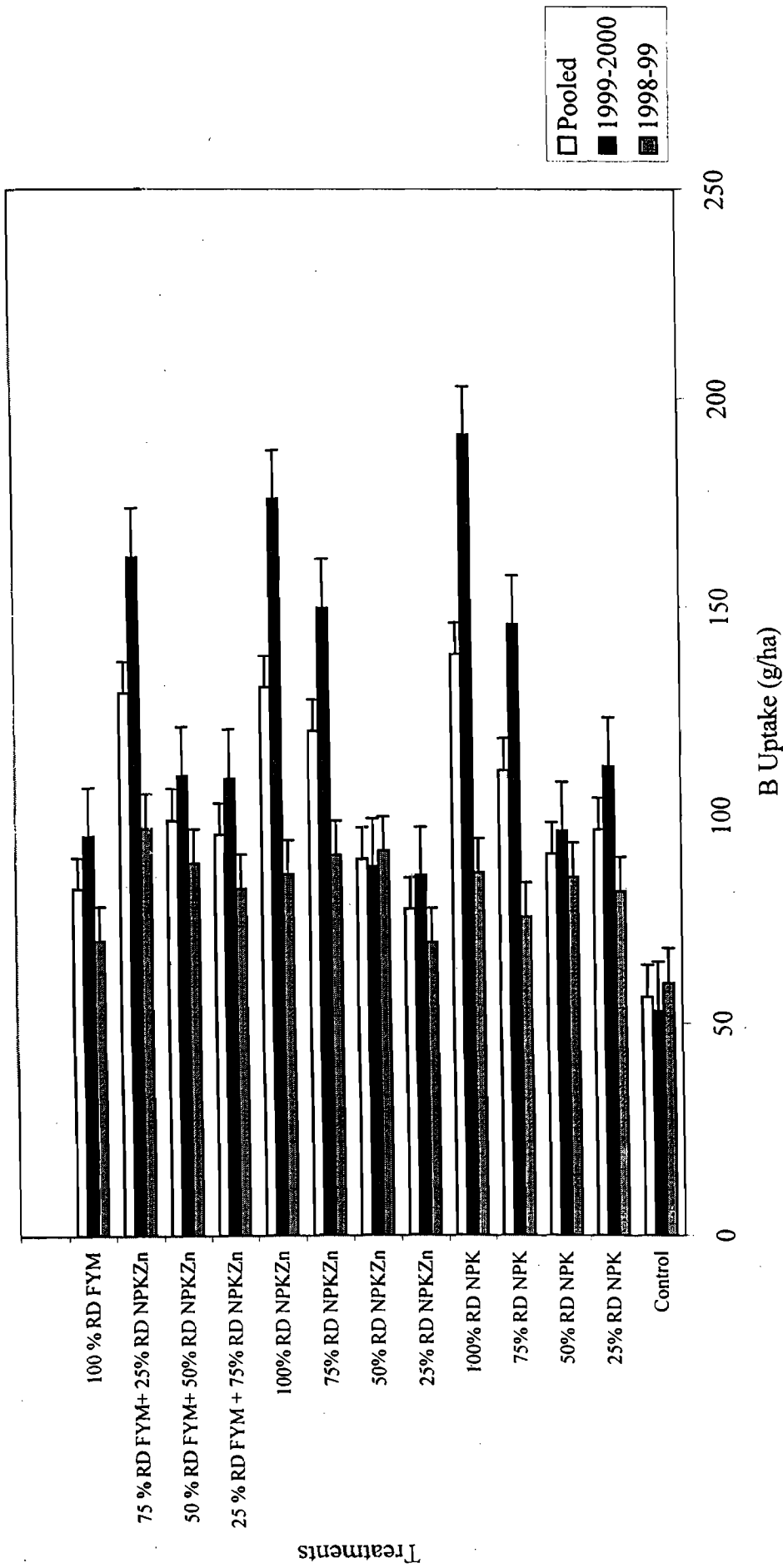


Figure 12: Effect of Chemical Fertilizer, FYM and their conjunctive use on B uptake (g/ha) of aromatic rice-wheat sequence

A comparison of pooled B uptake data noted under different levels of  $RD_{NPKZn}$  and  $RD_{NPK}$  revealed that a significant decrease in total B uptake was observed due to zinc application at all levels except for 50%  $RD_{NPKZn}$  which recorded a non-significant decrease in B uptake. Application of 75%  $RD_{NPKZn}$ , however, increased total B uptake of the rice-wheat sequence, as compared to corresponding NPK level.

#### 4.4.12 Molybdenum Uptake

The data on the effect of soil application of chemical fertilizers, FYM and their combinations on the molybdenum uptake by grain, straw and total crop of aromatic rice and wheat are presented in table 36.

##### RICE

It is evident from the data that increasing levels of  $RD_{NPK}$  significantly increased the molybdenum uptake by grain, straw and total rice crop over control in both the years, except for the increase in uptake noted at 25%  $RD_{NPK}$  by straw during first year; and also at 25%, 50% and 75%  $RD_{NPK}$  by grain during second year.

Application of increasing levels of  $RD_{NPKZn}$  also significantly increased the molybdenum uptake by grain, straw and total crop over control during both the years, except for the increase noted in molybdenum uptake at 50%  $RD_{NPK}$  by grain during second year.

Application of 100% FYM significantly increased molybdenum uptake by grain and total crop over control during first year and by straw and total crop over control during second year.

All combinations of FYM and  $NPKZn$  significantly increased molybdenum uptake by grain, straw and total crop over control during both the years, except for the increase in uptake noted under 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  and 75%  $RD_{FYM} + 25\% RD_{NPKZn}$  by straw during first year and by grain during second year.

##### WHEAT

It is evident from the data pertaining to molybdenum uptake of wheat crop that application of 25%  $RD_{NPK}$  significantly decreased molybdenum uptake

**Table 36: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Molybdenum Uptake (g/ha) of Aromatic Rice – Wheat**

Treatment	Molybdenum Uptake (g/ha) by Aromatic Rice					
	1998 – 1999			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	0.954	0.874	1.828	0.432	0.365	0.798
25% RD <sub>NPK</sub>	1.213	0.950	2.163	0.522	1.624	2.146
50% RD <sub>NPK</sub>	1.485	1.314	2.799	0.480	1.572	2.051
75% RD <sub>NPK</sub>	1.571	1.566	3.137	0.339	1.984	2.324
100% RD <sub>NPK</sub>	1.415	2.893	4.308	0.630	3.215	3.845
25% RD <sub>NPKZn</sub>	1.305	1.881	3.187	0.948	1.079	2.027
50% RD <sub>NPKZn</sub>	1.259	1.459	2.718	0.534	1.281	1.816
75% RD <sub>NPKZn</sub>	1.759	1.827	3.586	1.257	2.172	3.429
100% RD <sub>NPKZn</sub>	1.571	1.298	2.870	1.034	3.995	5.029
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.244	1.163	2.407	1.142	2.987	4.129
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.219	0.960	2.180	0.422	1.115	1.537
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	1.430	0.757	2.187	0.532	1.314	1.845
100 % RD <sub>FYM</sub>	1.244	1.019	2.263	0.435	1.129	1.564
CD (p=0.05)	0.143	0.147	0.207	0.107	0.228	0.264
	Molybdenum Uptake (g/ha) by Wheat					
	1998 – 99			1999 – 2000		
	Grain	Straw	Total	Grain	Straw	Total
Control	0.512	1.488	2.000	0.127	0.598	0.725
25% RD <sub>NPK</sub>	0.301	0.563	0.864	0.251	0.516	0.767
50% RD <sub>NPK</sub>	0.429	0.999	1.428	0.286	0.781	1.067
75% RD <sub>NPK</sub>	0.777	1.086	1.863	0.624	1.502	2.126
100% RD <sub>NPK</sub>	1.158	2.149	3.307	0.804	2.335	3.140
25% RD <sub>NPKZn</sub>	0.923	1.443	2.366	0.380	0.811	1.191
50% RD <sub>NPKZn</sub>	0.784	0.945	1.729	0.434	0.928	1.361
75% RD <sub>NPKZn</sub>	3.025	1.829	4.854	2.642	2.596	5.238
100% RD <sub>NPKZn</sub>	2.448	1.196	3.644	2.839	3.216	6.054
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.613	0.834	2.447	1.357	1.607	2.965
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	2.714	1.420	4.134	1.677	1.153	2.830
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	2.220	1.110	3.330	2.373	1.584	3.958
100 % RD <sub>FYM</sub>	1.934	1.000	2.934	1.304	0.697	2.001
CD (p=0.05)	0.168	0.178	1.736	0.323	0.224	0.396

by grain and straw over control, during first year. Application of 50%  $RD_{NPK}$  also significantly decreased molybdenum uptake by straw over control during first year. Application of 75%  $RD_{NPK}$  significantly increased molybdenum uptake by grain over control during both the years, and by straw and total crop over control during second year, but significantly decreased molybdenum uptake by straw over control during first year. Application of 100%  $RD_{NPK}$  significantly increased molybdenum uptake by grain, straw and total crop over control during both the years.

Application of increasing levels of  $RD_{NPKZn}$  significantly increased molybdenum uptake by grain, straw and total crop over control during both the years, except for the uptake noted at 25%  $RD_{NPKZn}$  by straw during first year; and by grain and straw during second year; at 50%  $RD_{NPKZn}$  by total crop during first year and by grain during second year. Application of 50 and 100%  $RD_{NPKZn}$  significantly decreased molybdenum uptake by straw in comparison to control during first year.

Application of 100%  $RD_{FYM}$  significantly increased molybdenum uptake by grain and total crop during both the years, but, significantly decreased molybdenum uptake by straw over control during first year.

The combinations of FYM and NPKZn significantly increased molybdenum uptake by grain, straw and total crop over control during both the years, except for uptake noted under all combinations during first year, at which molybdenum uptake by straw significantly decreased in comparison to control.

#### **TOTAL UPTAKE BY RICE-WHEAT SEQUENCE**

As shown in figure 13, application of  $RD_{NPK}$ , especially at higher levels, significantly increased total Mo uptake of aromatic rice- wheat sequence over control in both the years. For yearwise pooled data, the magnitude of increase in total Mo uptake of rotation at 25, 50, 75 and 100 %  $RD_{NPK}$  was 10.8, 32.8, 76.5 and 259.7 percent over control, respectively. However, the increase noted at 25 and 50%  $RD_{NPK}$  over control was statistically not significant.

