

RESPONSE OF RICE TO ORGANIC NUTRITION UNDER RICE-WHEAT CROPPING SYSTEM

BY
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CERTIFICATE - I

This is to certify that this thesis entitled "**Response of rice to organic nutrition under rice-wheat cropping system**", submitted for the degree of **Master of Science** in the subject of **Agronomy**, to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Mr. Nguyen Le Thang**, under my supervision and no part of the thesis has been submitted for any other degree.

All the assistance and help received during the course of investigation have been duly acknowledged.

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This is to certify that this thesis entitled "**Response of rice to organic nutrition under rice-wheat cropping system**", submitted by **Mr. Nguyen Le Thang** to Chaudhary Charan Singh Haryana Agricultural University, Hisar, in partial fulfilment of the requirement for the degree of **Master of Science** in the subject of **Agronomy** has been approved by the Student's Advisory Committee after an oral examination on the same.

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CHAPTER I

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops occupying primary position among the food grain crops in terms of both acreage and production globally. India produces 140.2 million tons of paddy rice only next to China (Encarta Encyclopaedia, 2006). In India, most of the growth in rice production during green revolution period could be attributed to release of high yielding varieties responsive to higher dose of fertilizers and irrigation. But use of higher dose of high analysis fertilizers (containing high amounts of N, P and K only) and insufficient use of organics have created deficiencies of secondary and micronutrients particularly Zn and Fe and the soils are showing signs of fatigue, as judged by decline in the yield of rice as well as a lower response to applied chemical fertilizers. Excessive use of chemical fertilizers and pesticides have also increased the environmental concerns and causing ecological imbalances. Chemicals used in agriculture leave residues in food that may cause cancer or genetic disorder. Other aspects of food quality have also been changed to the worse. Instead of recycling our wastes back into the soil as the source of nutrients, we burn them to pollute the environment. We use non-renewable energy resources to produce chemical fertilizers. In future, we may force to make radical adjustment in such agricultural practices.

Organic systems avoid the use of synthetic fertilizers, pesticides, and growth regulators. Instead they rely on crop rotations, crop residues, animal manures, legumes, green manures, off-farm wastes, mechanical cultivation, mineral-bearing rocks, and biological pest control, etc to maintain soil health, enrich soil organic carbon, supply plant nutrients, improve soil properties, and minimize insect pests-diseases and weeds. It is generally preferred due to improvement in quality of food grain and other natural resources as well as elimination of ground water and atmosphere pollution.

Organic farming is the agricultural system which aims at cultivation of the land in a way so that the soil is kept dynamic with living activities and in good health, at the same time keeping the environment clean, maintaining the ecological balance and providing stability to the production level without polluting soil, water and air. In this method, the use of chemicals is kept at its minimum, i.e. to the level of bare necessity. This method is self-sufficient and self-dependent as compared to modern chemical farming relying more on chemical inputs. It is concerned with the best use of natural resources and maintaining their balance. In this system, soil

is not only considered to be physical medium for standing crop but also as a shelter of innumerable living entities. In this method, system is self-sufficient and self-dependent with the best use of natural resources and maintaining their balance. In fact, it is the only means to achieve the stable/sustainable target of production. It is feasible by adopting multi-dimensional approach which involves co-ordination and interaction between several major or minor factors, the cumulative effects of which are astonishing. Organic farming has been recommended for sustainability in productivity of various systems by several workers in Haryana (Singh *et al.*, 2000 and Kumar *et al.*, 2003).

The strong balance of evidence from research, field trials and farm experience is that organic agricultural practices are generally more environmentally friendly than conventional agriculture, particularly with regard to lower pesticide residues, a richer biodiversity and greater resilience to drought. Organic farming systems also hold the potential to lower nutrient run-off and reduce greenhouse gas emissions.

Organic farming practices have to play big role in intensive and exhaustive crop rotation like rice-wheat, to maintain long-term sustainability. It may particularly be of significance in scented rice for the purpose of producing value added product. For high yield environment, long-term yield advantage may be maintained by adopting organic farming concepts. Therefore, investigating the optimum practice of organic farming is the need of the time for a cropping system like rice-wheat. Nutrient management in terms of supply is an important part of organic farming practices which may affect yield and quality of rice crop under Haryana conditions.

Presently the cultivation of organic basmati paddy is gaining popularity in Haryana. In Haryana total area under basmati paddy was estimated to be 144 thousand hectares during 2001-02. The area under organic basmati during this period was about 200 hectares. It is mainly grown in Karnal, Kaithal, Sonapat, Panipat, Yamunagar and Jind districts (Manjunath, 2005). Production of high quality aromatic rice by the farmers for domestic as well as export purposes is major concern of future agriculture strategy (Ghosh *et al.*, 2004).

The high yielding varieties of rice with dwarf and semi-dwarf characteristics respond to intensive and high level of inputs, mainly fertilizers. During green revolution, these varieties could yield as much as 9 tons ha⁻¹ with increased use of fertilizers. Presently also these have very high production potential under high input environment. On the contrary, Basmati rice having tall growth nature can tolerate low to medium fertility condition. In Basmati rice, quality is the important parameter for consideration of demand of good quality. In organically produced Basmati rice nutrients demand of plants are met by supplies from organic sources which help in

growing crop without lodging giving good yield. Thus, both types of these rice need different environments. Moreover, organically produced Basmati rice fetch higher price, therefore, economically Basmati can give higher return as compared to high yielding dwarf rice varieties despite Basmati being low yielder than dwarf varieties. Therefore, there is need to compare growth behaviour, productivity and quality of these two types of rice under organic farming situation.

In view of the above, field and laboratory investigations were conducted on rice grown in rice-wheat cropping system with the following objectives:

1. To study yield behaviour of high yielding and scented varieties of rice under various treatments.
2. To study the effect of various organic treatments on quality of rice and soil properties.
3. To study economics of various treatments.

CHAPTER II

REVIEW OF LITERATURE

2.1. Importance of organic farming

Evidence concerning the economic performance of organic compared to conventional farming systems is mixed. While yields tend to be lower on organic farms, and labour costs higher

than on conventional farms, profitability is generally higher, due to price premiums and - in many countries - support payments. However, differences in yields and price premiums vary between organic and conventional agricultural products. Returns to organic farming are also affected by changes in the farm production mix, for example due to increased use of crop rotation. Generalized economic performance comparisons between organic and conventional farms are not always meaningful - there can be as much variation within each farm system as across them (OECD, 2003).

2.1.1. Farm production and profit under organic farming

2.1.1.1. Crop yield

Absolute yield levels under organic management are increasing over time, but at a slower rate than conventional system (Lampkin, 1990) and are significantly higher than yields achieved in pre-1950s agriculture, to which organic farming is sometimes likened.

The work done in India and abroad reveals that organic farming is possible without much loss in the productivity. However, integrated nutrient management practices by reducing the use of chemicals and increasing use of organics have been proved to be very effective in sustainable growth in productivity in field crops (Patra *et al.*, 1998; Singh *et al.*, 1999).

Yong *et al.* (2004) reported that crop productivity was decreased slightly in organic farming compared to that of conventional farming. In contrast to the crop productivity, bulk density and porosity rate of soil had no significant differences by application of organic materials compared to those of NPK application. Eghball *et al.* (2004) reported that residual effect of manure or compost application on crop production and soil properties can last for several years. Das *et al.* (2003) reported that incorporation of crop residues (rice and wheat straw) increased yield components and yield of rice. Krishnakumar *et al.* (2005) reported that FYM + Neemcake at the rate 90 kg N ha⁻¹ gave significantly higher grain and straw yields.

2.1.1.2. Product quality

Anecdotal evidence suggested that food products using organic methods taste better and contains a better balance of vitamins and minerals than conventionally grown food. However, there is no clear scientific evidence with some studies showing increases in vitamin C, minerals and proteins (Lampkin, 1990) and others not. Organic wheat usually has lower protein levels than conventionally grown crops (Starling and Richards, 1993). However, milling quality in organic wheat can be achieved through careful choice of variety and management (Thompson *et al.*, 1993). Satheesh and Balasubramania (2003) reported that combined 50% of nitrogen as press-mud (10 tons ha⁻¹) and 50 % N as poultry manure (3 tons ha⁻¹) being at par in producing significantly higher crude protein (7.88%), alkaline value (6.22%), fat (0.54%), carbohydrate and

amylose content (23.95%) than control or 100% NPK treatments. This treatment was also significantly higher in head rice recovery (71.92%) and gave higher with 7.4 point in rice cooking colour, 7.2 point for taste acceptability. Best organic rice is because of its lustre and pleasant eating qualities (Anonymous, 2006).

2.1.2. Soil properties

2.1.2.1. Physical properties

Aggregate stability is increased under organic management (Gerhart, 1997; Siegrist *et al.*, 1998), while porosity also increases (Gardner and Clancy, 1996; Gerhardt, 1997). Such changes in soil structure largely result from changes in the management of crop residues and organic matter inputs and may lead to increased aeration and water holding capacity of soils under organic management. Increases in the depth of the horizon of the soil have also been recorded for organic systems, which may result from decreased bulk densities and/or decreased soil losses through erosion (Reganold *et al.*, 1993 and Gerhardt, 1997).

Parihar (2004) reported that incorporation of crop residues like rice and wheat straw and FYM decreased the bulk density, increased the hydraulic conductivity, organic carbon and water holding capacity of the soil. Incorporation of rice and wheat straw improved the physico-chemical properties of soil which provided better soil environment for crop growth (Das *et al.*, 2004). The paddy soil was loose and had deeper mud, which was attributed to higher soil organic matter accumulating as a result of crop residue recycling at 3-4 tons ha⁻¹ and animal manure 1-2 tons ha⁻¹ crop⁻¹ (Mendoza, 2004). Krishnakumar *et al.* (2005) reported that application of FYM + Neemcake @ 90 kg N ha⁻¹ significant reduced bulk density and increased hydraulic conductivity, water holding capacity and percent pore space.

2.1.2.2. Chemical properties

Increases in soil organic matter for soils under organic management are widely reported (Reganold *et al.*, 1993; Gardner and Clancy, 1996; Gerhardt, 1997; Clark *et al.*, 1998 and Sharma *et al.*, 2000; Das *et al.*, 2003; Zoltán, 2005). Such increases reflect the inclusion of leys and manures into the soil. Wander and Traina (1994) have also measured higher levels of C in the "light fraction" of soils under organic management, which is thought to represent a more biologically active pool.

Available phosphorus and potassium have been shown to increase (Clark *et al.*, 1998; Yong *et al.*, 2004) and decrease (Nguyen *et al.*, 1995) in soils under organic management. In New Zealand, Nguyen *et al.* (1995) measured lower levels of total sulphur and total phosphorus in soils under organic management, as conventionally managed soils often received large inputs of

these nutrients. Clark *et al.* (1998) showed that most changes in soil chemical properties could be predicted from a consideration of the inputs of nutrient to the system.

The results of 12 years (1988-1999) research reveal that rice yield increased and stability in soil carbon content also increased in organic system of nutrient supply as compared to chemical nutrition (Singh *et al.*, 2004).

2.1.2.3. Biological properties

Increased microbial populations in cultivated organically managed soil have been measured by a number of workers (Sivapalan *et al.*, 1993 and Gunapala and Scow, 1998). Higher levels of biological activity have also been reported in soil managed organically (Wander Traina, 1994; Nguyen *et al.*, 1995 and Gunapala and Scow, 1998). However, bacterial biomass was similar in long-term grassland, whether managed organically or conventionally (Yeates *et al.*, 1994). Gunapala *et al.* (1998) measured both increased abundance and diversity of the microbial community in soils managed organically.

N'Dayegamiye and Sen (2001) reported that two green manures applications did not influence the C and N contents but significantly increased those of whole soil, and microbial respiration (CO₂). Yadav *et al.* (2003) reported that population of beneficial microorganisms in soil increased due to green manuring. The population of bacteria, fungi and actinomycetes in the soil increased under application of FYM + Neemcake (Krishnakumar *et al.*, 2005).

2.2. Responses of rice to inorganic fertilizers

Nitrogen is the most limiting element for crop production. Soils of Indo-Gangetic alluvial plains are generally low in organic matter with less than 0.4% organic carbon content, deficient in nitrogen, phosphorus and several other plant nutrients. The trends in responses of rice and wheat to applied nitrogen in these soils showed that both rice and wheat crops respond to higher levels of N. The application of 150 kg N ha⁻¹ is, therefore, common recommendation for both rice and wheat grown in Haryana (Anand and Yaduvanshi, 2004).

Inorganic fertilizers have a major role in intensive cropping system, which brought about commendable increase in crop production (Parihar, 2004). High yielding varieties produced greater production as it needed more nutrients supply. Das *et al.* (2003) reported that increasing levels of NPK application increased the yield attributing characters and gave highest yield. Mhaskar and Thorat (2005) reported that every increment in the levels of nitrogen was found beneficial in enhancing the NPK uptake in rice to a significant level with maximum at 120 kg N ha⁻¹ which is always better for higher efficiency of applied nitrogen.

For grain production, rice plants use nitrogen most efficiently when it is applied at the

maximum tillering stage. Rice plant use N around the panicle initiation/pointing stage also. Therefore, split application of N, half at transplanting + one – fourth at tillering, one – fourth at panicle initiation.

Phosphorus is the most critical nutrient required for efficient crop production in normal soil. Phosphorus applied @ 22 kg P ha⁻¹ to either or both rice and wheat crop rotation significantly enhanced the grain yield of rice. Singh *et al.* (2003) reported the yield attributes, viz, ear m⁻², grain per ear and grain weight per ear, measured at maturity in rice and wheat revealed a significant increase of 5.5 to 10.9%, 9-10% and 13.1 to 19.4%, respectively, with 120 kg N and 26 kg P ha⁻¹ compared to 120 kg N alone. Ram *et al.* (1995) reported that 30 kg P₂O₅ ha⁻¹ applied through single superphosphate is most suitable for Taraori Basmati. Pandey *et al.* (2001) also use 60 kg P₂O₅ ha⁻¹ as basal dose for supplying phosphate to high yielding variety. Malarkodi and Singaram (2003) reported that 50 kg P₂O₅ ha⁻¹ through single superphosphate and combination with FYM significantly increased the grain yield, quality parameter and nutrient uptake in rice.

Application of K fertilizer to either or both the crops had no effect on yields of rice and wheat in Haryana soils. Lack of crops responses to applied K in these soils is attributed to (i) high available K status due to presence of K bearing minerals, and (ii) large contribution of non-exchangeable K (97%) towards total K uptake by plants. The application of K fertilizer to rice – wheat system can be avoided without having any adverse effect on crop productivity and K fertility status.