Application of  $RD_{NPKZn}$ , especially at higher levels (75 and 100%  $RD_{NPKZn}$ ), significantly increased total Mo uptake of rotation over control in both the years. For the yearwise pooled data, the magnitude of increase in total Mo

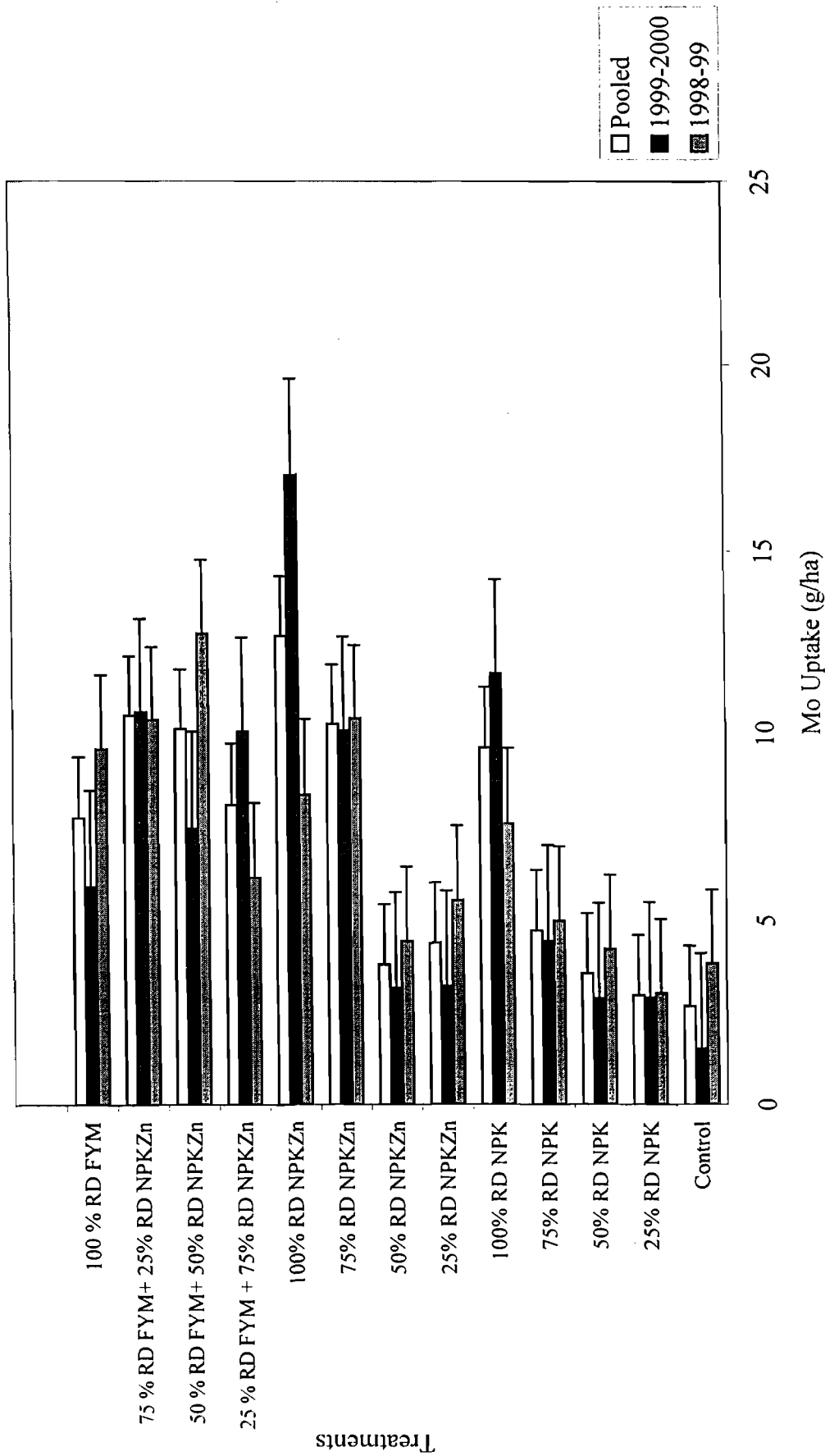


Figure 13: Effect of Chemical Fertilizer, FYM and their conjunctive use on Mo uptake (g/ha) of aromatic rice-wheat sequence

uptake of the rotation at 25, 50, 75, 100 %  $RD_{NPK}$  was 63.8, 42.2, 282.8 and 374.3 percent over control, respectively. However, the increase noted at 50%  $RD_{NPKZn}$  over control was statistically not significant.

Application of FYM alone (100%  $RD_{FYM}$ ) also significantly increased total Mo uptake of rotation in comparison to control in both the years. For yearwise pooled data, the application of 100%  $RD_{FYM}$  significantly increased the total Mo uptake of rotation by 189.9 percent over control.

Various combinations of FYM and NPKZn also significantly increased total Mo uptake of rice-wheat sequence over control, in both the years. For yearwise pooled data, the application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$ , 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  significantly increased total Mo uptake of rotation by 203.0, 278.4 and 292.2 percent over control, respectively.

A comparison of pooled Mo uptake data recorded for various combinations of FYM and NPKZn with the values noted at corresponding  $RD_{NPKZn}$  levels revealed that significant effect of FYM in promoting total Mo uptake of rotation was noted at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  combination. However, application of 25%  $RD_{FYM}$  + 75%  $RD_{NPKZn}$  significantly decreased the Mo uptake in comparison to corresponding values of  $RD_{NPKZn}$  alone.

Application of 75 and 100%  $RD_{NPKZn}$  significantly increased total Mo uptake of rotation in comparison to the values of Mo uptake obtained at corresponding  $RD_{NPK}$  levels. It clearly indicated that the application of Zn at higher levels enhanced the total Mo uptake of the rotation.

## **4.5 Relationship between Quality Parameters and Nutrient Content of Leaf and Grain of Aromatic Rice**

### **4.5.1 Relationship between Nutrient Composition of Index leaf and Quality Parameters in Aromatic Rice**

Simple correlations coefficients calculated between nutrient composition of index leaf and grain quality of aromatic rice from the pooled data of two years are presented in table 37.

**Table 37: Simple Correlation Coefficients (r) between Nutrient Concentration in Index leaf and Grain Quality Parameters in Aromatic Rice (Pooled Data of Two Years)**

Quality parameters	Simple Correlation Coefficients ( r )												
	N	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe	B	Mo	
Aroma	-0.122	0.213	0.126	-0.139	0.177	0.008	-0.110	-0.082	-0.159	0.119	0.128	-0.161	
Grain length	0.084	-0.072	0.209	-0.040	-0.181	0.246	0.203	-0.027	-0.010	-0.316	0.123	0.223	
Grain breadth	-0.334	-0.155	-0.253	0.123	0.132	-0.229	0.001	-0.212	0.408*	0.390*	-0.117	-0.407*	
L:B ratio	-0.010	-0.148	0.147	-0.002	-0.164	0.208	0.237	-0.101	0.112	-0.228	0.096	0.132	
Alkali value	-0.107	0.389*	0.263	-0.108	0.055	-0.210	-0.207	-0.049	0.013	0.223	0.246	-0.136	
% Milling yield	-0.124	0.301	0.489*	-0.332	-0.003	-0.207	0.218	0.255	-0.283	-0.035	0.103	-0.101	
% Head rice based on Paddy	-0.206	0.788**	0.665**	-0.676**	-0.124	-0.505**	0.163	0.227	-0.287	-0.344	0.358	-0.278	
% Head rice based on brown rice	-0.394*	0.278	0.147	-0.252	0.305	-0.086	0.010	-0.233	-0.210	0.175	0.475*	-0.362	
% Hull	-0.047	-0.588**	-0.512**	0.450*	0.209	0.348	-0.163	-0.366	0.128	0.375	-0.167	0.130	
% Broken kernels	-0.035	-0.202	-0.457*	0.200	-0.002	0.355	-0.269	-0.028	0.208	-0.089	-0.369	0.084	

\*\*significant at p = 0.01

\* significant at p = 0.05

It is apparent from the values of correlation coefficients ( $r$ ) that grain breadth was significantly and positively correlated to the content of Mn and Fe, but negatively correlated to the content of Mo in index leaf at probability level  $p=0.05$ . Alkali value of aromatic rice was also significantly and positively correlated to the concentration of P in the index leaf at  $p=0.05$ . The percent milling yield of rice was significantly and positively correlated to the K content of index leaf at  $p=0.05$ . The percent head rice yield based on paddy was strongly and positively correlated to the concentration of P and K, but negatively correlated to Ca and S content in the index leaf. All  $r$ -values were significant at  $p=0.01$ . The per cent head rice yield based on brown rice showed significant and positive correlation with B concentration but negative correlation with N concentration in index leaf at  $p=0.05$ . The percent hull showed significant and positive correlation with Ca concentration in index leaf at  $p=0.05$  but strong negative correlation with P and K concentration in index leaf at  $p=0.01$ . The percent broken kernel showed a significant and negative correlation with K concentration in index leaf at  $p=0.05$ .

Rest other grain quality parameters such as aroma, grain length, L:B ratio failed to show a significant correlation with nutrient concentration in index leaf of aromatic rice.

Multiple regression equations based on step-wise analysis to predict rice grain quality on the basis of nutrient content of index leaf of aromatic rice are presented in table 38.

As shown in table, the contents of N, K, Mg, S, Zn, Cu, Fe and B in the index leaf accounted 56.7% variation in grain length of aromatic rice. The contents of P, K, Ca, Mg, S, Mn and Fe in index leaf explained 63.8% variation of grain breadth of aromatic rice. The concentrations of P, Ca, Zn, Cu and Fe in the index leaf explained 44.9% variation in alkali score of aromatic rice. The contents of K, Mg, Cu and B in index leaf could account 40.9% variation in percent milling yield. The contents of N, P, Zn, Cu, Mn and Mo in the index leaf accounted 77.5% variation in percent head rice yield based on paddy. The concentrations of P, Ca, Mg, Zn and Cu in index leaf explained 55.4% variation in percent hull of aromatic

**Table 38: Multiple Regression Equation based on Stepwise Analysis of Rice Grain Quality on Nutrient Content of Index leaf of Aromatic Rice ( $b_1$ )**

Quality Parameters	a	Partial Regression Coefficients ( $b_i$ )												$R^2$		
		N	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe	B	Mo			
Aroma	1.547		6.738				2.576	-0.017				-0.002	0.004		-0.685	0.241
Grain length	7.834	-2.272		0.439		-0.972	1.208	0.007	-0.041				-0.002	0.011		0.567*
Grain Breadth	2.010		-0.642	-0.102	-0.159	0.432	-0.487					0.0005	0.0002			0.638**
L:B Ratio	4.832		-1.302	0.182		-0.327	0.330	0.003	-0.021	-0.002		0.0002	-0.0009	0.006		0.532
Alkali Value	-2.309		11.327		0.864			-0.015	0.068				0.0057			0.449*
% Milling Yield	25.551			6.509		16.221			0.597					-0.134		0.409*
% Head Rice based on Paddy	53.89	-1.387	46.756					0.074	0.481	-0.0041					-1.475	0.775**
% Head Rice based on Brown Rice	94.06	-1.767				3.702		-0.045		-0.0077			0.0056	0.222	-1.677	0.483
% Hull	41.61		-30.717		-2.159	3.609		-0.062	-0.412							0.554**
% Broken Kernels	40.56	-2.106	36.728	-5.689		-11.924	14.256	-0.578							-0.211	0.585*

\*\*significant at  $p = 0.01$

\*significant at  $p = 0.05$

rice. The concentrations of N, P, K, Mg, S, Zn and Mo in the index leaf accounted 58.5% variation in percent broken kernel in aromatic rice.