In the studies on the effect of N on tall scented variety (Taraori Basmati), Ram *et al.* (1995) concluded that plant height increase significantly with each successive increase in N rate up to 90 kg ha⁻¹ but number of panicles per hill and number of grains per panicle increased up to 60 kg ha⁻¹. Grain yield did not significantly differ between 60 and 90 kg N/ha. Adhiki and Mishra (2004) reported aromatic rice variety Pusa Sugandh-2 more responsive to N application than Basmati 370 and highest grain yield was obtained at 120 kg N ha⁻¹ through prilled urea. Mehla and Panwar (2001) had also reported that the yield of tall varieties (Taraori Basmati and Basmati 370) increased significantly up to 60 kg N ha⁻¹ and decreased at 90 kg ha⁻¹ while grain yield of semi-dwarf varieties (Pusa Basmati - 1 and Haryana Basmati - 1) increased significantly up to 90 kg N ha⁻¹. Mhaskar *et al.* (2005) reported that semi-dwarf scented varieties like Pusa Basmati - 1 and Indrayani supplied with 120 kg N ha⁻¹ produced higher leaf area and maximum grain of rice. Similarly, hybrid scented variety showed significant increase in growth, yield

attributes, yield and nitrogen use efficiency up to 75 kg N ha⁻¹ (Shivay and Singh 2003).

2.3. Organic farming and rice

The work on the organic farming in rice crop started in the form of integrated nutrient management. The present review is concerned with the integrated use of organic manures and biofertilizers as alternative nutrient source for rice as well as their effects on soil health.

2.3.1. Effect on plant growth

Sharma and Mitra (1990) at Kharagpur reported more plant height due to addition of various organic materials. While conducting experiments, Bhattacharya and Mandal (1996) also observed increase in total dry matter yield, plant height and basal girth of rice in two types of soils (sandy loam and silt loam soil). Significant increase in plant height of rice due to *Sesbania cannabina* green manuring was reported by Satapathy (1999). Das *et al.* (2003) reported that incorporation of 5 tons of rice or wheat straw gave similar effect to 75% recommended dose of NPK on effective tillers m⁻² and grain per panicle. The root length density and yields were higher in green manure plots than in fallow both in rice as well as in succeeding wheat crop (Mandal *et al.*, 2003).

2.3.2. Effect on yield attributes and yield

2.3.2.1. Response of rice to farm yard manures

The beneficial effects of FYM on grain and straw yields in rice have been reported by other workers (Tiwari *et al.*, 1998; Satapathy, 1999). Summarizing the work done in China where FYM is widely used, FAO (1978) reported that application of 30-40 tonnes FYM ha⁻¹ increased the yield ranging from 24-89% as compared to control. Meelu and Morris (1984) revealed that application of 12 tonnes FYM ha⁻¹ to rice in rice-wheat cropping system resulted in a saving of 40 kg N ha⁻¹ in rice and 20 kg P₂O₅, 30 kg K₂O ha⁻¹ in succeeding wheat crop. Rajput and Warri (1992) reported that application of 50-60 kg N ha⁻¹ through FYM increased the yield by 64% over control. Malik and Jaiswal (1993) noted that half to two-third of chemical N can be substituted by FYM without any loss in yield depending upon the rate of N applied to rice crop.

Subramanian and Rangarajan (1990) observed that combined application of green leaf manure (*Azadirachta indica*), FYM and cow dung slurry gave the highest grain yields on previous organically than inorganically fertilized plots (6.8 and 5.7 t ha⁻¹ respectively). The results from a field experiment conducted for 2 years during 1992 - 93 and 1993 - 94 (Singh *et al.*, 1996) in Madhya Pradesh (India), showed that application of FYM @ 10 t ha⁻¹ significantly increased the rice yield and succeeding wheat in both years compared to control (no manure) and was at par with application of 50% recommended fertilizers (40 kg N + 25 kg P₂O₅ + 15 kg K₂O kg ha⁻¹).

By application of FYM with 50% recommended NPK, grain yield of rice was comparable to that obtained with 100% recommended NPK in both years but the grain yield of wheat grown in rotation was significantly higher in FYM applied plots compared to fertilizer alone. Mishra and Prasad (2000) reported that the productivity of rice-wheat rotation was lowest in the control plots and reached 8.1 tons ha⁻¹ at 80 kg N ha⁻¹. This level of yield could be achieved by FYM application without fertilizer-N and with 80 kg N ha⁻¹, FYM produced 9.2-9.3 t ha⁻¹, which was about one t ha⁻¹ more than what is produced with 120 kg N ha⁻¹.

Multi-locational experiments being carried out under All-India-Coordinated Agronomic Research Project (AICARP) have shown that productivity of cropping systems was generally higher with the integrated use of FYM and fertilizers because of overall improvement in soil fertility (Singh and Dwivedi, 1999). Anand and Yaduvanshi (2004) reported that efficient and integrated nutrient management (green manure and farmyard manure combined with 125 kg N) along with effective soils reclamation is vital for sustaining rice-wheat system on salt affected soils. An application of 20 kg N ha⁻¹ along with 15 tonnes FYM ha⁻¹ to rice gave highest grain yield of rice as well as wheat, besides to build-up total N in mid-hill soils of Uttaranchal (Ghosh and Singh, 2003). Singh *et al.* (2004) reported that FYM increased yield of succeeding crop (wheat) by about 6% compared to urea applied alone. Senapati and Senapati (2004) from the studies on long-term effect of manure application and fertilizer on the upland rainfed rice-cropping system revealed that highest grain yield (2.1 tons ha⁻¹) was obtained with FYM supplying 30 kg N and half-recommended dose.

FYM supplemented with nitrogen (50 kg ha⁻¹) in rice and residual effect of FYM with N:P:K (100:30:30 kg ha⁻¹) in wheat crop was significantly superior to FYM alone (Krishna, 2006). The residual effect of the organic materials applied to rice on the succeeding wheat crop during all the years was positive and the increase in wheat grain yield ranged from 4 to 8%, the total annual productivity (rice + wheat yield) during eighth cycle was highest in FYM amended treatment (Mehla *et al.*, 2006).

2.3.2.2. Response of rice to green manures

The utility of green manuring for increasing soil productivity had been recognized from ancient times in rice tracts of China, India and North-East Asia (Jiao Bin, 1983; Pandey *et al.*, 2001; Senapati and Senapati 2004; Sheeba and Kumaraswamy, 2005). Green manuring improves the supply of plant nutrients and organic matter content, also improves the physical, chemical and biological properties of the soil. Among cultivated annual legumes *Sesbania spp.* has been used most widely for rice. Increase in plant height, tiller number, grain and straw yield of rice due to

green manuring with cowpea (*Vigna unguiculata*) or sunhemp (*Crotalaria juncea*) was also reported by Ahmed and Miah (1988). According to Manguiat *et al.* (1992), 1000 grain weight increased from 23.2 gram with 30 kg N to 30.5 gram with green manure of *Sesbania rostrata* plus 30 kg N ha⁻¹.

MacRae, and Mehuys, (1985) reported that green manuring had positive effects on soil aggregate distribution and stability, bulk density, moisture retention, and water movement.

Positive benefits of *Sesbania* green manuring on grain and straw yields in rice have also been reported by other workers (Rana *et al.*, 1988; Tiwari *et al.*, 1998). The results of the experiments conducted recently at IARI showed that green manuring of *Sesbania* during summer months (May-June) increased grain yield of rice by 0.4 t ha⁻¹ and succeeding wheat by 0.2-0.7 t ha⁻¹ (Sharma *et al.*, 1995). In subsequent study *Sesbania aculeata* and *Sesbania rostrata* were compared and found that both the species being at par, increased rice yield over summer fallow by 0.6-1.0 t ha⁻¹ and the succeeding wheat yields by 0.2-0.3 t ha⁻¹. Green manure of Dhaincha (*Sesbania aculeata*) provided sufficient nutrients to the basmati crop (Dhiman *et al.*, 2002).

Five years of experimentation on integrated nutrient management in rice - wheat cropping system at Raipur revealed significant effect of organic manure in sustaining yield level. Supplement 50% of recommended dose of N with green manure (*Sesbania aculeata*) resulted in significantly higher yield (Upadhyay *et al.*, 2003).

In Thailand the on-station studies and on-farm participatory experimentation show convincing results of increasing rice yield over 20%, which was equivalent to yield obtained by applying 54 kg N ha⁻¹ (Budsara, 2003).

Singh *et al.* (2004) reported that organic manuring with FYM plus GM without the application of any inorganic fertilizer proved quite effective in producing higher rice yield. Kaleeswari and Subramania (2004) reported maximum higher (5.06 tons ha⁻¹) and significantly (8.68 %) higher over control by incorporation of green leaf manure of *Gliricidia sepium*.

2.3.2.3. Response of rice to Press-mud

There are number of reports about effect of press-mud on growth of rice when it is applied separately or in combination with another nutrition sources like green manuring, FYM, neem-cake and fertilizers (Anand and Yaduvanshi, 2004; Mehla *et al.*, 2006). Application of PMC at 5 t ha⁻¹ was as efficient as 13 kg P ha⁻¹ in increasing grain yield of rice. Wheat responded to direct application of 26 kg P ha⁻¹. In the presence of PMC at 5 t ha⁻¹ applied to rice, grain yield responses were obtained up to 13 kg P ha⁻¹. Application of PMC helped to raise the yield potential of rice and wheat when compared with application of chemical P fertilizer

(Singh *et al.*, 2005).

2.3.2.4. Response of rice to Zinc

High pH, low organic matter content and high calcium carbonate, limit the solubility of Zn in the calcareous alkali soils. Most of the alkali soils contain high amount of total Zn (40 to 100 mg Zn kg⁻¹ soil but the available Zn (DTPA extractable) is quite often less than 0.6 ppm. Rice crop raised in these soils invariably suffers due to deficiency of Zn. The affected plant showed stunted growth, poor tillering, delayed maturity and low grain yield. An application of 10 to 20 kg of zinc sulphate is sufficient to get optimum yield of crops (Anand and Yaduvanshi, 2004).

Haluk *et al.* (2001) observed a considerable increase in grain yield with Zn application. It was 12.3% and 8.4% in 1998 and 1999, respectively. On an average, grain yield increase was 8.9% and Zn concentration of the plant and the rice grain increased with Zn application. In addition to these, the days to maturity and spikelet sterility decreased, and the number of panicle per square meter and head rice yield increased with Zn application. Homogeneous matured rice was harvested from Zn applied plots.

The results of long term fertility experiment under the rice-wheat rotation in Nepal indicated that the balanced use of N:P:K (100:30:30 kg ha⁻¹) along with ZnSO₄ (25 kg ha⁻¹) in rice and the same dose of N:P:K in wheat were the best combinations to obtain better grain yields from both the crops. The effect of zinc in addition to N:P:K was minimum on rice, however, the residual effect of zinc on wheat was significant in enhancing the grain yield (Krishna, 2006).

2.3.3. Effect on nutrient concentration

Tiwari *et al.* (1980) observed that *Sesbania* green manure increased the N, P, and K contents in plants and their availability in soil. Similarly, Sharma and Mitra (1988) observed marginal increase in N content of straw due to application of organic materials over their removal. However, inorganic sources seem to be more effective on nutrient assimilation in plant noted by several researchers. Kadu *et al.* (1991) recorded the highest P and K contents in grain with the highest NPK plus FYM, but N percentage was highest with the highest NPK rate without FYM. According to Wang *et al.* (1998), the concentration of Kjeldahl-digested N was significantly higher in milled rice grains cultivated under conventional farming practices than in those grown organically.

2.3.4. Effect on nutrient uptake

From pot trials with rice grown with different P₂O₅ and FYM rates, Verma and Singh (1981) reported that P uptake increased with increasing P rates: it was higher with 2% FYM than with 1% FYM mixed with the soil or no FYM. P uptake was increased due to FYM application

under non-saline soil condition (Dravid and Goswani, 1987).

Application of Udaipur rock-phosphate amend with a combination of FYM, green leaf manure, biogas spent slurry and PSM increased P- solubilization and its uptake by rice crop (Mohod *et al.*, 1989).

Tiwari *et al.* (1980) observed significantly higher N, P, and K uptake of rice due to *Sesbania aculeata* green manure over no-application. Balasubramaniyan *et al.* (1991) reported that green manure incorporation of 12.5 t ha⁻¹ of *Crotalaria juncea* significantly increased NPK uptake of rice; possibly due to the enhanced availability of these nutrients due to green manure effects. Similarly, Zia *et al.* (1992) recorded an increase in N uptake of rice due to application of *Sesbania aculeata*, FYM and rice straw (RS); the additional uptake amounts were in the order of GM > FYM > RS. Sharma *et al.* (1995) revealed that in the absence of urea-N to rice, green manure with *Sesbania* increased above ground plant-N of rice by 17 kg N ha⁻¹. Sharma *et al.* (1995) reported ground plant-N of rice-wheat cropping system increased over summer fallow by 19-30 kg N ha⁻¹. Contrary to this, Nair and Gupta (1999) noted that the total N and K uptake in rice crop did not differ significantly due to green manure treatments, except total P uptake. Satapathy (1999) also reported that the N uptake of rice in urea plots was higher than in FYM plots, whereas, P uptake was comparable. Das *et al.* (2003) reported that incorporation of rice and wheat straws significantly increased nutrient uptake.

2.3.5. Effect on rice quality

The appearance of milled rice is important to the consumer, which makes it also important to the producer and the miller. Farmer's and miller's concern is to get higher price of produce to be determined by market quality standard composed of shape, size and colour of rice, percentage of hulling, milling and head rice recovery. Consumer is also concerned about good cooking and eating qualities, which are determined by physical-chemical properties of starch like amylose content, gelatinization temperature etc.

Tamaki *et al.* (1995) researched the relationships between the duration of organic farming culture and amylographic characteristic and mineral contents of rice. The experimental results after 16 years showed that maximum viscosity and breakdown values of rice slowly increased with duration of organic farming practices. Mineral contents of rice one year after the start of organic farming practices were similar to those of rice grown conventionally. N, P, K contents decreased with duration of organic farming, while Mg content gradually increased. Dhiman *et al.* (1999) at Kaul, studied the effects of organic farming (green manuring and FYM at 20 t ha⁻¹) and chemical fertilizers on scented rice (Basmati 370 and Taraori basmati), and found that rice quality was not affected by sources of nutrients. Milling, hulling and elongation ratio

were greater in Basmati 370 but higher values of rice length and kernel length after cooking were observed in Taraori Basmati. Hemalatha *et al.* (1999) also reported that grain quality (amylose and crude protein content) was better with *Sesbania aculeata* and 50% N plus *Azospirillum*.

According to Battan *et al.* (2003), the quality of rice produced at these places (Haryana, Punjab and some part of Uttranchal) is much superior due to soil and climatic conditions of these areas. However, higher doses of nitrogenous fertilizers increased the amylase content in Basmati rice and affect the cooking quality. That is why the cooking quality of traditionally tall type Basmati rice varieties is better than semi - dwarf basmati varieties.

At high yield levels, late nitrogen (N) fertilizer application at flowering at the International Rice Research Institute (IRRI) farm often resulted in increased rough rice yield of IR cultivars and accompanied by higher milled rice protein and increased total and head-milled rice contents. The combined effects of N application at flowering resulted in a 30-60% increase in head-rice protein yield. In most cases, there was a significant positive correlation between head rice content, milled rice protein, and translucency. Late N fertilizer application provides an option to improve milling and nutritional quality of rice grain (Consuelo *et al.*, 1996). Satheesh and Balasubramanian (2003) concluded that applied organic manures would increase head rice recovery.

Correlation studies among quality attributes indicated that long-grained varieties had lower head rice recovery ($r=-0.690$) due to more breakage during milling (Ghosh *et al.*, 2004). Timing of field draining and harvesting of rice with meteorological conditions can allow growers to foster conditions for high head rice yield (Elaine, 2005).

2.3.6. Rice cooking quality

Cooking, processing and baking qualities of rice established the economic values of rice grains and flours. Great part of polished rice is consumed directly after cooking. Important cooking qualities of rice are water absorption, swelling fragility, hardness and gelation properties. Cooking qualities depend on cooking time, stickiness, cohesiveness and tenderness (Chrastil, 1992). The breadth wise expansion of rice on cooking is not a desirable trait in high quality rice and development of breadth wise rings without splitting is the characteristic unique feature of basmati rice (Sankar, 1998). Cooking quality of Basmati rice is greatly influenced by environmental factors, soil fertility, irrigation practices, spacing, storage, etc (Ahuja *et al.*, 1995). In spite of its being important as requisite factor/element for quality, reports available on organic farming and rice quality are scanty (Ram *et al.*, 1995).

Rice variety and grain type are also factors that influence the loss of grain quality (Chen and Kunze, 1983). Malakodi and Singaram (2003) reported that highest crude protein was obtained by combining rock phosphate, FYM and phosphobacteria. Satheesh and

Balasubramanian (2003) reported organic manure in combination of press-mud with neemcake or press-mud with poultry manure superior in recording higher kernel length after cooking (9.8mm); length/breadth ratio and elongation ratio. Battan *et al.* (2003) reported that the proportion of amylase and amylopectin affected the quality traits to a great extent in Basmati rice. The good quality Basmati rice contains medium type of amylase content (20-25%). He had also mentioned that cooking qualities would be better with photoperiod sensitive varieties and high temperature at the time of maturity reduces the aroma content of Basmati rice.

2.3.7. Effect on soil properties

2.3.7.1. Effect of farmyard manures

Werner *et al.* (1988) noted that application of FYM over a period of 24 years increased the organic carbon content and total N content of the soil. Bhagat and Verma (1991) revealed that incorporation of FYM resulted in higher percentage of water stable aggregate, lower bulk density, higher porosity, higher available water holding capacity and higher hydraulic conductivity. Zia *et al.* (1992) studied the effect of green manure, FYM and rice straw on soil fertility and found that residual soil N was highest following green manure of *Sesbania aculeata* and lowest following rice straw incorporation; residual soil P was highest following FYM application, whereas residual soil K was highest following rice straw incorporation. Sharma and Sharma (1993) reported the increase in organic carbon, total N and available N, P and K, decrease in bulk density with the application of fertilizer levels or FYM compared to the initial or unmanured plots.

Whereas Lian (1993) reported, in long-term experiments in Asia, that effects of continuous manure application increased soil organic matter and nitrogen content, but the increases was less significant in tropical and subtropical countries than in temperate regions due to more rapid turnover of organic carbon. The increase in infiltration rates, organic carbon content, available N, P, and K in soil were reported by More (1994).

Gupta (1995) recorded that the moisture percentage at 0-15 cm soil depth was highest (19.19 %) with FYM followed by pig manure and poultry manure, whereas at 15-30 cm soil depth the moisture percentage was highest with tank clay and NPK fertilizers. He concluded that application of organic manures as pig manure, poultry and FYM are beneficial to rice cultivation in Alfisols due to retention of soil moisture in the rooting zone. According to Mishra and Prasad (2000), addition of fertilizer-N tended to decrease soil organic carbon (SOC) after rice harvest, while application of FYM prevented the decline in SOC. Application of FYM and fertilizer-N increased alkaline permanganate oxidizable N.

In the studies on organic farming of Basmati rice, Dhiman *et al.* (2002) suggested that enriched FYM with rock phosphate is good source of nutrition. Suhag *et al.* (2003) reported that when organic manures like FYM, compost, crop wastes, slurry, vermicompost, etc, were added to

soil, it was not only the fertility of the soil but there was also change in the rhizosphere environment because it improved the microflora, temperature, aeration and water holding capacity of the soil. The P, S and Zn balances were favorable in those plots where cowdung was applied (Saha *et al.*, 2003). The beneficial role of FYM in improving the physical, chemical and biological properties of soil have been reported by Ghosh and Singh (2003), Kumar *et al.* (2003) and Singh *et al.* (2004).

2.3.7.2. Effect of green manuring

The reports from IARI showed that *Sesbania* green manuring increased soil organic carbon over summer fallow by 0.030-0.162%, Kjeldahl N by 0.005-0.003% and available P by 4.0-6.9 kg ha⁻¹ (Sharma *et al.*, 2000). Chaphale *et al.* (2000) also observed that the addition of green manure (*Gliricidia*) over a period of 5 years led to increase in organic carbon, total N, available N, P, K and water holding capacity, but density of soil decreased as compared to control. Nitrogen fertilizer rates could be reduced after the incorporation of green manures having high yields and N contents in the previous season (N'Dayegamiye and Sen, 2001).

Green manuring by contributing organic matter may prevent leaching loss, render unavailable forms of nutrients into available forms and increase permeability and drainage capacity of soil besides ensuring steady SUW nitrogen throughout the growth period of different crops (Yadav *et al.*, 2003). Incorporation of green manure crops into the soil had shown to increase soil organic carbon (Sharma and Mitra, 1988; and Cassman *et al.*, 1996; Singh *et al.*, 2004). Bhardwaj and Datt (1995) while examining the effect of legume green manures on some microbiological properties in an acid rice soil found significant improvement in the microbial biomass, dehydrogenase activity and bacterial populations in the field soil green manured for rice for 3 years as compared with fertilized soil. Prasad *et al.* (1995) conducted experiment with various sources of green manures, organic manures and rates of Zinc and found that green manures and organic manures can substitute 25 kg ZnSO₄ ha⁻¹ in calcareous soil and the residual effect of Dhaincha is equivalent to 25 kg ZnSO₄ ha⁻¹ on succeeding wheat crop. They also recorded the significant effect of green manuring on available N, P, K, and Zn. Yadav *et al.* (2003) reported that Dhaincha (*Sesbania aculeata*) brings the nutrients from the lower layer of the soil to upper layer, and also in soluble form, thus increases the availability of nutrients like nitrogen, phosphorus, potassium calcium, magnesium, iron, zinc, etc. The pH of the soil is also decreases, which enhances the availability of nutrient.

Yadav *et al.* (2003) stated that Dhaincha (*Sesbania aculeata*) is an excellent crop with good vegetative growth, which can fit well in the rice-wheat rotation. Because of its capability to

withstand draught, waterlogging, salinity, etc, it is better than other green manure crops. Kumar *et al.* (2003) reported that different green manures and grain legumes are used to increase the nitrogen content and physical-chemical properties of the soil. Crops like Sunhemp (*Crotalaria juncea*), Dhaincha (*Sesbania aculeata*) and other several other leguminous green manuring crops can add up to 120-175 kg N ha⁻¹.

The magnitude of reduction in bulk density due to green manuring over fallow was 0.03-0.07 Mg m⁻³ in 0-15 cm soil layer and 0.05-0.09 Mg m⁻³ in 15-30 cm soil layer during the growth of rice and wheat (Mandal *et al.*, 2003). Senapati and Senapati (2004) stated that with the continuous addition of green leaf manures, organic carbon content as well as organic matter of the soil increased, thereby influencing nutrient availability and improving soil fertility. Anand and Yaduvanshi (2004) reported that total N lost and percentage of urea loss was minimum (16.08 and 13.40 respectively) under recommended dose of NPK combined with green manuring as compared to 21.75 and 18.13 in NPK applied alone plots.

2.3.7.3. Effect of press-mud

Efficient utilization of P from press-mud cake (PMC) in rice-wheat rotation is critical in reducing the costs of fertilizer P and improving soil fertility (Singh *et al.*, 2005). Phosphorus responses in rice were obtained at 13 kg P ha⁻¹ under rice-wheat rotation on a silt loam (Aquic Ustorthent) soil in the flood plains of Punjab, India. Application of PMC increased the organic carbon and available P contents in soil.

Applications of the mixture of tank silt and press-mud improved the physical condition of the soil by reducing the hydraulic conductivity, pH, porosity and bulk density and by increasing the organic matter content and the water holding capacity of the soil (Annadurai *et al.*, 2005)

Long-term experiment in rice-wheat cropping systems (Mehla *et al.*, 2006) reported significant build up in soil organic carbon content in press mud and FYM amended treatments over green manured, burnt rice husk and inorganic fertilizers treatments only. Prasad *et al.* (2006) reported that Press-mud when combinative with gypsum and FYM reduced soil pH, ESP, SAR and increased the available N, P. It also increased grain and straw yields of hybrid rice.

2.4. Integrated use of organic and inorganic fertilizers in rice

Integrated approach of plant nutrient has a major role to play in solving the problem of nutrient mining. In simple words, it involves the judicious use of organic, chemical and microbial sources to sustain the soil health to provide crop nutrition packages, which are technically feasible and environmentally safe.

In practice, the nutrient management strategies adopted in one crop often influence the fertilizer needs of the succeeding crops due to carry over effect of nutrients and crop residues,

which is most significant under integrated nutrient management systems. Crops response to organic and biological nutrient carriers is not as spectacular as to the fertilizers, but supplementary and complementary use of these sources is known to enhance the use efficiency to applied fertilizers, improve crops yield and physical status of soil (Lal and Mathur, 1989).

2.4.1. Farm yard manures in combination with inorganic fertilizers

Integrated use of organic manures and fertilizers is an established practice for providing stability in crop production in cereal based cropping systems (Lal and Mathur, 1988; Tripathi and Chaubey, 1996; Sumanthy *et al.*, 1999). While studying rice – wheat cropping system it was observed that amount of N, P and K added through chemical fertilizers, organic manures and bio-fertilizers were found to be effective in building up N and P but not K as removal of K was more than that of applied through various treatments (Prasad, 1994).

The superior benefits of integrated use of organic manures and chemical fertilizers over its application alone have been reported by many researchers. Kulkarni *et al.* (1983) reported that significant increase in rice yield was due to combined use of fertilizer N with FYM. Meelu and Morris (1984) stated that integrated use of organic manures and chemical fertilizers in rice had considerably direct and residual effects on yield and improvement in soil fertility. Ghosh *et al.* (1994) also reported the beneficial effect of integration of organic and inorganic sources of N to rice grown under water logged condition.

Mathew *et al.* (1993) also reported a reduction in the mineral fertilizer requirement to the extent of one-third dose of N and K_2O and two third dose of P_2O_5 from recommended fertilizer dose of 70:35:35 kg ha⁻¹ when FYM was applied regularly @ 5 tons ha⁻¹ in all seasons.

Mathukrishnan *et al.* (1998) reported that the maximum rice (cv. ADT 38) yield was recorded with application of organic manure adjusted with mineral fertilizer. Sharma and Sharma (2002) revealed that, combination of NPK plus FYM significantly increased the productivity of rice-wheat cropping system over N alone by 1.2-1.3 t ha⁻¹, whereas the combination of NP, NK, and NPK had no significant effect on the productivity of both rice and wheat grown in sequence. They also pointed out that N, P and K uptake were increased by 38-45, 7-10 and 25-42 kg ha⁻¹, respectively in the treatment with organic and inorganic combination. Similarly, organic carbon content of soil was also increased by 0.09 to 0.15%, available N by 6-14 kg ha⁻¹, available P by 7-8 kg ha⁻¹ and K by 7-32 kg ha⁻¹ over N alone. Combined application of Jhabua rock phosphate and superphosphate in 1:1 ratio along with FYM (12.5 tons ha⁻¹) and phosphobacteria significantly increased the grain yield, quality parameter and total NPK uptake (Malarkodi and Singaram, 2003)

From the pot and field experiments conducted in Côte d'Ivoire (Ivory Coast) to study the

impact of combined legume and phosphate rock on rice performance, Eklou *et al.* (2003) reported that soil properties was improved significantly. Kundu *et al.* (2004) reported that all the yield attributing characters and consequently the yield of crop was administered with organic nitrogenous fertilizers along with crop residues. Maximum response of crop yield was observed when the crop was fed with crop residues, FYM along with inorganic fertilizers. Inorganic fertilizers along with 15 Mg FYM ha⁻¹ produced significantly higher grain yield and nutrient uptake of rice (Mehla *et al.*, 2006).

2.4.2. Economics of production under integrated nutrition management and organic farming

Mathew *et al.* (1993) noted the highest gross and net income and benefit: cost ratio with use of 66% of recommended N, K₂O and 33% P₂O₅ + 5 tons FYM ha⁻¹ as compared to 100% recommended N, P₂O₅, K₂O and all other inorganic and organic combinations. Singh *et al.* (1996) obtained the highest net return in rice-wheat cropping system by using poultry manures @ 10 tons ha⁻¹ with or without recommended NPK as compared to FYM @ with or with out NPK. In rice – mustard cropping system on an average, 22.2% more net profit was obtained when FYM was applied along with P (Sharma and Tripathi, 1999). Maximum grain monetary equivalence (GME) as well as highest monetary advantage was obtained from 75% NPK + 10 tons cow dung ha⁻¹ or 100% recommended dose of NPK (Puste *et al.*, 1999). Ram and Saha (1999) observed highest gross and net return and net return per rupee investment under 50:50 ratio of poultry manure or FYM combined with chemical N in comparison to N applied as urea alone. Menadoze (2004) reported that organic farming utilized only 33% (US\$39 ha⁻¹) of the cash capital required to grow a hectare of rice when compared to conventional farm which spent US\$118 ha⁻¹. The net revenue in organic farming was higher (US\$332 ha⁻¹) than in the conventional farm (US\$290 ha⁻¹) due to less energy input, synthetic products input and premium costs of organic products despite the slightly lower yields.

2.5. Rice lodging

The existing varieties of scented rice are tall and prone to lodging particularly when higher dose of nitrogen are applied at improper time. Higher dose of nitrogen applied particularly at later stage (42 DAT) proves ineffective or even harmful as the crop showed lodging tendency under such conditions (Ram *et al.*, 1995). Dhiman *et al.* (2002) reported that tall varieties of Basmati had the tendency of lodging at the time of ear emergence and/or grain development. Excess nutrients, more poundings of water and very early planting are major causes for this unwanted incidence of Basmati.

Yang *et al.* (2004) indicated that a combined application of chemical fertilizers and

organic materials could markedly increase the diameter, wall thickness and weight of basal stems, greatly increased the K_2O and SiO_2 contents in rice basal stems, but reduced plant height, which resulted in the effective increase of snapping resistance (RS) and marked decrease of lodging index (LI).

CHAPTER III

MATERIALS AND METHODS

The details of the materials used and methodology adopted during the course of investigation are presented in this chapter.

2.5.1. Plan of Research Work

Field experiment was conducted during *kharif* season of 2005 to study the "Response of rice to organic nutrition under rice-wheat cropping system".

2.5.2. Details of the Experimental Site

The experimental trial was laid out in the field No. 79/17 of the research farm of Rice Research Station, Kaul, Kaithal, Haryana during *kharif* season of 2005.

2.5.3. Climate and weather Conditions

Rice Research Station (Kaul) is situated at $29^{\circ} 51'$ N latitude and $76^{\circ} 39'$ E longitudes. The climate of this area is hot semiarid with hot and dry summers and cold winters and falls under the agro-climate zone "Trans-Gangetic plains". Summer months May and June are the hottest with the maximum temperature ranging between 36 and $40.7^{\circ}C$. The minimum temperature ranged from 8.4 to $27.5^{\circ}C$.