Aromatic rice quality parameters like aroma, L:B ratio and percent head rice yield based on brown rice yield could not be successfully predicted on the basis of nutrient contents of nutrients in the index leaf.

#### 4.5.2 Relationship between Nutrient Composition of Grain and Aromatic Rice Quality Parameters

Simple correlation coefficients ( $r$ ) computed between nutrient concentration in grain and grain quality parameters of aromatic rice from the pooled data of two years study are presented in table 39.

It is evident from  $r$ -values that both grain length and L:B ratio of aromatic rice had significant and negative correlation with Mg concentration in grain at  $p=0.05$ . The percent head rice yield based on paddy had a significant and positive correlation with Mn concentration in grain at  $p=0.01$ , but negative correlation with Zn, K and N concentrations in grain at  $p=0.01$  and  $0.05$ , respectively. The percent hull had a significant and positive correlation with K and Zn concentrations in grain, but negative correlation with P and Mn concentrations at  $p$  levels of  $0.05$  and  $0.01$ , respectively.

Other rice grain quality parameters, like aroma, grain breadth, alkali value, per cent milling yield, per cent head rice yield based on brown rice and per cent broken kernels failed to show any significant relationship with the concentration of any nutrient in rice grain.

Multiple regression equations based on step-wise analysis to predict rice grain quality on the basis of nutrient concentrations in grain of aromatic rice are presented in table 40.

It is clear from the values contained in table that the concentrations of K, Mg, S, Zn and Mn in grain accounted 65.9% variation in the percent head rice yield based on paddy. The concentrations of P, K, Mg, Zn, Mn and B in grain explained 62.7% variation in the percent hull of aromatic rice. The concentrations of N, Mg, S, Cu, Mn and B in grain accounted 45.9% variation in the percent of broken kernels of aromatic rice. Other aromatic rice quality parameters such as aroma, grain length, grain breadth, L:B ratio, alkali value, percent milling and

**Table 39: Simple Correlation Coefficients (r) between nutrient concentration in grain and grain quality parameters in aromatic rice (pooled data of two years)**

Quality Parameters	Simple Correlation Coefficients (r)											
	N	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe	B	Mo
Aroma	0.106	-0.113	0.061	0.094	-0.039	0.067	-0.090	0.194	0.090	-0.088	0.022	-0.208
Grain length	-0.029	0.083	-0.236	-0.138	-0.418*	-0.202	-0.332	0.081	0.046	0.126	-0.215	-0.090
Grain breadth	-0.064	-0.158	0.078	-0.225	0.083	0.221	0.181	-0.329	-0.137	-0.013	-0.110	0.146
L:B ratio	-0.041	0.038	-0.232	-0.224	-0.463*	-0.173	-0.320	-0.021	0.001	0.139	0.218	-0.051
Alkali value	-0.050	-0.148	-0.007	-0.047	0.120	0.291	-0.030	0.079	0.207	-0.104	-0.186	-0.010
% Milling yield	-0.095	0.056	-0.152	-0.183	-0.103	0.141	-0.059	-0.036	0.312	0.112	-0.048	0.085
% Head rice based on Paddy	-0.449*	0.269	-0.497**	-0.363	-0.352	0.062	-0.526**	0.293	0.654**	0.263	-0.294	-0.065
% Head rice based on brown rice	-0.141	-0.177	-0.126	-0.155	-0.148	0.264	-0.228	-0.019	0.110	0.029	-0.164	0.055
% Hull	0.274	-0.453*	0.454*	0.187	0.178	-0.063	0.447*	-0.335	-0.535**	-0.290	0.096	0.145
% Broken kernels	0.193	-0.003	0.168	0.287	0.048	-0.189	0.163	0.291	-0.276	-0.221	0.212	0.135

\*\* significant at  $p = 0.01$

\* significant at  $p = 0.05$

Table 40: Multiple regression equation based on stepwise analysis of rice grain quality on nutrient content of grain of aromatic rice (b<sub>i</sub>)

Quality Parameters	a	Partial Regression Coefficients (b <sub>i</sub> )											R <sup>2</sup>					
		N	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe	B		Mo				
Aroma	3.833		-7.637	3.707		-35.381	16.225		0.473								-0.468	0.265
Grain length	7.646		1.449			-17.199		-0.0059							0.0272			0.350
Grain breadth	1.882					-4.604	2.264	0.0016	-0.050						-0.0073		-0.0251	0.361
L:B ratio	4.664	0.057	0.621	0.549	-1.032	-9.923		-0.0033							0.0149			0.460
Alkali value	2.482		-7.812	1.923			26.426					0.031	-0.0035					0.393
% Milling yield	35.00	2.093				-189.32	97.310		-1.381	0.149							0.995	0.293
% Head rice based on Paddy	64.574					-188.296	99.801	-0.056				0.138						0.559**
% Head rice based on brown rice	94.703		-25.252	6.305	8.361	-278.066	143.686					0.0448			-0.163			0.451
% Hull	34.230		-18.372	6.960		-57.88		0.066				-0.0414			-0.0087			0.527**
% Broken kernels	31.725	-1.762				155.320	-104.901		2.153	-0.1039					0.213			0.559*

\*\*significant at p = 0.01

\*significant at p = 0.05

per cent head rice yield based on brown rice could not be successfully predicted only on the basis of nutrient concentrations in rice grain.

### **4.5.3 Interrelationship among Aromatic Rice Quality Parameters**

Simple correlation coefficients ( $r$ ) computed among aromatic rice quality parameters using two years pooled data are shown in table 41.

It is clear from the  $r$ -values that aroma had a significant ( $p=0.05$ ) and positive correlation with alkali value of aromatic rice. Grain length was significantly and positively correlated to L:B ratio at  $p=0.01$ , but negatively correlated to grain breadth at  $p=0.05$ . Grain breadth showed a significant and positive correlation with percent hull at  $p=0.01$ . The per cent milling yield showed a significant and positive correlation with per cent head rice yields based on paddy and also on brown rice at  $p=0.01$  and  $0.05$  level, respectively, but negative correlation with per cent broken kernels at  $p=0.01$ . The per cent head rice yield based on paddy had a significant and positive correlation with per cent head rice yield based on brown rice at  $p=0.05$ , but negative correlation with per cent hull at  $p=0.01$ . The percent hull was significantly and negatively correlated to percent broken kernel at  $p=0.05$ .

### **4.6 Effect of chemical fertilizers, FYM and their conjoint use on the build up of soil Organic Carbon and Extractable Nutrients in Soil at Harvest of Aromatic Rice – Wheat Sequence**

The contents of organic carbon, alkaline  $\text{KMnO}_4$  hydrolysable N, 0.15%  $\text{CaCl}_2$  extractable S and Mehlich-3 extractable P, K, Ca, Mg, Zn, Cu, Mn, Fe and B in soil under different treatments after the harvest of aromatic rice – wheat sequence are presented for both the first and second years in the tables 42, 43 and 44.

Table 41: A Matrix of Simple Correlation Coefficients (r) among Rice Quality Parameters of Aromatic Rice (Pooled Data of Two Years)

Quality Parameters	Simple correlation coefficients (r)										
	Aroma	Grain Length	Grain Breadth	L:B ratio	Alkali Score	% Milling Yield	% Head Rice Yield based on Paddy	% Head Rice Yield based on Brown Rice	% Hull	% Broken Kernels	
Aroma	1.000	0.104	-0.278	0.037	0.453*	-0.090	0.160	0.088	-0.225	0.342	
Grain Length			-0.579*	0.962**	-0.345	0.060	0.131	-0.068	-0.269	0.000	
Grain Breadth				-0.336	0.067	-0.074	-0.275	0.183	0.505**	-0.168	
L:B ratio					-0.377	0.038	0.046	-0.024	-0.133	-0.050	
Alkali Score						-0.010	0.147	0.321	-0.087	-0.062	
% Milling Yield							0.607**	0.431*	-0.213	0.656**	
% Head Rice Yield based on Paddy								0.442*	-0.725**	-0.307	
% Head Rice Yield based on Brown Rice									0.081	-0.391*	
% Hull										-0.012	
% Broken Kernels											

\*\* significant at  $p = 0.01$

\* significant at  $p = 0.05$

#### 4.6.1 Soil Organic Carbon

It is evident from the data (table 42) that soil organic C content under 75% RD<sub>NPK</sub> in the first year and under 100% RD<sub>NPK</sub> in the second year was significantly higher over control. Among RD<sub>NPKZn</sub> levels, 50 and 100% RD<sub>NPKZn</sub> levels maintained higher soil organic C content over control in the first year, while in the second year, all levels of RD<sub>NPKZn</sub> maintained significantly higher level of soil organic C in comparison to control. This could be attributed to increased production of underground decomposable biomass under chemical fertilizer treatments.

Highest content of soil organic C was noted in the treatment receiving 100% RD<sub>FYM</sub> in both the years. Several workers (Havangi and Mann, 1970; Gattani *et al*, 1976; Prasad, 1983; Sharma *et al*, 1985; Nahar *et al*, 1995) have also reported that regular application of organic manure increased content of soil organic matter. All combinations of FYM and NPKZn also had significantly higher content of soil organic C as compared to control in both the years. A comparison of soil organic C contents under various combinations of FYM and RD<sub>NPKZn</sub> with those at corresponding level of RD<sub>NPKZn</sub> revealed that the combinations of 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> maintained significantly higher level of soil organic C content in comparison to 50% RD<sub>NPKZn</sub> and 25% RD<sub>NPKZn</sub> alone, respectively. The treatment 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> resulted significantly higher soil organic C content than 75% RD<sub>NPKZn</sub> in the first year only.

#### 4.6.2 Alkaline KMnO<sub>4</sub> Hydrolysable Nitrogen

The contents of alkaline KMnO<sub>4</sub> hydrolysable N in soil (table 42) after harvest of aromatic rice – wheat sequence under all levels of RD<sub>NPK</sub> or RD<sub>NPKZn</sub> were significantly higher over control in both the years; the highest content was recorded at 75% RD<sub>NPK</sub> or RD<sub>NPKZn</sub> level. Addition of Zn at different levels of RD<sub>NPK</sub> resulted significant depletion of alkaline KMnO<sub>4</sub> hydrolysable N due to higher biomass production and consequent increase in N requirement of crops.