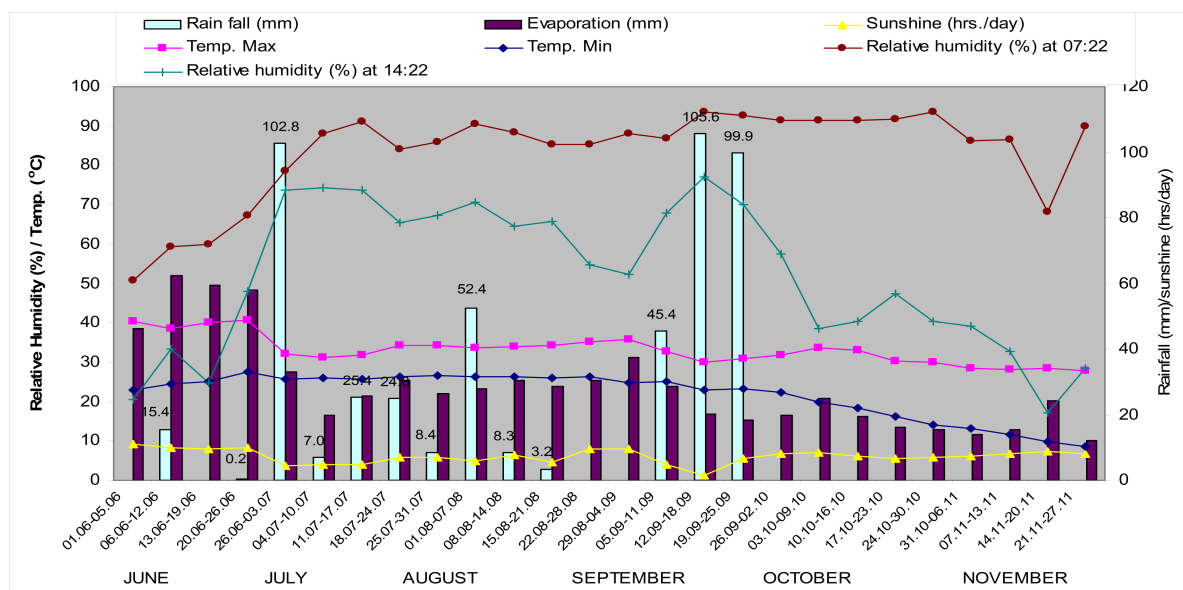


Fig. 1. Weekly meteorological data during crop season, 2005

The most of the rainfall occurred during June to September and was 498.8 mm during the crop growth period. The meteorological data recorded at Karnal district, collected and weekly average are presented in Appendix 1 and Fig. 1.

2.5.4. Soil Characteristics

Before start of the experiment, a composite soil sample was collected from experimental field and analyzed for mechanical composition and important characteristics are given in Table 3.1. The soil of the experimental field was a clay loam and had moderate water holding capacity. The soil was low in organic C, low in total nitrogen content, medium in available phosphorus and high in available potassium.

Table 3.1. Mechanical and chemical characteristics of soil of the experimental field

Particulars	Value
<i>Mechanical composition</i>	
(Hydrometer Method, Bouyoucos, 1962)	
Textural class	Clay loam
<i>Chemical composition</i>	
1. pH (1:2:5; Soil : water ratio)	7.8
(Ellico pH meter, Piper, 1950)	

2. Electrical conductivity (dSm^{-1} 25°C) (Solubridge Method, Piper, 1950)	0.24
3. Organic C (%) (Walkley and Black Method, Piper, 1950)	0.41
4. Available N (kg ha^{-1}) (Subbiah and Asija, 1956)	141
5. Available P (kg ha^{-1}) (Olsen's <i>et al.</i> , 1954)	21
6. Available K (kg ha^{-1}) (Jackson, 1973)	301

2.5.5. Cropping History of the Experimental Site

The cropping history of the experimental field for the last five years is given in Table 3.2.

Table 3.2: Cropping history of the experimental field

Year	<i>Kharif</i>	<i>Rabi</i>
2000-2001	Rice	Wheat
2001-2002	Rice	Wheat
2002-2003	Rice	Wheat
2003-2004	Rice	Wheat
2004-2005	Rice	Wheat

2.5.6. Experimental Details

The experiment was laid out in split-plot design with four replications. The treatments were comprised of six main plot treatments of nutrition sources (Control, Green manure, Press-mud, FYM, RF + FYM and RF) and two sub-plot varieties; Taraori Basmati (Scented rice) and HKR126 (high yielding variety). Thus, there were 12 treatments in all. The allocation of various treatments to different plots was done by randomization using Fisher and Yates random table.

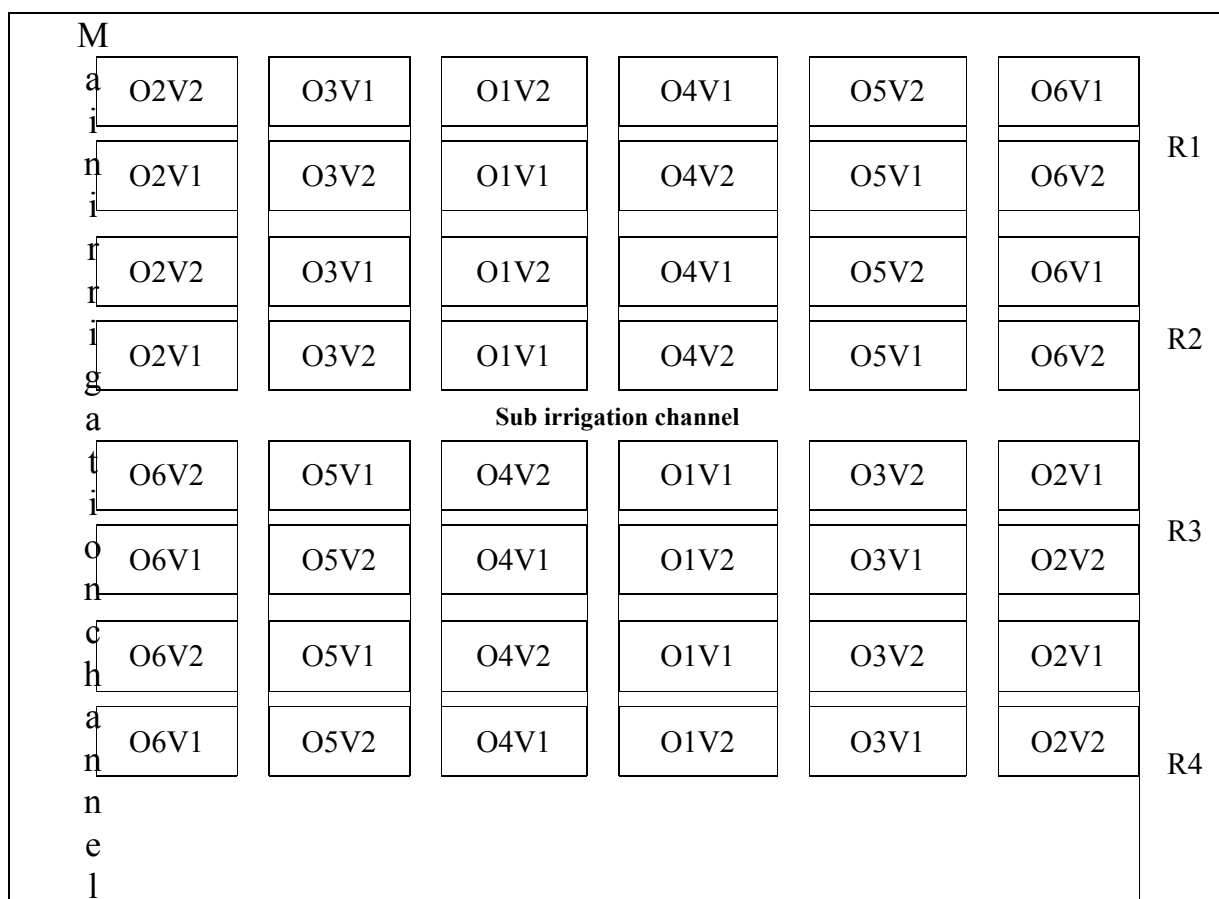
Main plot: Nutrients sources

- O₁ - Control (No manure, no fertilizers)
- O₂ - Green manuring
- O₃ - Press-mud 7.5 tons ha^{-1}
- O₄ - FYM 15 tons ha^{-1}
- O₅ - R.F + FYM 5 tons ha^{-1}
- O₆ - R.F*

Sub-plot: Varieties

V₁ - HKR-126 (High yielding dwarf rice)

V₂ - Taraori Basmati (Scented rice)

Experiment layout

Recommended dose of fertilizers (RF*):

For HKR-126 (150 N + 60 P₂O₅ + 60 K₂O + 25 ZnSO₄ kg ha⁻¹)

For Taraori Basmati (60 N + 30 P₂O₅ + 30 K₂O + 25 ZnSO₄ kg ha⁻¹)

Total treatment combinations	: 12
Experimental Design	: Split – plot design
No. of Replications	: 4
Total plots	: 48
Gross plot	: 32 m ² (8 x 4 m)
Net plot	: 21 m ² (7 x 3 m)

3.6.1. Important characteristics of the experimental materials

3.6.1.1. Crop variety

Taraori Basmati (HBC-19): This is a scented variety and was developed through pure line selection from the material known as Karnal local and was released for cultivation in 1992 (Ahuja *et al.*, 1995).

HKR 126: It is high yielding dwarf variety, and a cross between Namsagui 19/IR 4215-301-2-2-6/IR 5853-162-1-2-3 which was released in 1992 for irrigated medium ecosystem by CCS HAU (Singh, 2003).

3.6.1.2. Fertilizer materials

Nitrogen: commercial grade urea containing 46% N was used.

Phosphorus: Diamonium phosphate (DAP) of commercial grade containing 18 % N and 46 % P₂O₅ was used as a nitrogen and phosphorus source.

Potassium: Muriate of potash was the source of potassium (50% K₂O)

Zinc sulphate: for supply of Zinc.

3.6.1.3. Organic materials

F.Y.M: Well decomposed farm yard manure was used having 23.9 % C, 0.57 % N, 0.37 % P and 2.47 % K.

G.M: *Sesbania aculeata* was sown on 20.05.2005 with hand plough in the row at a uniform spacing of 35 cm. It was grown to flowering (60 DAS) and then incorporated with the help of tractor drawn soil turning plough on 14.07.05. Total biomass was estimated at incorporation time 32 tons ha⁻¹ by taking samples and subsequently weighed.

Press-mud: Taken from sugar mill Shuhbed, District of Kurukshetra, Haryana contain: 40.3 % C, 1.89 % N, 1.41 % P and 0.49 % K.

3.6.2. Details of cultural operation

The details of cultural operations done during experimentation are given in Table 3.3 and the main operations are described below.

3.6.2.1. Raising of nursery

The nursery area was puddled well and raised bed of 10 m x 1 m were prepared. Sprouted seeds were broadcasted uniformly on the wet nursery at the rate of 300 g bed⁻¹. The nursery was irrigated frequently. Fifteen days after sowing the beds was weeded and a nitrogen

dressing (250g) urea 10 m^{-2} was given. The seedlings were grown to an age of 30 days old.

3.6.2.2. Major field operations

Preparatory cultivation: The field was filled with water and puddled twice using a tractor drawn off set disc and was levelled with the help of planker.

Transplanting: Two healthy rice seedlings per hill were transplanted at a spacing of 20 cm x 15 cm for Taraori basmati and spacing of 15 x 15 cm for HKR126.

Gap filling: A week after transplanting of rice, gap filling was done in the plots wherever it was felt necessary to maintain uniform plant population.

Intercultural operations: One hand weeding was done at 42 days after transplanting.

Irrigation: The crop was irrigated to maintain 3-5 cm standing water in the field. However, plots were drained during fertilizer application and 15 days before harvesting.

Fertilizer application: Half dose of nitrogen, full dose of phosphorus as diamonium phosphate, potassium as muriate of potash, FYM and Press-mud as per treatment were applied as basal before transplanting and mixed well and remaining half dose was given 45 days after transplanting.

Harvesting and threshing: The net plots after removing the crops from border rows, were harvested and left to dry for 5-6 days in the field. The threshing-was done with manual labour through beating the each bundle.

Table 3.3. Schedule of cultural operations done in the field

Operations	Date
<i>Nursery:</i>	
Land preparation for nursery raising	20.05.05
Sowing of sprouted seeds	19.06.05
Weeding and dressing	06.07.05
<i>Main field:</i>	
Sesbania sowing	20.05.05
Sesbania green manure incorporation	10.07.05
Ploughing with a country plough, puddling and planking	14.07.05
Basal application of FYM, Press-mud and fertilizers	14.07.05
Transplanting	15.07.05
Gap filling	22.07.05
Fertilizer application-II	07.08.05
Hand weeding	19.08.05

Harvesting & threshing

HKR126

24.10.05

Taraori Basmati

18.11.05

3.6.3. Details of observations**3.6.3.1. Growth parameters****a. Plant height**

Plant height of five plants selected randomly from each plot was measured from the ground level up to the longest leaf at 30, 60, 90 DAT and at harvest from ground level to the tip of the longest panicle at harvest and mean values were computed.

b. Number of tillers

Number of tillers five of hills were counted at 30, 60, 90 DAT and at harvest an average number of tillers per square metre were worked out as follows:

Number tillers m^{-2} = Number tillers per hill x Number of hills in a square metre.

c. Dry matter accumulation

Plants of five hills were collected randomly from each plot and cut at ground level. These plants were oven dried at 60-65°C to a constant weight and dry weight was recorded and dry matter production per square meter was calculated with the help of following formula:

Dry matter production (kg m^{-2}) = Dry weight of plant x Number of plants in a square meter.

Then dry matter production per hectare was computed.

d. Leaf Area Index (LAI)

Four plants per plot was collected and all the leaf was cut out and used in Leaf area meter to measure leaf area at 30, 60 and 90 DAT.

$$\text{LAI} = \frac{\text{Leaf area per tiller (cm}^2\text{)} \times \text{no. of tillers m}^{-2}}{10.000}$$

3.6.3.2. Post harvest observations**a. Number of panicles per square meter**

Five hills of sample plants were selected from net plot and the total number of panicles were counted and the average number of panicles per square metre were worked out as follows:

Number of panicles m^{-2} = Number panicles per hill x Number of hills in a square metre.

b. Weight of panicle

At harvest, five panicles per plot were collected; dried under sunlight and weighed by

electrical balance. The mean value of panicles weight was computed.

c. Filled grains per panicle

From the five panicles selected randomly, grains were separated, cleaned and filled grain were separated and counted with the help of grain counter. The mean value of filled grains per panicles was computed.

d. Grain and straw yields

The net plot leaving two border rows on each site and four hills from other two sides of the plot were harvested and sun dried for three days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying the grain yield was recorded. Straw yield was obtained by subtracting grain yield from total biomass yield. Yield was expressed in quintals per hectare.

e. Harvest Index

Harvest Index was calculated by using the following expression (Singh and Stoskoff, 1971)

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Grain yield} + \text{straw yield}}$$

3.6.4. Chemical analysis

3.6.4.1. Plant analysis

The plant samples were dried, ground and analyzed for total nitrogen content in the plant samples at harvest by modified Kjeldahl method (Prasad, 1982). Total phosphorus and potassium were estimated at harvest by Vanadomolybdo phosphoric acid yellow colour method and flame photometer method, respectively (Prasad, 1982) in a nitric-perchloric di-acid digest plant material.