Application of 100% RD<sub>FYM</sub> maintained significantly higher amount of alkaline KMnO<sub>4</sub> hydrolysable N in comparison to control in both the years. All

**Table 42: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Build Up of Organic Carbon and Macronutrients Concentration in Soil**

Treatment	Organic Carbon and Macronutrients Concentration in Soil									
	Organic Carbon (%)		Nitrogen (kg/ha)		Phosphorus (ppm)		Potassium (ppm)			
	1998-1999	1999-2000	1998-1999	1999-2000	1998-1999	1999-2000	1998-1999	1999-2000	1998-1999	1999-2000
<b>Control</b>	0.57	0.45	105.7	81.2	14.38	11.23	45.8	52.7		
<b>25% RD<sub>NPK</sub></b>	0.62	0.53	161.5	118.8	15.46	12.65	48.9	54.2		
<b>50% RD<sub>NPK</sub></b>	0.64	0.50	181.8	123.1	17.10	14.28	52.9	59.8		
<b>75% RD<sub>NPK</sub></b>	0.73	0.51	207.7	160.1	18.39	13.99	51.5	54.2		
<b>100% RD<sub>NPK</sub></b>	0.65	0.62	152.0	152.0	16.39	16.15	49.6	54.9		
<b>25% RD<sub>NPKZn</sub></b>	0.63	0.60	142.5	118.9	16.89	14.42	49.8	51.5		
<b>50% RD<sub>NPKZn</sub></b>	0.75	0.59	137.4	101.8	14.91	14.42	49.0	50.6		
<b>75% RD<sub>NPKZn</sub></b>	0.64	0.66	177.7	158.5	14.97	14.30	49.4	52.7		
<b>100% RD<sub>NPKZn</sub></b>	0.84	0.70	121.8	131.0	17.98	14.87	51.9	58.1		
<b>25 % RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub></b>	0.80	0.63	242.6	143.2	14.61	13.87	49.8	56.0		
<b>50 % RD<sub>FYM</sub> + 50 % RD<sub>NPKZn</sub></b>	0.89	0.74	218.9	153.1	18.22	13.98	51.2	54.8		
<b>75 % RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub></b>	0.82	0.85	173.3	125.2	14.99	15.31	50.2	54.0		
<b>100 % RD<sub>FYM</sub></b>	1.09	0.97	148.1	113.7	16.68	12.75	52.6	56.3		
<b>CD (p=0.05)</b>	0.09	0.09	18.4	15.0	1.51	0.91	3.9	5.4		

combinations of FYM and NPKZn also maintained significantly higher content of alkaline  $\text{KMnO}_4$  hydrolysable N over control in both the years. Comparison of alkaline  $\text{KMnO}_4$  hydrolysable N under various combinations of FYM and NPKZn with those at corresponding levels of  $\text{RD}_{\text{NPKZn}}$  revealed that addition of FYM helped in maintaining higher level of alkaline  $\text{KMnO}_4$  hydrolysable N in the first year, but in the second year, this trend was noted only under 50%  $\text{RD}_{\text{FYM}}$  + 50%  $\text{RD}_{\text{NPKZn}}$  level.

#### 4.6.3 Mehlich-3 Extractable Phosphorus

Application of increasing levels of  $\text{RD}_{\text{NPK}}$  maintained significantly higher content of extractable P over control in both the years, except at 25%  $\text{RD}_{\text{NPK}}$  level in the first year (table 42). Application of increasing levels of  $\text{RD}_{\text{NPKZn}}$  also resulted significantly higher content of extractable P in soil over control in both the years except at 50 and 75%  $\text{RD}_{\text{NPKZn}}$  levels in the first year.

Application of 100%  $\text{RD}_{\text{FYM}}$  also resulted significantly higher extractable P in soil in comparison to control in both the years. All combinations of FYM and NPKZn also maintained significantly higher content of extractable P in soil in comparison to control in both the years except at 25%  $\text{RD}_{\text{FYM}}$  + 75%  $\text{RD}_{\text{NPKZn}}$  and 75%  $\text{RD}_{\text{FYM}}$  + 25%  $\text{RD}_{\text{NPKZn}}$  during first year.

#### 4.6.4 Mehlich-3 Extractable Potassium

Application of 50 and 75%  $\text{RD}_{\text{NPK}}$  significantly increased Mehlich-3 extractable K in soil in comparison to control during both the years and first year, respectively (table 42). Application of 25 and 100%  $\text{RD}_{\text{NPKZn}}$  significantly increased extractable K over control during the first year and in both the years, respectively. Application of 100%  $\text{RD}_{\text{FYM}}$  significantly increased extractable K over control in the first year. All combinations of FYM and NPKZn significantly increased extractable K content over control during the first year.

#### 4.6.5 Mehlich-3 Extractable Calcium

Application of 75% RD<sub>NPK</sub> significantly increased the content Mehlich-3 extractable Ca in soil over control during first year (table 43), but in the second year even lower levels of RD<sub>NPK</sub> were effective in significantly increasing extractable Ca in soil over control.

Application of 25% RD<sub>NPKZn</sub> significantly increased extractable Ca in soil over control, while 75% RD<sub>NPKZn</sub> level significantly decreased it in comparison to control during first year. In the second year, all levels of RD<sub>NPKZn</sub> significantly increased extractable Ca in soil over control.

Application of 100% RD<sub>FYM</sub> significantly increased extractable Ca in soil over control during second year only. The combinations of 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> significantly increased extractable Ca in soil over control in both the years. Application of 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> significantly decreased extractable Ca in soil over control in the first year but during second year, these treatments also maintained significantly higher levels of extractable Ca in soil over control.

#### 4.6.6 Mehlich-3 Extractable Magnesium

The effect of different treatments on the content of Mehlich-3 extractable Mg in soil was found to be statistically not significant (table 43).

#### 4.6.7 0.15% CaCl<sub>2</sub> Extractable Sulphur

Application of all levels of RD<sub>NPK</sub> and RD<sub>NPKZn</sub> significantly increased 0.15% CaCl<sub>2</sub> extractable soil S over control in both the years (table 43), however, the increase recorded at 25% level in the first year and at 75% RD<sub>NPK</sub> and 100% RD<sub>NPKZn</sub> during second year was statistically not significant.

Application of 100% RD<sub>FYM</sub> significantly increased the content of extractable soil S over control in both the years.

All combination of FYM and NPKZn significantly increased extractable soil S over control in both the years except for 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> during second year.

**Table 43: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Build Up of Secondary Nutrients Concentration in Soil**

Treatment	Secondary Nutrients Concentration in Soil					
	Calcium (ppm)		Magnesium (ppm)		Sulphur (ppm)	
	1998-1999	1999-2000	1998-1999	1999-2000	1998-1999	1999-2000
Control	631.8	506.2	131.7	132.9	25.5	22.4
25% RD <sub>NPK</sub>	656.9	593.5	131.8	132.6	29.0	35.3
50% RD <sub>NPK</sub>	669.7	582.3	131.7	133.3	37.5	39.8
75% RD <sub>NPK</sub>	728.1	690.3	130.6	133.2	54.4	23.2
100% RD <sub>NPK</sub>	600.5	505.1	131.6	132.3	68.5	33.3
25% RD <sub>NPKZn</sub>	763.6	598.1	132.6	133.0	26.8	33.8
50% RD <sub>NPKZn</sub>	655.2	562.4	131.4	131.4	49.0	32.6
75% RD <sub>NPKZn</sub>	555.0	649.6	131.5	133.0	43.5	33.8
100% RD <sub>NPKZn</sub>	641.3	566.2	132.3	131.2	56.3	29.5
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	554.5	766.6	132.0	134.1	48.8	39.5
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	745.7	694.1	134.4	133.5	45.8	33.2
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	549.8	562.7	130.9	131.8	47.0	26.6
100 % RD <sub>FYM</sub>	661.8	646.8	132.6	134.8	54.4	37.8
CD (p=0.05)	56.6	50.1	NS	NS	7.2	7.6

#### 4.6.8 Mehlich-3 Extractable Zinc

Application of 100% RD<sub>NPK</sub> significantly increased the content of Mehlich-3 extractable soil Zn over control in the first year only (table 44).

Application of 100% RD<sub>NPKZn</sub> also significantly increased the content of extractable soil Zn over control in both the years.

Application of 100% RD<sub>FYM</sub> significantly increased the content of extractable soil Zn over control in both the years, however, the increase recorded during the first year was statistically not significant. The treatments comprising 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> also maintained significantly higher content of extractable soil Zn in comparison to control during first year.

#### 4.6.9 Mehlich-3 Extractable Copper And Iron

The contents of Mehlich-3 extractable soil Cu and Fe were found to be not significantly influenced by different treatments (table 44).

#### 4.6.10 Mehlich-3 Extractable Manganese

Application of all levels of RD<sub>NPK</sub> and RD<sub>NPKZn</sub> significantly increased the content of Mehlich-3 extractable Mn in soil over control in the first year only (table 44). In many studies, extractable Mn in soil or Mn in soil solution has been reported to increase with addition of zinc to soil (Sekhon and Chopra, 1971; Venkata Subrahmanyam and Mehta, 1985; Mandal and Haldar, 1980; Patra, 1981; Antil and Dahiya, 1986; Sadana and Takkar, 1988).

Application of 100% RD<sub>FYM</sub> also significantly increased the content of extractable soil Mn over control during first year.

All combinations of FYM and NPKZn significantly increased the content of extractable soil Mn over control during the first year.

#### 4.1.11 Mehlich-3 Extractable Boron

Application of all levels of RD<sub>NPK</sub> and RD<sub>NPKZn</sub> significantly increased the content of Mehlich-3 extractable B in soil over control during the second year only.

**Table 44: Effect of Soil Application of Chemical Fertilizers, FYM and their Combinations on the Build Up of Micronutrients Concentration in Soil**

Treatment	Micronutrients Concentration in Soil													
	Zinc (ppm)			Copper (ppm)			Iron (ppm)			Manganese (ppm)			Boron (ppm)	
	1998-1999	1999-2000	1999-2000	1998-1999	1999-2000	1999-2000	1998-1999	1999-2000	1999-2000	1998-1999	1999-2000	1999-2000	1998-1999	1999-2000
Control	1.19	1.01	1.02	1.08	1.01	1.02	133.6	128.7	128.7	23.8	28.0	28.0	1.10	0.74
25% RD <sub>NPK</sub>	1.32	1.02	1.04	1.01	0.95	1.02	133.7	128.7	128.7	31.5	24.9	24.9	1.06	1.02
50% RD <sub>NPK</sub>	1.27	1.07	1.04	1.10	1.04	1.02	133.1	129.1	129.1	36.4	29.7	29.7	1.04	1.02
75% RD <sub>NPK</sub>	1.29	1.08	1.02	1.13	1.02	1.02	134.0	129.8	129.8	33.7	27.0	27.0	1.04	1.16
100% RD <sub>NPK</sub>	1.48	0.89	0.98	1.07	0.98	0.98	133.9	129.1	129.1	35.8	26.7	26.7	1.06	1.02
25% RD <sub>NPKZn</sub>	1.24	1.12	0.98	1.04	0.98	0.98	133.7	128.5	128.5	38.4	24.6	24.6	1.08	1.04
50% RD <sub>NPKZn</sub>	1.27	1.17	0.96	1.13	0.96	0.96	133.9	128.3	128.3	39.1	24.0	24.0	1.06	1.06
75% RD <sub>NPKZn</sub>	1.31	1.04	0.99	1.08	0.99	0.99	133.9	129.3	129.3	38.9	27.3	27.3	1.06	0.96
100% RD <sub>NPKZn</sub>	1.42	1.29	0.97	1.12	0.97	0.97	134.1	128.7	128.7	30.8	24.1	24.1	1.02	1.08
25% RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	1.29	1.15	1.07	1.09	1.07	1.07	133.4	128.8	128.8	29.4	30.5	30.5	1.06	0.98
50% RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	1.47	1.04	0.97	1.11	0.97	0.97	134.1	128.7	128.7	33.3	32.0	32.0	1.00	1.04
75% RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	1.54	1.23	0.94	1.05	0.94	0.94	134.0	128.4	128.4	31.6	23.6	23.6	1.06	1.16
100% RD <sub>FYM</sub>	1.35	1.39	0.96	1.06	0.96	0.96	134.1	128.8	128.8	38.4	33.3	33.3	1.08	1.02
CD (p=0.05)	0.18	0.28	NS	NS	NS	NS	NS	NS	NS	4.6	NS	NS	NS	0.14

Application of 100% RD<sub>FYM</sub> significantly increased the content of extractable B in soil over control during the second year.

All combinations of FYM and NPKZn significantly increased the content of extractable B in soil over control during the second year only. In general, the increasing proportion of FYM in the combined applications of FYM and NPKZn was found to increase the content of extractable soil B after the harvest of aromatic rice – wheat sequence.

**SUMMARY**  
**AND**  
**CONCLUSION**

## 5. Summary and Conclusion

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Field experiments were conducted during 1998-2000 at Research Station, Nagina, Distt. Bijnor, U.P. to investigate the effect of soil application of chemical fertilizers, farmyard manure and their conjunctive use on the yields, nutrient content and uptake of aromatic rice – wheat sequence and quality of aromatic rice. The results of the present study are summarized herein:

1. The highest grain yield (18.2 q/ha) of aromatic rice was recorded at 75%  $RD_{NPKZn}$  level during 1998-99, which was significantly higher over 75%  $RD_{NPK}$  but at par with 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$ . In the second year (1999-2000), the highest grain yield (17.44 q/ha) of aromatic rice was recorded at 100%  $RD_{NPK}$  which was at par with yields obtained at 75%  $RD_{NPKZn}$  or 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$ .

The highest grain yield of wheat (18.80 q/ha during 1998-99, 18.28 q/ha during 1999-2000 and 18.54 q/ha for yearwise pooled data) was noted in treatment receiving 100%  $RD_{NPKZn}$ ; the yield under this treatment was at par with that of 100%  $RD_{NPK}$  in both the years, but it was significantly higher over 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$ .

Application of recommended fertilizer dose of NPK through FYM equivalent to that of 100%  $RD_{NPK}$  significantly increased aromatic rice grain yield by 17.1% in 1998-99 but failed to increase grain yield significantly over control in 1999-2000. Application of FYM alone to supply 100%  $RD_{NPK}$  failed to increase grain, straw and total DM yields of wheat over control during both the years.

On the basis of yearwise pooled grain yield data, the total productivity of aromatic rice – wheat rotation was highest (35.98 q grain/ha) under 75%  $RD_{NPKZn}$  treatment for rice and 100%  $RD_{NPKZn}$  treatment for wheat.

2. Application of chemical fertilizers did not adversely affect aroma score of rice in comparison to control. The best aroma score (5.0) was recorded under 100% FYM application in both the years followed by 75%  $RD_{NPKZn}$  (4.5 in 1998-

99 and 4.63 in 1999-2000) and the score under both these treatments was significantly higher in comparison to control.

3. The application of 50% RD<sub>NPK</sub>, 25% RD<sub>NPKZn</sub>, 100% RD<sub>NPKZn</sub>, 100% RD<sub>FYM</sub>, 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> and 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> significantly increased the alkali score over control, during first year, second year and for pooled data.

4. The highest grain length (7.84 mm, average of two years), significantly higher over control, was recorded under application of FYM alone. The application of 50% RD<sub>NPK</sub> significantly increased the grain length over control, during both the years and also for pooled data. The application of 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub> significantly increased the grain length over control during first year only. However, the application of 100% RD<sub>NPKZn</sub>, 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> significantly decreased the grain length over control during first year and for pooled data.

5. Application of 50% and 75% RD<sub>NPKZn</sub> and 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> significantly decreased grain breadth over control during both the years and also for the pooled data. Application of 75% and 100% RD<sub>NPK</sub> significantly decreased the grain breadth over control, during first year only. Application of FYM alone (100% RD<sub>FYM</sub>) significantly decreased grain breadth of rice in comparison to control in both the years and also for pooled data, the grain breadth recorded under this treatment was the lowest (1.63 mm, pooled average).

6. Among all treatments, the highest L:B ratio was recorded under 100% RD<sub>FYM</sub> treatment. In the first year (1998-99), the L:B ratio increased significantly over the control under 50% RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub> and 75% RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub>. The L:B ratio decreased significantly under the treatments with 100% RD<sub>NPKZn</sub> and 25% RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub> in comparison to control, during both years and also for yearwise pooled data.

7. The percent broken kernels under 75% RD<sub>NPKZn</sub> was significantly higher over control in the first year. Application of 75% RD<sub>NPK</sub> and 25% RD<sub>NPKZn</sub> significantly decreased the percent broken kernels over control in the second year and also for pooled data. Application of FYM alone (100% RD<sub>FYM</sub>) or combinations of chemical fertilizers and FYM failed to influence the percent broken kernels of aromatic rice.

8. The maximum percent milling yield (49.04%) was recorded under 75%  $RD_{NPK}$  in the second year. Application of FYM alone had no significant effect on the percent milling yield of rice. The yearwise pooled data showed that the combined application at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  level significantly increased the percent milling yield over control.

9. Application of all levels of  $RD_{NPK}$  decreased the percent hull content over control in both the years and also for pooled data. Application of 50, 75 and 100%  $RD_{NPKZn}$  significantly decreased the percent hull content over control in both the years except for the decrease noted under 100%  $RD_{NPKZn}$  in the first year. Application of FYM alone (100%  $RD_{FYM}$ ) significantly decreased the percent hull content of rice in comparison to control during the first year and also for pooled data. All combinations of  $NPKZn$  and FYM significantly decreased percent hull content of aromatic rice during the first year and for pooled data, however, the decrease noted at 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  was only significant in the second year.

10. Application of 50 and 75%  $RD_{NPKZn}$  significantly decreased percent head rice yield based on brown rice over control in both the years and for yearwise pooled data, however, the decrease recorded under former treatment during first year was not significant. Application of FYM alone or in combination with chemical fertilizers failed to influence this parameter significantly.

11. Application of the increasing levels of  $RD_{NPK}$  significantly increased percent head rice yield based on paddy over control during both the years and also for pooled data, however, no significant increase was noted under 50%  $RD_{NPK}$  level.

Application of 50 and 75%  $RD_{NPKZn}$  significantly increased percent head rice yield based on paddy over control in the first year, while in the second year and also for yearwise pooled data, a significant increase was recorded under 100%  $RD_{NPKZn}$  treatment.

Application of FYM alone (100%  $RD_{FYM}$ ) and the combination of 50%  $RD_{FYM}$  + 50%  $RD_{NPKZn}$  significantly increased percent head rice yield based on paddy in both the years and also for pooled data. The pooled analysis of data

revealed significant increase in percent head rice yield based on paddy under 25%  $RD_{FYM} + 75\% RD_{NPKZn}$  and 50%  $RD_{FYM} + 50\% RD_{NPKZn}$  treatments only.

12. Application of increasing levels of  $RD_{NPK}$  generally increased the contents of N and Cu but decreased those of Fe and Mo in aromatic rice leaves in the first year, while in the second year, it increased the contents of P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, B and Mo but decreased that of N in aromatic rice leaves. Application of  $RD_{NPKZn}$  levels generally increased the contents of N, K and Mn but decreased that of B in aromatic rice leaves in first year, while in the second year, it increased the contents of N, P, K, Ca, Mg, S, Cu, B and Mo but decreased that of Mn in aromatic rice leaves.

Application of 100%  $RD_{FYM}$  increased the contents of K, Cu and B but decreased those of Mg, Mn and Mo in aromatic rice leaves in first year, while in the second year, it increased the contents of P, K, Ca, Mg, S, Zn, B and Mo but decreased those of N and Mn in aromatic rice leaves.

Increasing proportion of FYM in the joint treatments of chemical fertilizer and FYM generally increased the contents of N, Zn and Cu but decreased that of Mo in aromatic rice leaves in the first year, while in the second year, it increased the contents of P, Ca, Mg, S, Zn, Cu, B and Mo but decreased that of Mn in aromatic rice leaves.

The contents of nutrients in grain and straw of aromatic rice were also influenced by the treatments.

13. Application of increasing levels of  $RD_{NPK}$  generally increased the contents of N, P, Mg, Fe and B but decreased that of Mo in wheat leaves in the first year, while, in the second year, it increased the contents of N, P, K and Mn but decreased that of Cu in wheat leaves.

Application of  $RD_{NPKZn}$  generally increased the contents of Mg, S and Fe but decreased that of Mo in wheat leaves in first year, while in the second year, it increased the contents of N, P, K, Ca, S, Zn, Cu, Fe and Mn but decreased that of B in wheat leaves.

Application of 100%  $RD_{FYM}$  increased the contents of N and Fe but decreased the content of Mo in wheat leaves in first year, while in the second

year, it increased the contents of P, K, Ca, Mg, S, Zn, Fe and B but decreased those of N, Mn and Mo in wheat leaves.

Increasing proportion of FYM in the joint treatments of chemical fertilizer and FYM generally increased the contents of N, Mg, S, Zn, Fe and B but decreased that of Mo in wheat leaves in the first year, while in the second year, it increased the contents of N, P, K, Ca, Mg, S, Zn, Fe and Mo but decreased those of Cu and B in wheat leaves.

The contents of nutrients in grain and straw of subsequent wheat were also influenced by the treatments.

14. Some quality parameters of aromatic rice were related to nutrient concentration in ~~flag~~<sup>index</sup> leaf. Grain breadth was significantly and positively correlated to the contents of Mn and Fe, but negatively correlated to the content of Mo. Alkali value of aromatic rice was also significantly and positively correlated to the concentration of P. The percent milling yield of rice was significantly and positively correlated to the K content. The per cent head rice yield based on paddy was strongly and positively correlated to the concentrations of P and K, but negatively correlated to Ca and S contents. The per cent head rice yield based on brown rice showed significant and positive correlation with B concentration but negative correlation with N concentration. The percent hull showed significant and positive correlation with Ca concentration but strong negative correlation with P and K concentrations. The percent broken kernel showed a significant and negative correlation with K concentration.