Nutrient uptake: Nitrogen, phosphorus and potassium uptake by rice was calculated by multiplying their respective chemical concentrations with dry matter production. The uptake by grain and straw was added to get the total uptake.

3.6.4.2. Soil analysis

Soil samples were collected from each plot after harvest of rice from a depth of 0-15 cm and were analysed for organic carbon by Walkley and Black's wet digestion method (Piper, 1950); available N by alkaline permanganate method (Subbiah and Asija, 1956); available P by using Olsen's method (Olsen *et al.*, 1954) and available K by extracting soil with 1 N ammonium acetate reading K on flame photometer (Jackson, 1973).

3.6.5. Economics of rice cultivation

Cost of cultivation was calculated based on the input prices during the crop season. Gross income was calculated based on the grain and their prevailing market prices during the crop season. Net income was obtained by subtracting cost of cultivation from gross income i.e.

$$\text{Net income} = \text{Gross income} - \text{Cost of cultivation (Rs. ha}^{-1}\text{)}$$

3.6.6. Grain quality characteristics

3.6.6.1. Test weight

The 1000 filled grains, counted from sample panicles with the help of seed counter were weighed.

3.6.6.2. Hulling percentage

Well dried paddy samples of 100 gm from each plot were hulled in a mini 'Satake Machine' and the weight of brown rice was recorded.

Hulling percentage was worked out as,

$$\text{Hulling \%} = \frac{\text{Weight of brown rice}}{\text{Weight of rough rice}} \times 100$$

3.6.6.3. Milling percentage

The brown rice obtained after hulling was passed through 'Satake Rice Whitening and Caking Machine' for 5 minutes to obtain uniformly polished grains.

The polished rice was weighted and milling percentage was calculated as,

$$\text{Milling percentage} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \times 100$$

3.6.6.4. Head rice recovery

From 10 grams milled rice, after removal all broken kernels by keeping 2/3 to whole kernel, were weighted and head rice recovery (HRR) percentage was computed as,

$$\text{HRR} = \frac{\text{Weight of completely milled rice (after removal of broken grains)}}{\text{Weight of rough rice}} \times 100$$

3.6.6.5. Kernel length and breadth before cooking

Randomly collected 20 milled kernels from the bulk sample of each plot were measured for their length and breadth by using a calibrated ruler.

3.6.6.6. Kernel length/breadth ratio

Ratio of kernel length to breadth was calculated with the help of formula:

$$L/B \text{ ratio} = \text{Kernel length/Kernel breadth}$$

3.6.6.7. Density

10 gm of milling white rice was put in cylinder to measure volume and density was computed as:

$$\text{Density (g ml}^{-1} \text{ or g cm}^{-3}\text{)} = \frac{\text{Weight of rice}}{\text{Vol. of rice}}$$

3.6.7. Cooking quality

3.6.7.1. Optimum cooking time

Five test tubes were taken. To each 5 g rice was transferred. To this 30 ml water was added. All tubes were kept in boiling water bath. After every 5 minutes tubes were taken out from boiling water bath and rice was collected in strainer and weight of kernels was recorded. The curve of time vs. weight was plotted. Time cooking for the weight equal to 250 % grain was noted from curve.

3.6.7.2. Swelling Index

Rice at optimum cooking time was collected and excess water was removed by blotting paper. Volume of cooked rice was measured by dipping in kerosene contained in a volumetric cylinder.

$$\text{Swelling index} = \frac{\text{Vol. of cooked rice}}{\text{Vol. of raw rice}}$$

3.6.7.3. Water uptake ratio

It is the increase in the weight of cooked rice after draining off the excess water and calculated by:

$$\text{Water uptake ratio} = \frac{\text{Weight of cooked rice} - \text{Weight of raw rice}}{\text{Weight of raw rice}}$$

3.6.7.4. Cooking coefficient

Randomly chosen 20 kernels from optimum cooked rice were collected to measure length and breadth as above (3.6.6.5). Cooking coefficient was calculated by the following formula:

$$\text{Length of kernel of cooked rice} - \text{length of kernel of raw rice}$$

$$\frac{\text{Cooking coefficient}}{\text{Breadth of kernel of cooked rice} - \text{Breadth of kernel of raw rice}} =$$

3.6.7.5. Volatile substance residue (VSR)

Basmati rice is characterized by its fragrant odour called aroma. Aroma is measured in terms of VRS value which is defined as the amount (mg) of alkaline potassium permanganate (KMnO_4) required to oxidize the aroma giving compounds present in 100 gm of rice sample. Aroma is driven with the help of air current into a flask containing KMnO_4 , where it is absorbed quantitatively. The unreacted KMnO_4 is treated with iodine solution and unreacted iodine residual solution is titrated against sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) solution (AOAC, 1970).

The principle behind this process is that aroma oxidizes some part KMnO_4 and remaining KMnO_4 is oxidized by iodine and further, remaining iodine is oxidized by $\text{Na}_2\text{S}_2\text{O}_3$.

The VRS value is calculated by using the following relationship:

$$\text{VRS value} = \frac{6.32}{(B_2 - B_1)} \times (SR - E_2) \times 5$$

Where: B1 - Blank reading with iodine (ml)
 B2- Blank reading with iodine and potassium permanganate (ml)
 SR – sample reading
 6.32 is the factor calculated on basis of KMnO_4 and iodine reading
 5 is a dilution factor

3.6.8. Statistical analysis

The data related to each character were analysed statistically by computer programme MS Excel and OPSTAT (Statistical packages for Agricultural Worker) applying the technique of Analysis of Variance (ANOVA) as described by Cochran and Cox (1957). Test of significance were made at 5 percent level of significance for analysis of variance. To Judge the significance of difference between two treatment means, critical difference (CD) was computed as under:

$$\text{CD} = \frac{2 \text{ Error mean square}}{n} \times t \text{ value at } 5 \% \text{ level}$$

n = Number of replications of the factor for which CD is to be calculated.

t = t_{value} from Fisher's (1948) table for error degree of freedom at 5 % level of

significance.

CHAPTER IV

EXPERIMENTAL RESULTS

The experimental results obtained during the one year of investigation are presented in this chapter.

4.1. Growth parameters

Plant growth characters were evaluated in terms of plant height, number of tillers per unit area, leaf area index (LAI) and dry matter accumulation at 30 days after transplanting (DAT), 60 DAT, 90 DAT and at harvest stage of rice.

4.1.1. Plant height

The data on plant height recorded at different growth stages of rice as influenced by nutrition sources and varieties are presented in Table 4.1 and Fig. 2

At all stages, application of manures in any form increased plant height significantly over

control treatment. Among various sources, maximum plant height was recorded under green manuring treatment closely followed by recommended dose of fertilizers in combination with 5 tons FYM and 15 tons FYM treatments. Application of Press-mud produced minimum plant height among various nutrition sources. Recommended dose of fertilizers was also inferior to green manuring, FYM and RF + 5 tons FYM. Almost similar results were recorded at all stages. Data in Table 4.1 and Fig. 2 further reveal that variety Taraori Basmati was significantly taller than HKR 126 at all stages of growth.

Interaction effect of nutrition sources and varieties was significant on plant height at all stages of growth. HKR 126 did not show any definite pattern of height at early stages, however, at later stages of 90DAT and at harvest, RF + FYM produced significantly taller plants than organic sources alone that were at par with RF alone. Taraori Basmati had taller plants under green manuring at all stages.

Table 4.1: Effect of nutrition sources on plant height (cm) of rice varieties at different growth stages

Treatment	30 DAT			60 DAT			90 DAT			At harvest		
	HKR	Taraori	Mean	HKR	Taraori	Mean	HKR	Taraori	Mean	HKR	Taraori	Mean
	126	Basmati	(A)	126	Basmati	(A)	126	Basmati	(A)	126	Basmati	(A)
Nutrition sources (A)												
Control	57.2	55.1	56.2	97.2	97.4	97.3	109.8	142.9	126.4	108.3	140.0	124.2
GM	73.9	88.4	81.2	104.9	156.6	130.8	124.6	161.7	143.1	125.2	161.5	143.4
PM	70.4	76.7	73.6	96.3	138.9	117.6	112.4	154.8	133.6	112.3	155.5	133.9
FYM	66.9	75.9	71.4	110.6	123.4	117.0	119.4	161.9	140.7	111.4	161.3	136.3
RF+ 5 t FYM	71.2	76.2	73.7	107.6	140.0	123.8	131.0	161.3	146.1	129.4	160.5	144.9
RF	67.9	62.7	65.3	96.9	124.6	110.8	127.3	156.2	141.8	127.8	154.5	141.1
Mean (B)	67.9	72.5		102.2	130.2		120.7	156.4		119.0	155.5	
CD at 5% for nutrition sources A			4.54			7.90			3.81			3.26
CD at 5% for variety (B)			3.14			4.97			1.96			1.89
CD at 5% for A at same level of B			7.08			11.68			5.10			4.61
CD at 5% for B at same level of A			7.73			12.25			4.84			4.65

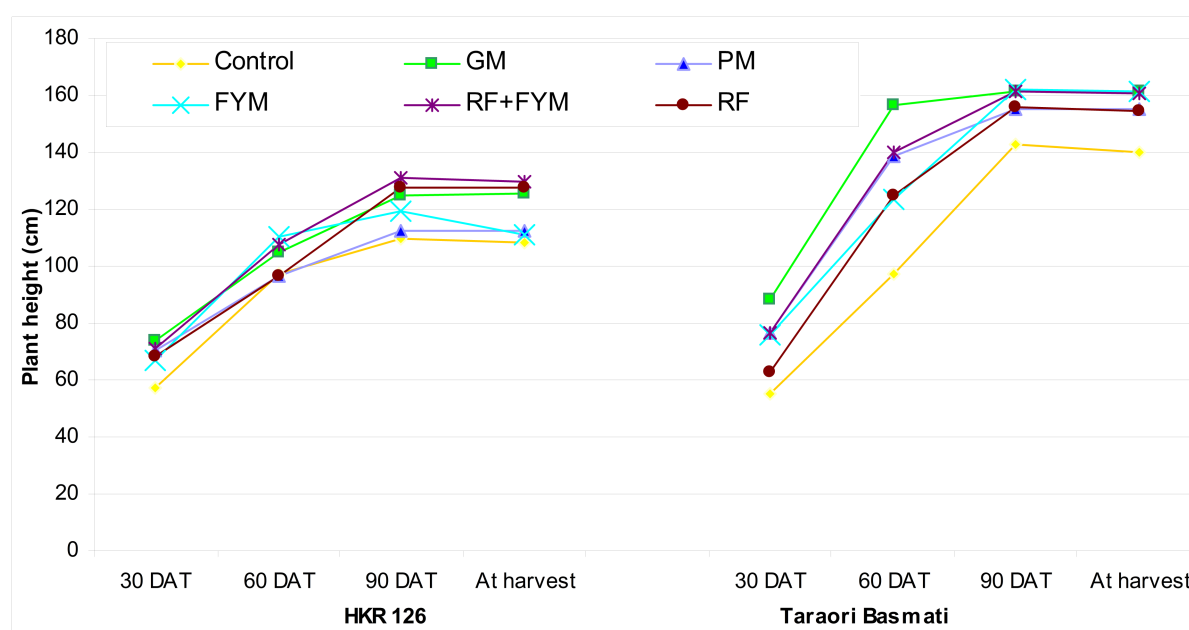


Fig. 2. Effect of nutrition sources on plant height (cm) of rice varieties at different growth stages

4.1.2. Number of tillers per square meter

The data on number of tillers per square meter recorded at different growth stages of rice as influenced by various treatments are presented in Table 4.2 and depicted in Fig. 3. The data in Table 4.2 and Fig. 3 indicated that the number of tillers was significantly affected by source of nutrition and varieties. In both varieties, number of tillers increased significantly by application of any source of nutrition over control. In general, application of recommended dose of fertilizers along with 5 tons FYM resulted into highest number of tillers per hill at all stages. Variety Taraori Basmati produced significantly higher number tillers as compared to HKR 126 at all the stages.

Interaction effects of nutrition sources and varieties were significant at 90 DAT and at harvest. At these stages, HKR 126 produced higher number of tillers under green manuring. However, Taraori Basmati recorded maximum number of tillers under combination of recommended dose of fertilizer and 5 tons FYM.

Table 4.2: Effect of nutrition sources on number tillers per hill of rice varieties at different growth stages

Treatment	30 DAT			60 DAT			90 DAT			At harvest		
	HKR	Taraori	Mean	HKR	Taraori	Mean	HKR	Taraori	Mean	HKR	Taraori	Mean
	126	Basmati	(A)	126	Basmati	(A)	126	Basmati	(A)	126	Basmati	(A)
Nutrition sources (A)												
Control	5.12	6.56	5.84	5.19	8.56	6.87	5.04	8.94	6.99	4.44	7.99	6.21
GM	7.69	10.31	9.00	7.69	12.25	9.97	6.98	12.06	9.52	6.63	10.06	8.34
PM	7.75	8.31	8.03	7.06	11.88	9.47	6.48	11.54	9.01	6.40	9.58	7.99
FYM	6.56	9.56	8.06	7.44	11.25	9.34	5.92	11.19	8.55	5.48	9.72	7.60
RF+ 5 t FYM	7.81	10.56	9.19	7.25	13.06	10.16	6.26	12.81	9.53	6.23	10.27	8.25
RF	7.25	8.88	8.06	6.88	10.31	8.59	6.11	10.12	8.12	6.00	10.09	8.05
Mean (B)	7.03	9.03		6.92	11.22		6.13	11.11		5.86	9.62	
CD at 5% for nutrition sources (A)			1.15				1.23				0.73	0.30
CD at 5% for variety (B)			0.83				0.82				0.36	0.17
CD at 5% for A at same level of B			N.S.				N.S.				0.96	0.43
CD at 5% for B at same level of A			N.S.				N.S.				0.89	0.43

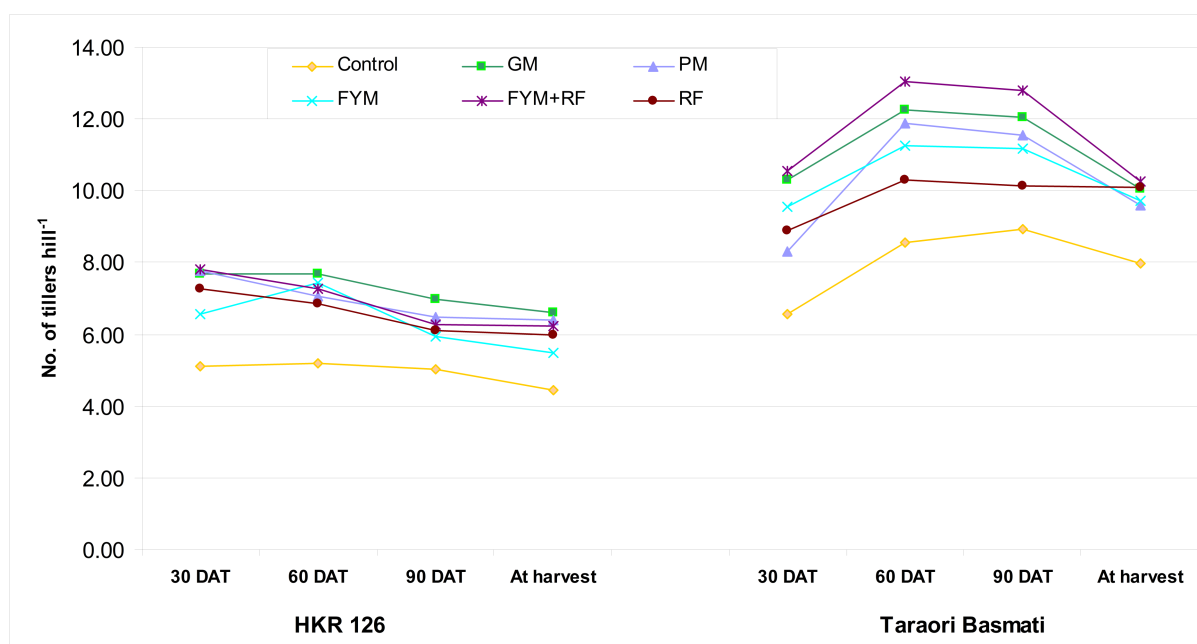


Fig. 3. Effect of nutrition sources on number of tillers hill⁻¹ of rice varieties at different growth stages.