Step wise multiple regression analysis showed that the contents of N, K, Mg, S, Zn, Cu, Fe and B in the ~~flag~~<sup>index</sup> leaf accounted 56.7% variation in grain length of aromatic rice. The contents of P, K, Ca, Mg, S, Mn and Fe in ~~flag~~<sup>index</sup> leaf explained 63.8% variation of grain breadth of aromatic rice. The concentrations of P, Ca, Zn, Cu and Fe in the ~~flag~~<sup>index</sup> leaf explained 44.9% variation in alkali score of aromatic rice. The contents of K, Mg, Cu and B in ~~flag~~<sup>index</sup> leaf could account 40.9% variation in percent milling yield. The contents of N, P, Zn, Cu, Mn and Mo in the ~~flag~~<sup>index</sup> leaf accounted 77.5% variation in percent head rice yield based on paddy. The concentrations of P, Ca, Mg, Zn and Cu in ~~flag~~<sup>index</sup> leaf explained 55.4% variation in percent hull of aromatic rice. The concentrations of N, P, K, Mg, S,

Zn and Mo in the <sup>index</sup> flag leaf accounted 58.5% variation in percent broken kernel in aromatic rice.

15. Some quality parameters of aromatic rice were related to nutrient concentrations in grain. Both grain length and L:B ratio of aromatic rice had significant and negative correlation with Mg concentration in grain. The percent head rice yield based on paddy had a significant and positive correlation with Mn concentration but negative correlation with Zn, K and N concentrations. The percent hull had a significant and positive correlation with K and Zn concentrations but negative correlation with P and Mn concentrations.

Step wise multiple regression analysis showed that the concentrations of K, Mg, S, Zn and Mn in grain accounted 65.9% variation in the percent head rice yield based on paddy. The concentrations of P, K, Mg, Zn, Mn and B in grain explained 62.7% variation in the percent hull of aromatic rice. The concentrations of N, Mg, S, Cu, Mn and B in grain accounted 45.9% variation in the percent of broken kernels of aromatic rice.

16. Some quality parameters of aromatic rice are interrelated. Aroma had a significant and positive correlation with alkali value of aromatic rice. Grain length was significantly and positively correlated to L:B ratio but negatively correlated to grain breadth. Grain breadth showed a significant and positive correlation with percent hull. The percent milling yield showed a significant and positive correlation with percent head rice yield based on paddy and also on brown rice but negative correlation with percent broken kernels. The percent head rice yield based on paddy had a significant and positive correlation with percent head rice yield based on brown rice but negative correlation with percent hull. The percent hull was significantly and negatively correlated to percent broken kernel.

18. Application of increasing levels of  $RD_{NPK}$  generally increased the total uptake of all nutrients by rice crop in both the years, except at lower levels for the uptake of N, K, Ca, Mg, Zn, Cu, Fe and Mn in first year and of Cu in second year. Application of increasing levels of  $RD_{NPKZn}$  increased the total uptake of all nutrients by rice crop in both the years, except at lower levels for the uptake of K and B in the first year. Application of FYM alone increased the total rice uptake

of Ca, S, Cu, Fe, B and Mo in both the years, of N and P in first year and of K and Mg in the second year in comparison to control. Increasing proportion of FYM in the combined application of chemical fertilizers and FYM increased the total uptake of all nutrients by rice in both the years, except at lower proportions for the uptake of K, Mg and S in first year.

19. Application of increasing levels of  $RD_{NPK}$  generally increased the total uptake of all nutrients by wheat crop in both the years, except at lower levels for the uptake of N, P, K, Ca, S, Zn, Fe, Mn and Mo in first year and of Cu and Mo in second year. Application of increasing levels of  $RD_{NPKZn}$  increased the total uptake of all nutrients by wheat crop in both the years, except at lower levels for the uptake of N, K, Ca, Mg, S, Zn, Cu, Mn, B and Mo in the first year and of Ca, Cu and B in the second year. Application of FYM alone increased the total uptake of S by wheat in first year and of P, S and Mo in the second year; but decreased the uptake of Zn in the second year in comparison to control. Increasing proportion of FYM in the combined application of chemical fertilizers and FYM increased the total uptake of all nutrients by wheat in both the years, except for the uptake of K, Mg, S, Zn, Cu, Mn, B and Mo at lower levels in first year and of Zn, Cu and Mn in the second year.

20. Application of increasing levels of  $RD_{NPK}$  generally increased the total uptake of all nutrients by aromatic rice – wheat sequence in both the years, except at lower levels for the uptake of N, K, Ca, Zn, and Mo in first year and of Mo in second year. Application of increasing levels of  $RD_{NPKZn}$  increased the total uptake of all nutrients by aromatic rice – wheat sequence in both the years, except at lower levels for the uptake of N, K and Mo in the first year and of Mo in the second year. Application of FYM alone increased the uptake of P, Ca, S, Cu, Fe, B and Mo in both the years and of N and K in the second year in comparison to control. Increasing proportion of FYM in the combined application of chemical fertilizers and FYM increased the uptake of all nutrients in both the years, except for the uptake of N and K at lower levels in first year and of Cu at lower levels in the second year by the aromatic rice – wheat sequence.

for the uptake of N and K at lower levels in first year and of Cu at lower levels in the second year by the aromatic rice – wheat sequence.

20. Application of 100% RD<sub>NPK</sub> increased the contents of available soil N, P and S in both the years, of Zn, Mn in the first year and of B and Mo in the second year over control after the harvest.

Application of 100% RD<sub>NPKZn</sub> increased the contents of available soil P, K, Zn and Mo in both the years, of S and Mn in the first year and of N, Ca and B in the second year over control after crop harvest.

Application of 100% FYM alone increased the soil contents of N, P, S, and Mo in both the year and of K and Mn in the first year and of Ca, Zn and B in the second year over control after crop harvest.

Increasing proportion of FYM in the combined application of FYM and chemical fertilizers increased the soil contents of all nutrients in both the years, except at lower levels for the contents of P and Zn in first year and of K and S in the second year.

Thus, it may be concluded that aromatic rice responds favourably to chemical fertilizers and some quality parameters of grain are related to nutrient status of the plant. Application of only farmyard manure can produce the best quality aromatic rice in quantities slightly higher than harvested under no fertilizer application. Application of 45 kg N in three equal splits, 30 kg P<sub>2</sub>O<sub>5</sub>, 30 kg K<sub>2</sub>O and 37.5 kg ZnSO<sub>4</sub>/ha or 15 kg N in three equal splits, 10 kg P<sub>2</sub>O<sub>5</sub>, 10 kg K<sub>2</sub>O and 12.5 kg ZnSO<sub>4</sub> + 9 t FYM/ha helps in achieving higher yields of good quality aromatic rice (cv. Taraori.). Application of 120 kg N in three equal splits, 60 kg P<sub>2</sub>O<sub>5</sub>, and 60 kg K<sub>2</sub>O/ha to subsequent wheat crop (cv. UP-2338) gives the highest total productivity of aromatic rice – wheat sequence.

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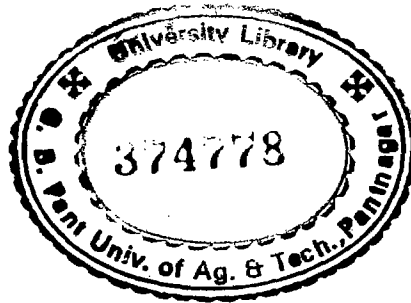
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# APPENDICES

## Appendix I: Weather during the Crop Season

Standard Week Number and Corresponding Dates		Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Wind Velocity (km/h)
		Max	Min	Max	Min		
23	June 1 – 6, 1998	39.1	24.1	61	32	33	
24	June 7 – 13	35.4	24.6	80	55	0	
25	June 14 – 20	34.8	25.1	73	47	50.6	
26	June 21 – 27	34.9	27	85	64	190.8	
27	June 28 – July 4	30.6	25.5	94	74	165.2	
28	July 4 – 11	33.2	25.4	91	70	200.8	
29	July 12 – 18	30.8	25.1	96	78	39.2	
30	July 19 – 25	32.2	26.3	86	71	90.4	
31	July 26 – August 1	32.8	26	86	72	111.2	
32	August 2 – 8	30.2	25.5	93	78	201.5	
33	August 9 – 15	29.4	24.8	97	88	27.8	
34	August 16 – 22	27.8	24.6	86	89	27	
35	August 23 – 29	31.6	24.1	95	76	7.2	
36	August 30 – September 5	32.6	24.9	89	62	27.4	
37	September 6 – 12	31.5	24.7	93	67	38.6	
38	September 13 – 19	31.5	24.8	91	74	164.6	
39	September 20 – 26	29.8	23.8	94	73	0	
40	September 27 – October 3	30.3	22	81	62	0	
41	October 4 – 10	32	21.2	95	55	194.4	
42	October 11 – 17	26.2	19.8	97	78	0	
43	October 18 – 24	30	18.6	93	48	0	
44	October 25 – 31	29.1	14.1	92	37	0	
45	November 1 – 7	27	15.4	94	56	0	
46	November 8 – 14	27.7	12.1	92	41	0	
47	November 15 – 21	27.3	11	95	37	0	
48	November 21 – 28	25.9	7.5	89	37	0	
49	November 29 – December 5	24.4	7.9	91	47	0	
50	December 6 – 12	23.6	7.3	100	43	0	0.56
51	December 13 – 19	21.9	6.1	99	49	0	0.74
52	December 20 – 26	14.8	5.9	100	82	0	2.24
1	December 27 – January 2	18.1	6.9	99	70	17.8	2.58
2	January 3 – 9	14.1	7.6	100	78	41.4	4.47
3	January 10 – 16	11.6	6.6	99	78	0	3.21