4.1.3. Dry matter production

The data on dry matter production recorded at different growth stages are presented in Table 4.3 and Fig. 4.

Data in Table 4.3 and Fig. 4 reveal that the dry matter accumulation of rice crop increased with growth stage, highest being recorded at harvest. At all stages, all nutrition sources produced significantly higher dry matter over control. At early stages of 30 and 60 DAT, green manuring gave highest dry matter accumulation. However, at 90 DAT and at harvest, maximum accumulation of dry matter was recorded under recommended dose of fertilizers in combination with 5 tons FYM which was significantly higher than all other treatments but at par with GM and RF at harvest.

Variety HKR 126 produced significantly higher dry matter than Taraori Basmati at all stages of growth.

Interaction effects of nutrition sources and varieties were significant at 60, 90 DAT and at harvest. At all these stages, Taraori Basmati produced maximum and significantly higher dry matter under green manuring than other nutrition sources while HKR 126 produced higher dry matter under recommended dose of fertilizers in applied alone or in combination with 5 tons FYM as compared to green manuring, press-mud and FYM applied alone.

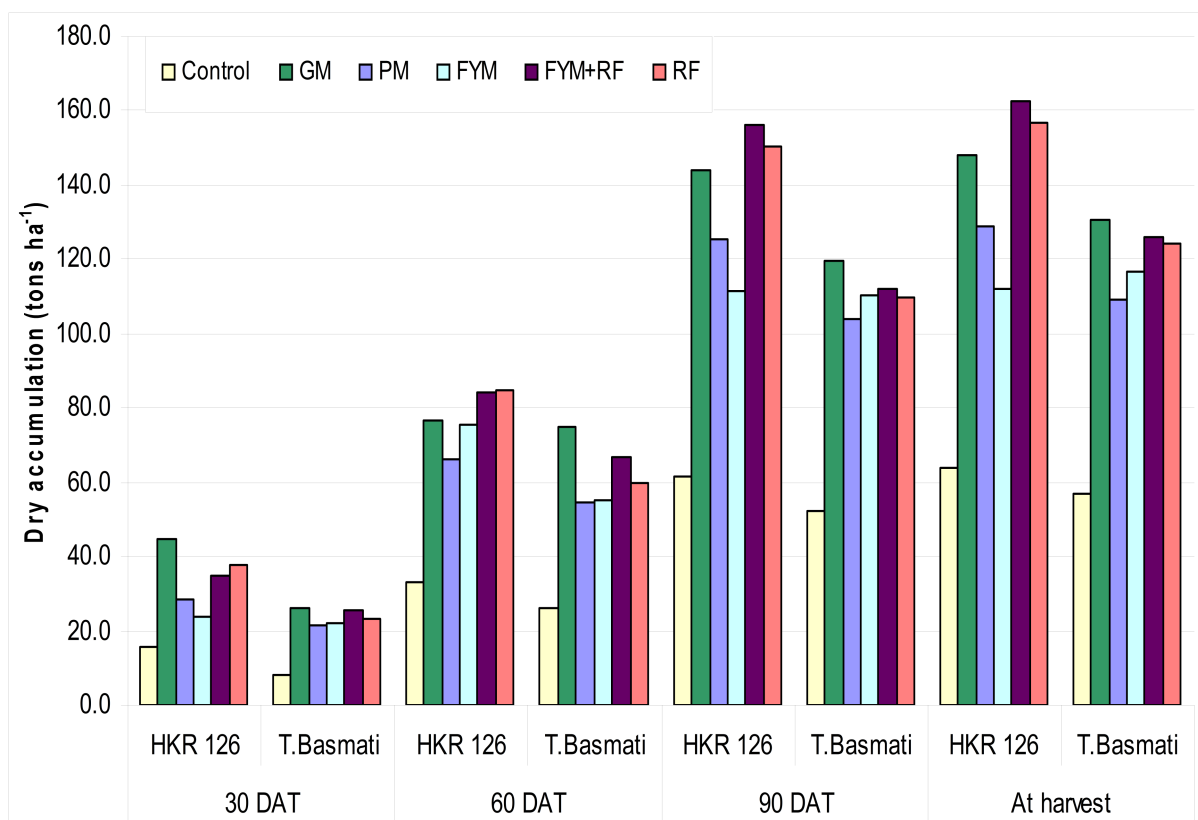


Fig. 4. Effect of nutrition sources on dry accumulation of rice varieties at different growth stages

Table 4.3: Effect of nutrition sources on dry matter accumulation of rice varieties at different growth stages (tons ha⁻¹)

Treatment	30 DAT			60 DAT			90 DAT			At harvest		
	HKR 126	Taraori Basmati i	Mean (A)	HKR 126	Taraori Basmati	Mean (A)	HKR 126	Taraori Basmati	Mean (A)	HKR 126	Taraori Basmati	Mean (A)
Nutrition sources (A)												
Control	15.6	7.9	11.7	32.9	26.4	29.7	61.7	52.4	58.6	64.1	56.7	60.4
GM	44.9	25.9	35.4	76.8	74.9	75.8	144.3	119.7	116.4	147.9	130.6	139.3
PM	28.7	21.4	25.1	66.2	54.4	60.3	125.2	103.7	107.7	128.7	109.0	118.9
FYM	24.1	22.0	23.0	75.4	55.0	65.2	111.4	110.2	103.8	112.2	116.6	114.4
RF+ 5 t FYM	34.7	25.8	30.3	84.3	66.6	75.4	156.2	112.0	123.9	162.5	126.0	144.3
RF	38.0	23.4	30.7	84.6	60.1	72.3	150.4	109.6	119.8	156.6	124.2	140.4
Mean (B)	31.01	21.05		70.03	56.24		114.75	95.35		128.68	110.54	
CD at 5% for nutrition sources (A)			4.47			2.45			4.40			6.65
CD at 5% for variety (B)			3.25			2.29			1.82			2.27
CD at 5% for A at same level of B			N.S.			5.60			4.51			5.62
CD at 5% for B at same level of A			N.S.			4.70			5.41			7.72

4.1.4. Leaf area index (LAI)

The data on leaf area index (LAI) were computed at 30, 60 and 90 DAT. Relevant data are presented in Table 4.4 and Fig. 5.

Table 4.4 and Fig. 5 reveal that all nutrition sources gave significantly more leaf area index (LAI) than control treatment. At 30 DAT green manuring produced significantly maximum LAI followed by FYM but at 60 and 90 DAT Press-mud, FYM and RF + FYM being at par with each other, better than other treatments in producing LAI.

At 30 and 90 DAT, HKR 126 gave significantly more LAI than Taraori Basmati but at 60 DAT Taraori Basmati produced higher LAI than HKR 126.

Interaction effects of nutrition sources and varieties were significant on LAI at 30 and 60 DAT. At 30 DAT HKR 126 produced significantly highest LAI under GM but all nutrition sources were at par in this respect. Taraori Basmati also produced highest LAI under GM which was at par with FYM and RF+ FYM only.

At 60 DAT, HKR 126 produced significantly higher LAI under RF + 5 tons FYM as compared to Press-mud and control treatment. Taraori Basmati produced at par LAI under Green manuring, Press-mud, FYM and RF + FYM.

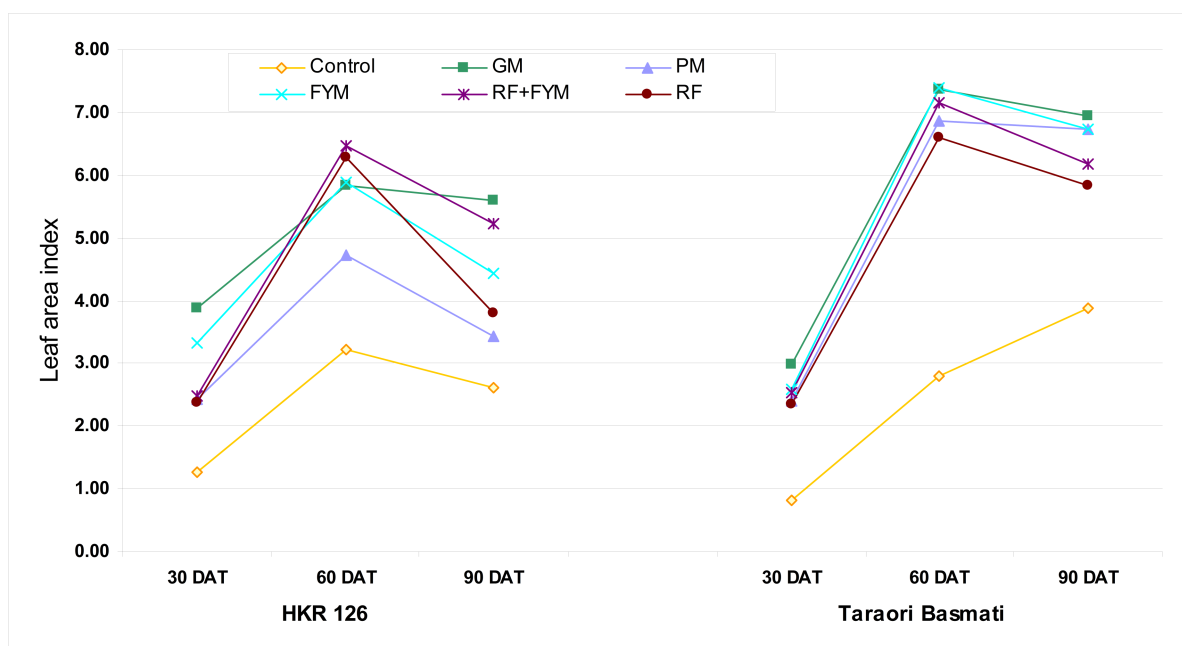


Fig. 5. Effect of nutrition sources on leaf area index of rice varieties at different growth stages.

Table 4.4: Effect of nutrition sources on leaf area index of rice varieties at different growth stages

Treatment	30 DAT			60 DAT			90 DAT			
	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmat i	Mean (A)	HKR 126	T. Basmati	Mean (A)	
Nutrition sources (A)										
Control	1.26	0.82	1.04	3.22	2.81	3.02	2.62	3.87	3.25	
GM	3.89	3.00	3.45	5.85	7.38	6.61	5.59	6.93	6.26	
PM	2.42	2.41	2.42	4.72	6.87	5.79	3.43	6.74	5.09	
FYM	3.34	2.60	2.97	5.88	7.40	6.64	4.44	6.73	5.58	
RF+ 5 t FYM	2.48	2.53	2.50	6.46	7.15	6.80	5.21	6.18	5.70	
RF	2.38	2.35	2.36	6.28	6.59	6.44	3.79	5.85	4.82	
Mean (B)	2.63	2.28		5.40	6.37		4.18	2.81		
CD at 5% for nutrition sources (A)			0.454				0.313			0.950
CD at 5% for variety (B)			0.164				0.268			0.479
CD at 5% for A at same level of B			0.535				0.560			N.S.
CD at 5% for B at same level of A			0.406				0.660			N.S.

4.1.5. Lodging observation

Taraori Basmati is a tall variety with plant height more than 140 cm (Table 4.1 and Fig. 2) so at flowering lodging appeared in this variety due to rain and wind under GM, RF and RF+FYM treatments and a about 35 % lodging percentage was estimated under GM at this stage. During grain filling and ripening, heavy lodging continued under RF + FYM. No lodging was recorded in HKR 126.

Table 4.5: Effect of nutrition sources on lodging percentage (%) of Taraori Basmati at different growth stages

Treatment	At flowering	Grain filling	Ripening
Control	0	0	0
GM	35	5	15
PM	0	0	15
FYM	15	4	25
RF+5 t FYM	20	10	30
RF	10	10	10

4.2. Yield components

4.2.1. Number of panicles per square meter

Number of panicles per square meter was recorded at harvest and the relevant data are presented in Table 4.6 and Fig. 6.

The data in Table 4.6 and Fig. 6 reveal that highest number of panicles per square meter was recorded under green manuring treatment. FYM alone produced significantly lesser number of panicles than other sources of nutrient. All nutrition sources were significantly better than control in producing panicles per square meter. Taraori Basmati produced significantly higher number panicles per square meter than HKR 126.

Interaction effect of nutrition sources and varieties were significant on number of panicles per square meter. Data in Table 4.6 and Fig. 6 indicate that HKR 126 produce higher number of panicles under green manuring while Taraori Basmati had maximum number of panicles under RF + 5 tons FYM. Treatment FYM alone had better effect on Taraori Basmati than HKR 126.

4.2.2. Number of filled grains per panicle

Number of filled grains per panicle as affected by various treatments has been presented in Table 4.6 and Fig. 6.

Number of grains was affected significantly due to the nutrition sources and varieties and their interaction. Among nutrients sources, RF alone or in combination with FYM produced significantly higher number of filled grains per panicles as compared to other sources. GM, Press-mud and FYM alone were also significantly superior to control in this respect. Variety HKR 126 produced almost double number of filled grains per panicles than Taraori Basmati.

Interaction effect of nutrition sources and varieties presented in Table 4.6 and Fig. 6 indicated that HKR 126 had better response to recommended dose of fertilizers alone or in combination with FYM than other sources in this respect. On the other hand, in Taraori Basmati FYM was significantly superior to GM and RF + 5 tons FYM.