4	January 17 – 23	21.9	9.3	95	50	0	4.62
5	January 24 – 30	18	5.6	99	51	0	3.6
6	January 31 – February 6	19	8.2	96	53	0	2.9
7	February 7 – 13	24.6	11	99	53	0	3.81
8	February 14 – 20	24.5	10.3	96	52	0	3.98
9	February 21 – 27	24.8	9.7	93	45	0	4.19
10	February 28 – March 6	28.9	12.5	90	34	8.2	3.93
11	March 7 – 13	27.4	9.1	85	28	0	4.6
12	March 14 – 20	29.4	10.7	85	26	0	5.37
13	March 21 – 27	33.8	13.7	85	20	0	7.13
14	March 28 – April 3	36.3	15	70	26	0	5.03
15	April 4 – 10	36.6	17.4	65	32	0	5.93
16	April 11 – 17	37.7	15	63	27	0	5.4
17	April 18 – 24	38.9	17.5	61	30	0	6.67
18	April 25 – 31	41.7	18.6	41	25	0	6.03
19	May 1 – 7	36.9	20.9	68	48	0	7.24
20	May 8 – 14	32.9	22.2	73	49	0	7.07
21	May 15 – 21	35.1	24.1	79	79	0	6.01
22	May 22 – 28	37.8	22.2	64	64	0	7.26
23	May 29 – June 5	36.2	22.5	69	44	0	5.01
24	June 6 – 12	35.6	24.5	88	85	0	8.15
25	June 13 – 19	34.5	26.5	83	57	0	5.8
26	June 20 – 26	36.5	28.3	81	62	0	5.59
27	June 27 – July 3	32.5	26.8	92	74	0	4.7
28	July 4 – 10	33.1	25.9	92	73	0	5.73
29	July 11 – 17	30.4	25.7	92	81	64.6	6.52
30	July 18 – 24	29.7	25.1	95	85	85.2	4.35
31	July 25 – 31	32.5	25.8	88	83	22.2	5.31
32	August 1 – 7	30	25.4	93	83	113.6	3.75
33	August 8 – 14	30.8	25.3	95	79	163.2	3.92
34	August 15 – 21	30.5	24.4	90	72	53.6	3.45
35	August 22 – 28	32.1	23.8	93	72	10.4	3.72
36	August 29 – September 4	40	24.3	95	78	95.4	2.42
37	September 5 – 11	30.3	23.7	96	77	92	2.48
38	September 12 – 18	31.2	23.8	96	73	49	3.43
39	September 19 – 25	30.6	23.2	92	70	39.6	2.99
40	September 26 – October 1	30.5	21.1	94	71	105.6	2.84
41	October 2 – 8	30.3	16.9	91	42	0	1.97

42	October 10 – 16	30.9	16.5	93	43	0	1.27
43	October 17 – 23	28.4	16.2	90	43	0	1.41
44	October 24 – 30	30.8	14.7	95	40	0	1.23
45	October 31 – November 6	29.2	11.2	89	40	0	2.4
46	November 7 – 13	27.4	9	90	30	0	2.28
47	November 14 – 20	25.8	7.5	93	37	0	1.9
48	November 21 – 27	29.9	8.4	93	46	0	1.82
49	November 28 – December 4	22.3	8.7	93	55	12.2	1.6
50	December 5 – 11	23.4	6.2	96	43	0	1.79
51	December 12 – 18	22.8	6.3	97	48	0	1.26
52	December 19 – 25	20.7	5.8	84	58	0	1.48
1	December 26 – January 1	15.8	4.3	97	73	0	2.23
2	January 2 – 8	16.8	9.3	96	67	13	3.41
3	January 9 – 15	19.1	5.5	96	51	0	6.47
4	January 16 – 22	20.5	7.5	96	50	0	4
5	January 23 – 29	20.6	7.4	66	55	0	6.3
6	January 30 – February 5	17.6	9.2	95	74	71	3.89
7	February 6 – 12	19.8	7.8	94	53	0	3.46
8	February 13 – 19	21.8	5.2	95	41	0	4.13
9	February 20 – 26	22.8	7.3	90	48	0	3.9
10	February 27 – March 4	25.5	10.2	92	39	0.4	5.35
11	March 5 – 11	26.6	10.4	80	41	0.2	5.44
12	March 12 – 18	35.2	11.3	81	49	0	4.56
13	March 19 – 25	31.5	14	87	37	0	2.84
14	March 26 – April 1	33	12.3	86	28	0	6.69
15	April 2 – 8	35.2	15.3	64	31	0	5.67
16	April 9 – 15	35.3	19.3	69	35	0	4.47
17	April 16 – 22	35.1	21.3	68	33	5.2	6.27
18	April 23 – 29	36.8	20.1	69	38	10.6	6.86
19	April 30 – May 6	33.1	23.5	73	50	17.6	4.81
20	May 7 – 13	36.2	25.8	73	41	0	6.57
21	May 14 – 20	31.2	25.1	83	58	2.7	9.03
22	May 21 – 27	35.9	24.7	81	53	20	6.19
23	May 28 – June 3	29.8	21.1	95	85	327.6	8.33

## **Appendix II: Elemental Composition of FYM**

<b>Elements</b>	<b>Composition</b>
N	0.5%
P	0.3%
K	0.7%
Ca	0.09%
Mg	0.06%
Zn	85 ppm
Cu	11 ppm
Fe	423 ppm
Mn	205 ppm
B	18 ppm
Mo	0.9 ppm

**Appendix III: Effect of soil application of chemical fertilizers, FYM and their combinations on the Nitrogen uptake (kg/ha) of aromatic rice – wheat**

Treatment	Nitrogen uptake (kg/ha)		
	1998-99	1999-2000	Pooled
Control	56.65	23.33	39.99
25% RD <sub>NPK</sub>	67.23	37.35	52.29
50% RD <sub>NPK</sub>	63.94	45.91	54.92
75% RD <sub>NPK</sub>	70.70	68.10	69.40
100% RD <sub>NPK</sub>	78.17	87.63	82.90
25% RD <sub>NPKZn</sub>	53.95	75.28	64.61
50% RD <sub>NPKZn</sub>	74.33	60.33	67.33
75% RD <sub>NPKZn</sub>	81.72	54.46	68.09
100% RD <sub>NPKZn</sub>	85.36	119.95	102.65
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	65.68	58.77	62.22
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	77.14	69.47	73.30
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	82.62	93.76	88.19
100 % RD <sub>FYM</sub>	51.46	59.13	55.30
CD (p=0.05)	10.08	8.94	NS

**Appendix IV: Effect of soil application of chemical fertilizers, FYM and their combinations on the Phosphorus uptake (kg/ha) of aromatic rice – wheat**

Treatment	Phosphorus uptake (kg/ha)		
	1998-99	1999-2000	Pooled
Control	18.60	14.87	16.74
25% RD <sub>NPK</sub>	22.26	24.12	23.19
50% RD <sub>NPK</sub>	24.51	24.28	24.39
75% RD <sub>NPK</sub>	29.73	30.05	29.89
100% RD <sub>NPK</sub>	33.32	29.98	31.65
25% RD <sub>NPKZn</sub>	23.91	22.10	23.00
50% RD <sub>NPKZn</sub>	23.70	26.38	25.04
75% RD <sub>NPKZn</sub>	30.48	30.85	30.66
100% RD <sub>NPKZn</sub>	28.11	33.56	30.84
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	25.09	24.17	24.63
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	26.45	21.21	23.83
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	26.21	30.32	28.27
100 % RD <sub>FYM</sub>	23.16	17.93	20.54
CD (p=0.05)	2.12	2.49	1.63

**Appendix V: Effect of soil application of chemical fertilizers, FYM and their combinations on the Potassium uptake (kg/ha) of aromatic rice – wheat**

Treatment	Potassium uptake (kg/ha)		
	1998-99	1999-2000	Pooled
<b>Control</b>	58.79	50.64	54.71
<b>25% RD<sub>NPK</sub></b>	76.31	89.08	82.69
<b>50% RD<sub>NPK</sub></b>	66.75	81.04	73.89
<b>75% RD<sub>NPK</sub></b>	95.03	129.54	112.28
<b>100% RD<sub>NPK</sub></b>	111.77	120.19	115.98
<b>25% RD<sub>NPKZn</sub></b>	64.21	81.82	73.01
<b>50% RD<sub>NPKZn</sub></b>	60.01	85.37	72.69
<b>75% RD<sub>NPKZn</sub></b>	85.46	103.51	94.49
<b>100% RD<sub>NPKZn</sub></b>	80.70	128.67	104.69
<b>25 % RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub></b>	82.66	104.22	93.44
<b>50 % RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub></b>	65.14	86.08	75.61
<b>75 % RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub></b>	61.04	121.71	91.37
<b>100 % RD<sub>FYM</sub></b>	52.88	74.85	63.86
<b>CD (p=0.05)</b>	9.49	8.35	6.32

**Appendix VI: Effect of soil application of chemical fertilizers, FYM and their combinations on the Calcium uptake (kg/ha) of aromatic rice – wheat**

Treatment	Calcium uptake (kg/ha)		
	1998-99	1999-2000	Pooled
Control	23.25	16.95	20.10
25% RD <sub>NPK</sub>	25.51	34.42	29.96
50% RD <sub>NPK</sub>	26.79	25.95	26.37
75% RD <sub>NPK</sub>	32.11	43.30	37.71
100% RD <sub>NPK</sub>	36.11	51.45	43.78
25% RD <sub>NPKZn</sub>	31.48	25.40	28.44
50% RD <sub>NPKZn</sub>	29.02	32.13	30.57
75% RD <sub>NPKZn</sub>	33.44	38.36	35.90
100% RD <sub>NPKZn</sub>	31.68	43.08	37.38
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	30.84	37.19	34.02
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	30.38	31.98	31.18
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	28.78	45.65	37.21
100 % RD <sub>FYM</sub>	27.28	27.68	27.48
CD (p=0.05)	2.58	4.33	2.52

**Appendix VII: Effect of soil application of chemical fertilizers, FYM and their combinations on the Magnesium uptake (kg/ha) of aromatic rice – wheat**

Treatment	Magnesium uptake (kg/ha)		
	1998-99	1999-2000	Pooled
Control	14.35	10.52	12.44
25% RD <sub>NPK</sub>	15.80	15.74	15.77
50% RD <sub>NPK</sub>	17.24	14.94	16.10
75% RD <sub>NPK</sub>	19.69	25.37	22.53
100% RD <sub>NPK</sub>	26.07	26.67	26.38
25% RD <sub>NPKZn</sub>	16.90	13.42	15.15
50% RD <sub>NPKZn</sub>	20.40	16.81	18.61
75% RD <sub>NPKZn</sub>	20.52	23.85	22.19
100% RD <sub>NPKZn</sub>	24.04	25.40	24.72
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	17.30	15.73	16.52
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	18.81	16.27	17.54
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	19.21	23.02	21.12
100 % RD <sub>FYM</sub>	15.16	11.81	13.48
CD (p=0.05)	1.90	1.67	1.26

**Appendix VIII: Effect of soil application of chemical fertilizers, FYM and their combinations on the Sulphur uptake (kg/ha) of aromatic rice – wheat**

Treatment	Sulphur uptake (kg/ha)		
	1998-99	1999-2000	Pooled
Control	7.93	8.22	8.07
25% RD <sub>NPK</sub>	10.79	17.58	14.18
50% RD <sub>NPK</sub>	11.23	13.73	12.48
75% RD <sub>NPK</sub>	12.88	19.86	16.37
100% RD <sub>NPK</sub>	16.21	22.15	19.18
25% RD <sub>NPKZn</sub>	11.06	17.03	14.05
50% RD <sub>NPKZn</sub>	12.67	14.31	13.49
75% RD <sub>NPKZn</sub>	14.92	16.51	15.72
100% RD <sub>NPKZn</sub>	13.62	21.59	17.60
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	13.26	17.06	15.16
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	11.36	15.01	13.18
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	11.50	22.83	17.17
100 % RD <sub>FYM</sub>	11.00	13.02	12.01
CD (p=0.05)	1.81	1.57	1.20