Table 4.6: Effect of nutrition sources on yield components of rice varieties

Treatment	Panicles m ⁻²			No. filled grains per panicle			Panicle weight (g)			W ₁₀₀₀ grain		
	HKR	Taraori	Mean	HKR	Taraori	Mean	HKR	Taraori	Mean	HKR	Taraori	Mean
	126	Basmati	(A)	126	Basmati	(A)	126	Basmati	(A)	126	Basmati	(A)
Nutrition sources (A)												
Control	197.2	266.2	231.7	102.1	58.8	80.4	2.59	1.61	2.10	23.23	22.62	22.92
GM	294.5	335.4	315.0	131.7	64.7	98.2	3.66	1.84	2.75	25.51	24.65	25.08
PM	284.3	319.3	301.7	132.9	68.4	100.6	3.42	1.85	2.63	24.12	24.35	24.23
FYM	243.5	324.0	283.7	128.5	72.8	100.6	3.51	1.96	2.74	25.30	24.04	24.67
RF+5 t FYM	276.9	342.2	309.5	156.9	62.4	109.6	4.30	1.74	3.02	26.11	23.56	24.83
RF	266.7	336.5	301.6	152.7	67.1	109.9	4.23	1.94	3.08	25.70	24.15	24.93
Mean (B)	260.5	320.7		134.1	65.7		3.32	1.82		24.99	23.89	
CD at 5% for nutrition sources (A)			11.72				3.43				0.087	0.246
CD at 5% for variety (B)			6.79				2.83				0.048	0.133
CD at 5% for A at same level of B			16.60				5.98				0.120	0.377
CD at 5% for B at same level of A			16.75				6.96				0.119	0.327

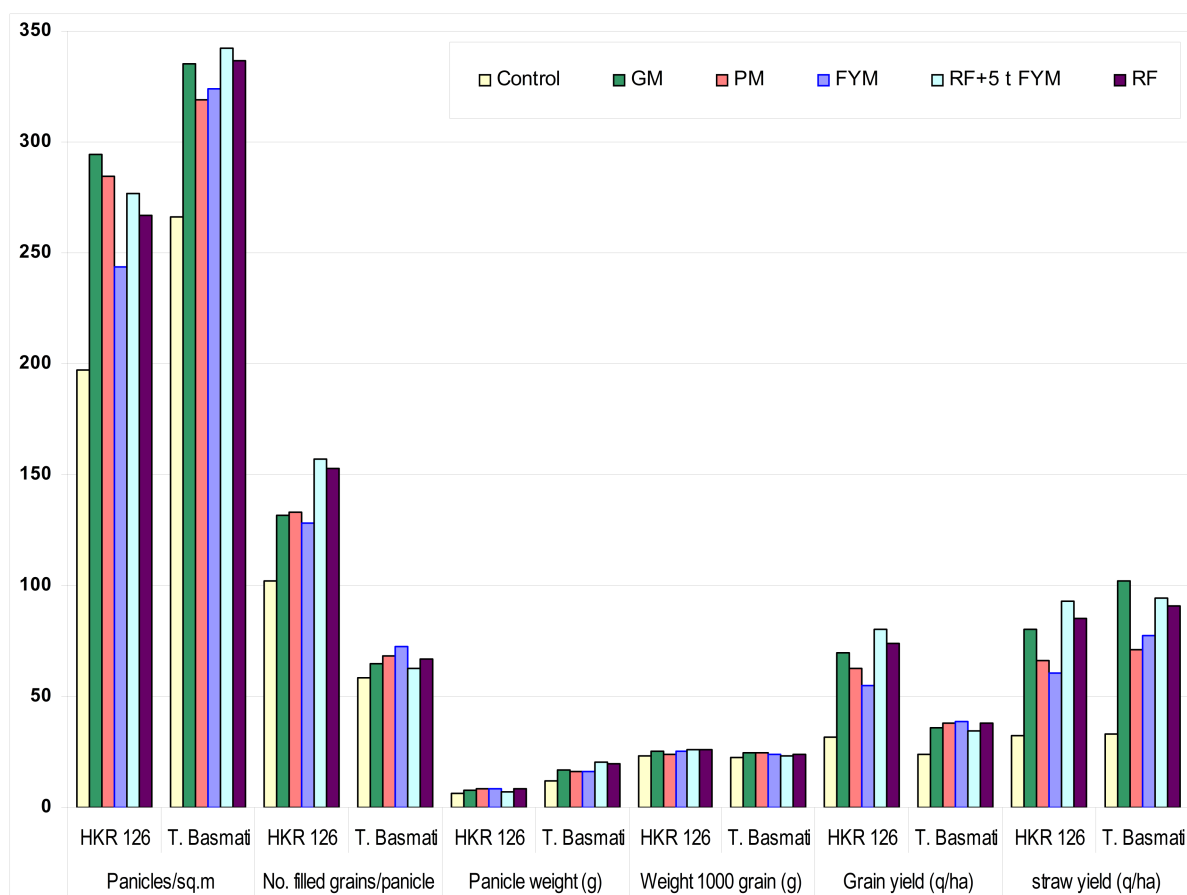


Fig. 6. Effect of nutrition sources on yield components and yield of rice varieties.

4.2.3. Weight of panicle

Weight of panicles was recorded at harvesting and the relevant data are presented in Table 4.6 and Fig. 6.

Data from Table 4.6 and Fig. 6 reveal that all the nutrition sources significantly increased weight of panicles over control. Maximum panicle weight was recorded under RF which was at par with RF + 5 tons FYM. Being high yielding variety, HKR 126 had significantly higher panicle weight as compared to Taraori Basmati.

Interaction effect of nutrition sources and varieties on panicle weight was significant.

Data in Table 4.6 and Fig. 6 also indicated that variety HKR 126 produced highest panicle weight under recommended dose of fertilizers in combination with 5 tons FYM, closely followed by RF which was significantly higher than other sources. However, variety Taraori Basmati had maximum panicle weight under application of 15 tons FYM. GM, Press-mud and RF were also superior to RF + FYM in this variety.

4.2.4. Weight of 1000-grains

The effect of nutrition sources on 1000-grain weight was recorded at harvest and data are presented in Table 4.6 and Fig. 6.

Perusal of data given in Table 4.6 and Fig. 6 reveal that nutrition sources produced significantly higher 1000-grain weight over control. Incorporation of green manuring produced maximum 1000-grain weight and was significantly at par with RF. Variety HKR 126 produced grain weight significantly higher over Taraori Basmati.

Interaction effect of nutrition sources and varieties on 1000-grain weight indicated that the variety HKR 126 produced maximum grain weight under application of recommended dose of fertilizers in combination with 5 tons FYM while Taraori Basmati produced highest grain weight under incorporation of green manuring which was statistical at par with Press-mud treatment in this respect.

4.3. Yield

4.3.1. Grain yield

The grain yield of rice as influenced by various treatments was recorded, computed, and presented in Table 4.7 and Fig. 6.

Table 4.7: Effect of nutrition sources on yield (q ha⁻¹) and harvest index

Treatment	Grain yield			Straw yield			Harvest Index			
	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)	
Nutrition source (A)										
Control	31.63	24.00	27.81	32.50	32.80	32.62	49.36	42.32	45.84	
GM	69.63	36.25	52.94	80.50	102.30	91.37	46.38	26.17	36.28	
PM	62.50	38.00	50.25	66.25	71.00	68.62	48.56	34.86	41.71	
FYM	54.75	38.88	46.81	60.25	77.80	69.00	48.33	33.35	40.84	
RF+5 t FYM	80.50	34.75	57.62	93.25	94.50	93.87	46.77	26.88	36.83	
RF	74.25	38.13	56.19	85.25	90.80	88.00	46.56	29.58	38.07	
Mean (B)	62.21	35.00		69.67	78.17		47.66	32.20		
CD at 5% for nutrition sources (A)			3.12				5.61			0.65

CD at 5% for variety (B)	1.25	2.22	0.30
CD at 5% for A at same level of B	3.80	6.80	0.84
CD at 5% for B at same level of A	3.09	5.49	0.75

Table 4.6 and Fig. 6 reveal that all nutrition sources produced significantly more grain yield over control. Maximum grain yield was recorded under RF + 5 tons FYM which was at par with RF applied alone. RF yielded significantly higher than green manuring, Press-mud and FYM. Among all sources, FYM alone yielded least grain yield of paddy. Variety HKR 126 produced significantly higher grain yield than Taraori Basmati.

Interaction effect of nutrition sources and varieties was significant on grain yield. Variety HKR 126 produced maximum grain yield of 80.5 q ha⁻¹ under recommended dose of fertilizers in combination with 5 tons FYM that was significantly better than control and other sources. In Taraori Basmati, FYM, Press-mud, RF and GM produced higher than control and RF + 5 tons FYM gave least yield among nutrition sources due to lodging of crop in latter treatment.

4.3.2. Straw yield

The effect of various treatments on straw yield of rice was recorded and presented in Table 4.7 and Fig. 6.

Data in Table 4.7 and Fig. 6 reveal that application of recommended dose of fertilizers + 5 tons FYM produced highest straw yield which was similar to green manuring treatment and was prominently higher than control and other treatments. Recommended dose of fertilizers also gave higher straw yield than Press-mud and FYM. Straw yield of Taraori Basmati was significantly higher than HKR 126.

Interaction effect of nutrition sources and varieties was significant on straw yield also. Variety HKR 126 produced maximum straw yield under recommended dose of fertilizers in combination with 5 tons FYM followed by RF and GM. Straw yield decreased drastically under Press-mud and FYM. On the other hand, Taraori Basmati variety produced significantly highest straw yield under incorporation of green manuring. It was followed by RF + 5 tons FYM and RF. There was drastic reduction in straw yield under Press-mud and FYM.

4.3.3. Harvest Index

The data in Table 4.7 reveal that highest harvest index was recorded under control treatment. Amongst the sources of nutrients, application of Press-mud gave higher HI than other sources. It was followed by FYM, RF and RF + 5 tons FYM. Variety HKR 126 gave more harvest index than Taraori Basmati.

The interaction effect shows that decrease in HI due to various nutrition sources was wider in Taraori Basmati as compared to HKR 126. Harvest index of Taraori Basmati decreased

with increasing rate of nutrition from Press-mud, FYM, RF, RF + 5 tons FYM and green manuring. A decrease in harvest index with increase in level of N was due to higher increase in straw yield than an increase in grain yield with the increasing level of fertilizer application. In HKR 126, application of nutrition sources had no significant effect on harvest index. High yield dwarf variety HKR 126 produced higher grain yield and lesser straw than Taraori Basmati, thereby, registering higher HI than tall scented variety Taraori Basmati.

4.3.4. NPK concentration

4.3.4.6.1.1. N concentration

N concentration in grain:

The data on N concentration in grain and straw of rice as affected by various treatments are presented in Table 4.8. It is clear from the Table 4.8 that various sources of nutrient did not influence nitrogen concentration significantly. However, maximum nitrogen concentration was recorded under RF + 5 tons FYM and minimum under control. Variety Taraori Basmati recorded significantly higher N concentration in grain than HKR 126.

Table 4.8: Effect of nutrition sources on nitrogen concentration (%) of rice varieties

Treatment	Grain			Straw		
	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)
Nutrition source (A)						
Control	0.81	0.96	0.89	0.33	0.35	0.34
GM	1.01	1.06	1.04	0.58	0.40	0.49
PM	0.97	1.08	1.02	0.36	0.45	0.41
FYM	0.85	1.01	0.93	0.34	0.45	0.40
RF+ 5 t FYM	1.05	1.11	1.08	0.40	0.46	0.44
RF	1.01	1.08	1.05	0.36	0.36	0.37
Mean (B)	0.95	1.05		0.40	0.42	
CD at 5% for nutrition sources (A)			N.S.	0.05		
CD at 5% for variety (B)			0.09	N.S.		
CD at 5% for A at same level of B			N.S.	0.06		
CD at 5% for B at same level of A			N.S.	0.05		

Interaction effect of nutrition sources and varieties was not significant for nitrogen concentration in grain.

N concentration in straw:

Data in Table 4.8 further reveal that nitrogen concentration in straw was significantly higher in all nutrition sources except RF over control. Green manuring gave significantly highest N concentration in straw. There was no significant difference in N concentration in straw of both varieties.

Interaction effect in Table 4.8 reveal that nitrogen concentration in straw Taraori Basmati was highest in RF + 5 tons FYM closely followed by FYM and Press-mud but in HKR 126, green manuring gave significantly highest nitrogen concentration.

4.3.4.6.1.2. P concentration

The data on P concentration in grain and straw of rice as affected by various treatments are presented in Table 4.9.

Table 4.9: Effect of nutrition sources on phosphorus concentration (%) of rice varieties

Treatment	Grain			Straw		
	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)
Nutrition sources (A)						
Control	0.250	0.298	0.274	0.069	0.085	0.077
GM	0.279	0.352	0.316	0.104	0.121	0.113
PM	0.269	0.340	0.304	0.073	0.097	0.085
FYM	0.327	0.329	0.328	0.069	0.083	0.076
RF+ 5 t FYM	0.334	0.329	0.332	0.090	0.075	0.083
RF	0.271	0.329	0.300	0.088	0.090	0.089
Mean (B)	0.288	0.329		0.082	0.092	
CD at 5% for nutrition sources (A)			N.S.	0.022		
CD at 5% for variety (B)			0.018	N.S.		
CD at 5% for A at same level of B			N.S.	N.S.		
CD at 5% for B at same level of A			N.S.	N.S.		

P concentration in grain:

Table 4.9 reveals that various sources of nutrient did not influence phosphorus concentration in grain significantly. However, highest P concentration in grain was recorded under RF + 5 tons FYM, FYM treatments and lowest P concentration was observed under control. Concentration of P in grains of Basmati was significantly more than in grain of Taraori HKR 126.

Treatment	Grain			Straw		
	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)
Nutrition sources (A)						

Control	0.111	0.138	0.125	1.430	1.315	1.373
GM	0.115	0.160	0.138	1.677	1.523	1.603
PM	0.122	0.153	0.137	1.640	1.363	1.505
FYM	0.140	0.138	0.140	1.488	1.535	1.513
RF+ 5 t FYM	0.143	0.145	0.144	1.628	1.460	1.545
RF	0.136	0.158	0.147	1.640	1.442	1.543
Mean (B)	0.128	0.149		1.586	1.442	
CD at 5% for nutrition sources (A)			0.010			N.S.
CD at 5% for variety (B)			0.009			0.095
CD at 5% for A at same level of B			N.S.			N.S.
CD at 5% for B at same level of A			N.S.			N.S.

Interaction effect of nutrition sources and varieties on K concentration in rice straw was not significant.

4.3.5. Nutrient uptake

4.3.5.1. Nitrogen uptake

The data on nitrogen uptake by rice as influenced by various treatments are presented in Table 4.11.

N uptake by grain:

Data from Table 4.11 reveal that various sources of nutrient increased uptake of N over control significantly. Maximum N uptake by rice grain was recorded under RF+ 5 tons FYM, which was at par with RF and both these were significantly higher than other sources. Among various sources, FYM had lowest N uptake by grain. Variety HKR 126 had significantly higher uptake of nitrogen than Taraori Basmati.

Interaction effect of nutrition sources and varieties from Table 4.11 indicates that uptake of N in grain of variety HKR 126 was significantly highest under RF + 5 tons FYM followed by RF and lowest in FYM. Variety Taraori Basmati recorded highest N uptake under RF but was statistically at par with all other sources.

N uptake by straw:

The data on nitrogen uptake in rice straw from Table 4.11 indicate that all nutrition sources were significantly better than control and green manuring was significantly superior among sources in this respect for both varieties. RF + 5 tons FYM was also recorded significantly

higher than other sources. However, in Taraori Basmati, it was at par with RF + 5 tons FYM.