**Appendix IX: Effect of soil application of chemical fertilizers, FYM and their combinations on the Zinc uptake (g/ha) of aromatic rice – wheat**

Treatment	Zinc uptake (g/ha)		
	1998-99	1999-2000	Pooled
Control	350.75	299.25	325.00
25% RD <sub>NPK</sub>	345.50	511.00	428.25
50% RD <sub>NPK</sub>	384.00	458.00	421.00
75% RD <sub>NPK</sub>	466.00	726.00	596.00
100% RD <sub>NPK</sub>	524.00	703.50	613.75
25% RD <sub>NPKZn</sub>	443.50	426.50	435.00
50% RD <sub>NPKZn</sub>	458.50	512.25	485.38
75% RD <sub>NPKZn</sub>	608.00	559.00	583.50
100% RD <sub>NPKZn</sub>	605.75	728.00	666.88
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	480.75	491.50	486.13
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	549.00	480.25	514.63
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	515.25	722.00	618.63
100 % RD <sub>FYM</sub>	376.50	321.75	349.13
CD (p=0.05)	43.06	49.12	32.66

**Appendix X: Effect of soil application of chemical fertilizers, FYM and their combinations on the Copper uptake (g/ha) of aromatic rice – wheat**

Treatment	Copper uptake (g/ha)		
	1998-99	1999-2000	Pooled
Control	25.80	20.27	23.04
25% RD <sub>NPK</sub>	28.81	30.87	29.84
50% RD <sub>NPK</sub>	32.17	26.05	29.11
75% RD <sub>NPK</sub>	38.49	48.97	43.73
100% RD <sub>NPK</sub>	44.28	47.73	46.00
25% RD <sub>NPKZn</sub>	32.92	30.23	31.58
50% RD <sub>NPKZn</sub>	33.27	39.55	36.41
75% RD <sub>NPKZn</sub>	40.97	48.81	44.89
100% RD <sub>NPKZn</sub>	39.84	46.89	43.37
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	31.53	38.54	35.03
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	37.82	26.41	32.11
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	36.55	38.47	37.51
100 % RD <sub>FYM</sub>	30.87	27.04	28.95
CD (p=0.05)	2.36	6.44	3.43

**Appendix XI: Effect of soil application of chemical fertilizers, FYM and their combinations on the Iron uptake (g/ha) of aromatic rice – wheat**

Treatment	Iron uptake (g/ha)		
	1998-99	1999-2000	Pooled
Control	2565	2490	2527
25% RD <sub>NPK</sub>	3018	4326	3672
50% RD <sub>NPK</sub>	3039	3966	3503
75% RD <sub>NPK</sub>	4580	6436	5508
100% RD <sub>NPK</sub>	4552	8065	6309
25% RD <sub>NPKZn</sub>	3758	3566	3662
50% RD <sub>NPKZn</sub>	3940	4405	4173
75% RD <sub>NPKZn</sub>	4009	6051	5030
100% RD <sub>NPKZn</sub>	3852	7793	5822
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	3944	6020	4982
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	3901	4058	3980
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	4010	6938	5474
100 % RD <sub>FYM</sub>	3243	3479	3361
CD (p=0.05)	255	473	269

**Appendix XII: Effect of soil application of chemical fertilizers, FYM and their combinations on the Manganese uptake (g/ha) of aromatic rice – wheat**

Treatment	Manganese uptake (g/ha)		
	1998-99	1999-2000	Pooled
<b>Control</b>	1411	1286	1349
<b>25% RD<sub>NPK</sub></b>	1560	2587	2074
<b>50% RD<sub>NPK</sub></b>	1668	2307	1988
<b>75% RD<sub>NPK</sub></b>	2066	3296	2681
<b>100% RD<sub>NPK</sub></b>	2664	3506	3085
<b>25% RD<sub>NPKZn</sub></b>	1964	2083	2024
<b>50% RD<sub>NPKZn</sub></b>	1909	1958	1933
<b>75% RD<sub>NPKZn</sub></b>	2315	2661	2488
<b>100% RD<sub>NPKZn</sub></b>	2270	3283	2777
<b>25 % RD<sub>FYM</sub> + 75% RD<sub>NPKZn</sub></b>	2116	2425	2270
<b>50 % RD<sub>FYM</sub> + 50% RD<sub>NPKZn</sub></b>	2002	2185	2094
<b>75 % RD<sub>FYM</sub> + 25% RD<sub>NPKZn</sub></b>	1937	3139	2538
<b>100 % RD<sub>FYM</sub></b>	1534	1538	1536
<b>CD (p=0.05)</b>	211	301	184

**Appendix XIII: Effect of soil application of chemical fertilizers, FYM and their combinations on the Boron uptake (g/ha) of aromatic rice – wheat**

Treatment	Boron uptake (g/ha)		
	1998-99	1999-2000	Pooled
Control	59.57	52.95	56.26
25% RD <sub>NPK</sub>	81.7	111.64	96.67
50% RD <sub>NPK</sub>	85.18	96.34	90.76
75% RD <sub>NPK</sub>	75.48	145.91	110.70
100% RD <sub>NPK</sub>	86.25	191.13	138.69
25% RD <sub>NPKZn</sub>	69.26	85.65	77.46
50% RD <sub>NPKZn</sub>	91.57	87.73	89.65
75% RD <sub>NPKZn</sub>	90.56	149.89	120.23
100% RD <sub>NPKZn</sub>	85.87	175.93	130.90
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	82.41	108.96	95.69
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	88.6	109.6	99.10
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	97.06	162.13	129.60
100 % RD <sub>FYM</sub>	69.64	95.23	82.44
CD (p=0.05)	8.36	11.68	7.06

**Appendix XIV: Effect of soil application of chemical fertilizers, FYM and their combinations on the Molybdenum uptake (g/ha) of aromatic rice – wheat**

Treatment	Molybdenum uptake (g/ha)		
	1998-99	1999-2000	Pooled
Control	3.83	1.52	2.68
25% RD <sub>NPK</sub>	3.03	2.91	2.97
50% RD <sub>NPK</sub>	4.23	2.89	3.56
75% RD <sub>NPK</sub>	5.00	4.45	4.73
100% RD <sub>NPK</sub>	7.62	11.66	9.64
25% RD <sub>NPKZn</sub>	5.55	3.22	4.39
50% RD <sub>NPKZn</sub>	4.45	3.18	3.81
75% RD <sub>NPKZn</sub>	10.42	10.09	10.26
100% RD <sub>NPKZn</sub>	8.39	17.04	12.71
25 % RD <sub>FYM</sub> + 75% RD <sub>NPKZn</sub>	6.17	10.08	8.12
50 % RD <sub>FYM</sub> + 50% RD <sub>NPKZn</sub>	12.78	7.49	10.14
75 % RD <sub>FYM</sub> + 25% RD <sub>NPKZn</sub>	10.40	10.61	10.51
100 % RD <sub>FYM</sub>	9.62	5.93	7.77
CD (p=0.05)	2.01	2.59	1.64

# VITA

The author was born on the 15<sup>th</sup> of June, 1976. He passed High School and Intermediate examinations of Board of High School and Intermediate Education, Uttar Pradesh in 1990 and 1992, respectively from SSSVI College, Faizabad. He obtained BSc degree from the Ewing Christian College, the University of Allahabad in 1995. Thereafter, in the same year, he joined the College of Post Graduate Studies, G B Pant University of Agriculture and Technology, Pantnagar for Masters Degree in Soil Science. He completed MScAg in 1997 and subsequently, joined PhD in the same year. He received a number of scholarships and fellowships during his academic career. He is member of several professional scientific societies.

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Thesis Title: **EFFECT OF CHEMICAL FERTILIZERS, FYM AND THEIR CONJUNCTIVE USE ON YIELDS, RICE QUALITY AND NUTRIENT UPTAKE OF AROMATIC RICE – WHEAT SEQUENCE**

Advisor: **Dr. P.C. Srivastava**

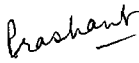
### ABSTRACT

Field experiments were conducted during 1998-2000 at Research Station, Nagina, Distt. Bijnor (U.P.) to study the effect of soil application of chemical fertilizers, FYM and their conjunctive use on yields, rice quality and nutrient uptake of aromatic rice – wheat sequence. The recommended fertilizer dose (RD) was supplied through chemical fertilizers and FYM. The treatments were 25, 50, 75 and 100% each of  $RD_{NPK}$ ,  $RD_{NPKZn}$ , and 100%  $RD_{FYM}$  and also the combinations of  $RD_{NPKZn}$  and  $RD_{FYM}$ . The application of zinc was limited to first rice crop only. The highest grain yield of aromatic rice was recorded at 75%  $RD_{NPKZn}$  and 75%  $RD_{FYM}$  + 25%  $RD_{NPKZn}$  during both the years, while the highest grain yield of wheat during both the years was noted in treatment receiving 100%  $RD_{NPKZn}$  and 100%  $RD_{NPK}$ . On the basis of yearwise pooled grain yield data, the total productivity of aromatic rice – wheat rotation was highest (35.98 q grain/ha) under 75%  $RD_{NPKZn}$  treatment for rice and 100%  $RD_{NPKZn}$  treatment for wheat.

The FYM application (100%  $RD_{FYM}$ ) had a positive effect on aroma, grain length, L:B ratio, thereby improving the fineness of grain, and % head rice yield based on paddy, while it could not significantly influence the % milling yield and % broken kernels. The chemical fertilizer had positive effect on the alkali value but negative effect on the hull content. The contents of nutrients in grain, straw and leaves of aromatic rice were also influenced by the treatments. Some quality parameters of aromatic rice were found to be related to nutrient concentrations in flag leaf and grain. Multiple regression equations based on step-wise analysis were also computed to predict the quality parameters of aromatic rice grain using the nutrient concentrations in flag leaf or rice grain as independent variables. Application of increasing levels of chemical fertilizers generally increased the total uptake of all nutrients by aromatic rice-wheat in both the years.

Thus, application of 45 kg N in three equal splits, 30 kg  $P_2O_5$ , 30 kg  $K_2O$  and 37.5 kg  $ZnSO_4$ /ha or 15 kg N in three equal splits, 10 kg  $P_2O_5$ , 10 kg  $K_2O$  and 12.5 kg  $ZnSO_4$  + 9 t FYM/ha helps in achieving higher yields of good quality aromatic rice (cv. Taraori.). Application of 120 kg N in three equal splits, 60 kg  $P_2O_5$ , and 60 kg  $K_2O$ /ha to subsequent wheat crop (cv. UP-2338) gives the highest total productivity of aromatic rice – wheat sequence.

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