Table 4.11: Effect of nutrition sources on nitrogen uptake (kg ha^{-1}) of rice varieties

Treatment	Grain			Straw			Total			
	HKR 126	T. Basm ati	Mean (A)	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basma ti	Mean (A)	
Nutrition sources (A)										
Control	25.7	23.0	24.4	10.7	11.3	11.0	36.4	34.3	35.4	
GM	70.4	38.5	54.4	46.6	41.3	44.0	117.0	79.8	98.4	
PM	60.5	41.2	50.9	23.7	32.2	28.0	84.3	73.4	78.9	
FYM	46.8	39.3	43.0	20.6	35.3	28.0	67.4	74.6	71.0	
RF+ 5 t FYM	84.7	38.7	61.7	37.7	44.1	40.9	122.4	82.8	102.6	
RF	75.0	41.3	58.2	30.5	33.3	31.9	105.6	74.6	90.1	
Mean (B)	60.5	36.1		28.3	32.9		88.8	69.9		
CD at 5% for nutrition sources (A)			3.1				2.3			5.3
CD at 5% for varieties (B)			1.2				0.9			2.1
CD at 5% for A at same level of B			3.7				2.8			6.5
CD at 5% for B at same level of A			3.0				2.3			5.3

Interaction effect of nutrition sources and varieties from Table 4.11 indicates that uptake of N in straw of variety HKR 126 was significantly highest under GM and superior to all other treatments. Variety Taraori Basmati recorded maximum N uptake under RF + 5 tons FYM, followed by GM.

Total N uptake:

The data on total uptake in Table 4.11 further reveal that total N uptake was maximum under RF + 5 tons FYM, followed by green manuring and RF. Among sources, total N uptake was lowest in FYM followed by PM. HKR 126 had higher total N uptake than Taraori Basmati.

Interaction effect of nutrition sources and varieties was significant on total N uptake. For both varieties, application of recommended dose of fertilizers in combination with 5 tons FYM followed by green manuring recorded higher total uptake of N but the differences were more marked in HKR126 than Taraori Basmati.

4.3.5.2. Phosphorus uptake

The data on phosphorus uptake by rice as influenced by nutrition sources are presented in Table 4.12.

P uptake by grain:

The data from Table 4.12 reveal that significantly highest P uptake in rice grain was recorded under incorporation of green manuring. RF alone or in combination with FYM also

recorded significantly higher P uptake in grain than Press-mud and FYM. All sources were significantly superior to control in this respect. Variety HKR 126 recorded higher uptake of P than Taraori Basmati.

Interaction effect of nutrition sources and varieties was significant in P uptake in rice grain. Superior P uptake was recorded under GM for both varieties. However, P uptake in Taraori Basmati grain was significantly higher under RF + 5 tons FYM than HKR 126.

P uptake by straw:

In straw maximum P uptake was recorded under RF+ 5 tons FYM which was significantly higher than other sources. Green manuring and recommended dose of fertilizers being at par with each other were superior to Press-mud and FYM. All sources were found better than control. Variety HKR 126 recorded significantly higher P uptake in straw than Taraori Basmati.

The interaction effect shows that HKR 126 had maximum P uptake in straw under RF + FYM and differences among various sources were well marked. But in Taraori Basmati highest uptake of P in straw was observed in Press-mud and differences among various sources could not be adjudged well marked.

Table 4.12: Effect of nutrition sources on phosphorus uptake (kg ha⁻¹) of rice varieties

Treatment	Grain			Straw			Total		
	HKR 126	T. Basma ti	Mean (A)	HKR 126	T. Basmat i	Mean (A)	HKR 126	T. Basmat i	Mean (A)
Nutrition sources (A)									
Control	2.75	2.25	2.50	7.91	7.15	7.53	9.84	9.84	10.03
GM	9.73	10.65	10.19	19.44	12.76	16.10	30.58	22.99	26.29
PM	6.43	5.18	5.80	16.80	12.90	14.85	21.83	18.97	20.66
FYM	5.02	5.35	5.18	17.91	12.80	15.35	23.18	18.74	20.53
RF+ 5 t FYM	6.99	8.47	7.73	26.92	11.44	19.18	35.37	19.00	26.91
RF	7.64	7.98	7.80	20.11	12.55	16.33	28.50	20.14	24.14
Mean (B)	6.64	6.43		18.18	11.60		24.82	18.03	
CD at 5% for nutrition sources (A)			0.52				0.92		
CD at 5% for varieties (B)			0.18				0.39		
CD at 5% for A at same level of B			0.61				1.14		
CD at 5% for B at same level of A			0.45				0.97		

Total P uptake:

The data in Table 4.12 further indicate that highest total P uptake was recorded under recommended dose of fertilizers, closely followed by green manuring which were significantly

higher than control and other sources. RF was also significantly better than Press-mud and FYM. Total P uptake in HKR 126 was significantly higher than Taraori Basmati.

The data on interaction effect of nutrition sources and variety from Table 4.12 also indicate that total P uptake in HKR 126 was recorded maximum under recommended dose of fertilizers in combination with 5 tons FYM and difference among various sources were well marked. Variety Taraori Basmati recorded significantly highest total P uptake under green manuring. But all other sources were at par in this variety.

4.3.5.3. Potassium uptake

The data on potassium uptake by rice as influenced by nutrition sources and varieties are presented in Table 4.13.

K uptake by grain:

The data from Table 4.13 reveal that significantly highest K uptake in rice grain was recorded under RF. All other sources were also significantly superior to control but was at par with one another in this respect. Variety HKR 126 recorded higher uptake of K than Taraori Basmati.

Interaction effect of nutrition sources and varieties was significant in K uptake in rice grain. In HKR 126 significantly highest K uptake was recorded under recommended dose of fertilizers in combination with 5 tons FYM, while recommended dose of fertilizers applied alone gave highest K uptake in Taraori Basmati. The differences among various sources were well marked in HKR 126 than in Taraori Basmati.

Table 4.13: Effect of nutrition sources on potassium uptake (kg ha^{-1}) of rice varieties

Treatment	Grain			Straw			Total		
	HKR 126	T. Bas mati	Mean (A)	HKR 126	T. Basmat i	Mean (A)	HKR 126	T. Basma ti	Mean (A)
Nutrition sources (A)									
Control	3.51	3.32	3.41	46.48	43.07	44.77	49.98	46.39	48.18
GM	8.01	5.80	6.90	134.97	155.76	145.36	142.98	161.56	152.27
PM	7.60	5.80	6.70	108.65	96.80	102.72	116.25	102.59	109.42
FYM	7.67	5.38	6.52	89.67	119.35	104.51	97.34	124.72	111.03
RF+ 5 t FYM	11.47	5.04	6.52	151.84	137.97	144.91	163.31	143.01	153.16
RF	10.09	6.00	8.04	139.81	130.83	135.32	149.90	136.84	143.37
Mean (B)	8.06	5.22		111.90	113.96		119.96	119.18	
CD at 5% for nutrition sources (A)			0.42				8.51		
CD at 5% for varieties (B)			0.17				N.S.		

CD at 5% for A at same level of B	0.51	10.32	10.81
CD at 5% for B at same level of A	0.42	8.33	8.75

K uptake by straw:

In straw K uptake was recorded significantly more under green manuring and RF + 5 tons FYM than other sources. RF also recorded more K uptake over Press-mud and FYM. Press-mud and FYM being at par with each other were superior to control. There was no significant difference between two varieties in this respect.

The interaction effect shows that HKR 126 had maximum K uptake in straw under RF + 5 tons FYM but in Taraori Basmati highest uptake of K in straw was observed under green manuring.

Total K uptake:

The data in Table 4.13 further indicate that total K uptake was significantly higher in recommended dose of fertilizers + 5 tons FYM and green manuring than under control and other sources. RF was also significantly better than Press-mud and FYM. Both varieties did not differ significantly for total K uptake.

The data on interaction effect of nutrition sources and variety from Table 4.13 also indicate that total K uptake in HKR 126 was recorded maximum under recommended dose of fertilizers in combination with 5 tons FYM. Variety Taraori Basmati recorded significantly highest total K uptake under GM.

4.4. Economics

The data on gross, net income and benefit cost ratio of rice as affected by nutrition sources and varieties are presented in Table 4.14 and Fig. 7. The details of economics are given in Appendix II to V.

The data from Table 4.14 and Fig. 7 reveal that variety HKR 126 gave highest gross and net income under RF + 5 tons FYM, followed by RF treatment. The net income of this variety decreased drastically under FYM treatment. The control treatment gave negative net return in HKR 126. On the contrary, Taraori Basmati gave highest gross and net income under FYM followed by RF and Press-mud. Control treatment gave positive income in this variety. Benefit cost ratio followed similar pattern in both varieties under all sources of nutrients.

Table 4.14: Effect of nutrition sources on gross income, net return (Rs. ha⁻¹) and benefit cost ratio of rice varieties

Treatment	Gross income		Net income		Benefit cost ratio	
	HKR 126	T. Basmati	HKR 126	T. Basmati	HKR 126	T. Basmati
Control	19350	29448	-2925	5502	0.87	1.23

GM	41775	44479	16644	16608	1.66	1.60
PM	37500	46626	12626	19013	1.51	1.69
FYM	32850	47700	8085	21586	1.33	1.83
RF+5 t FYM	48300	42638	20925	15606	1.76	1.58
RF	44550	46779	17985	20558	1.68	1.78

Note: Rice grain price Rs. 1227 q⁻¹ for Taraori Basmati and Rs. 600 q⁻¹ for HKR 126

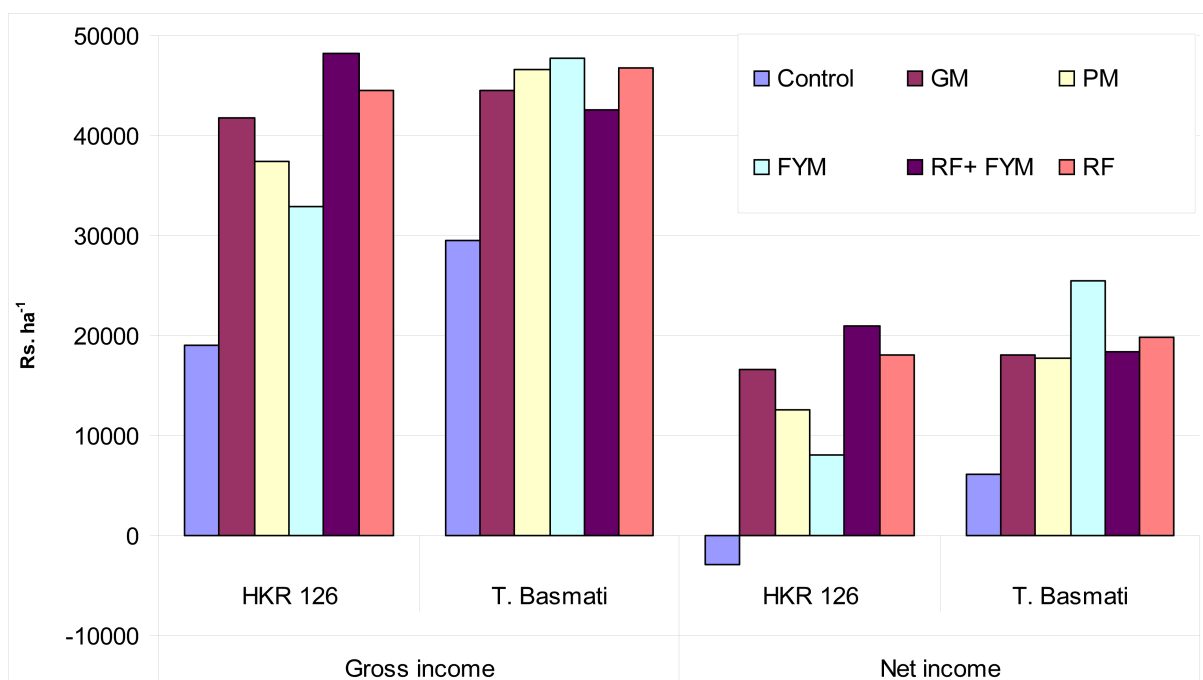


Fig. 7. Effect of nutrition sources on growth income, net return and benefit cost ratio of rice varieties.

4.5. Soil fertility status

The effects of organic and inorganic sources of nutrition on soil fertility were studied on organic C, alkaline permanganate oxidizable organic N (available N), 0.5 M NaHCO₃ extractable P and 1N ammonium acetate extractable K. The data were computed and presented in Table 4.15.

4.5.1. Organic carbon content

The data from Table 4.15 reveal that organic carbon content in soil was slightly increased after rice harvest as compared to initial value (1999). Incorporation of green manuring gave highest organic carbon content of the soil and it is significantly higher than control but was at par with RF + 5 tons FYM and an application of 15 tons FYM. Application of Press-mud and recommended dose of fertilizers also increased carbon content in soil but the differences were not well marked.

4.5.6.2. Available nitrogen

The data on available N of the soil after rice harvest show that in the treatment without any addition of fertilizer (control), there was a slight decrease in available N content as compared to initial value, whereas application of any sources increased the available N in soil over the initial level (Table 4.15).

Application RF + 5 tons FYM recorded maximum N content in soils, which was significantly higher than all other sources but at par with GM. Application of Press-mud, FYM and recommended dose of fertilizers had similar effect in available N in soil.

Table 4.15: Effect of nutrition sources on soil status of rice varieties after harvest of crop

Treatment	Organic C (%)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)
Control	0.41	139.8	17.97	297.2
GM	0.53	164.6	21.18	317.6
PM (7.5 tons)	0.45	159.4	19.49	305.5
FYM (15 tons)	0.50	155.5	19.66	321.4
RF + 5 tons FYM	0.51	168.6	20.36	333.5
RF	0.42	152.9	19.41	310.1
CD	0.08	10.95	1.16	22.49
Initial (1999)	0.41	141.0	21.0	301.0

4.5.6.3. Available phosphorus

The data on available phosphorus content (kg ha⁻¹) in soil after rice harvest as influenced by various sources are presented in Table 4.15.

The available P content in soil after harvest slightly decreased in the control as compared to initial value. Application of green manuring gave highest P content, closely followed by RF + 5 tons FYM. Press-mud, FYM and RF were at par in available soil P.

4.5.4. Available potassium

The data on available potassium content (kg ha^{-1}) in soil after rice harvest as influenced by sources of nutrition are presented in Table 4.15.

The available K status of the soil in the fertilized plots after rice harvest was found to be increasing compared to initial value, but slightly decreased in control treatment. The highest value of available K was recorded with recommended dose of fertilizers combined with 5 tons FYM that was significantly more than RF and Press-mud. GM, Press-mud, FYM and recommended dose of fertilizers did not differ significantly in this respect.

4.6. Grain quality characteristics

Data on quality parameters of rice, viz; hulling, milling, head rice recovery (HRR), L/B ratio before cooking and density were recorded and presented in Table 4.16 and Fig. 8.

4.6.1. Hulling percentage

The data from Table 4.16 and Fig. 8 reveal that there was no significant difference in hulling percentage of rice under various sources. Highest value of hulling percentage was recorded under RF + 5 tons FYM. Variety HKR 126 was significantly better in hulling percentage compared to Taraori Basmati.

Interaction effect of nutrition sources and varieties was significant on hulling percentage. Data from Table 4.16 and Fig 8 further reveal that RF + 5 tons FYM in HKR 126 gave maximum hulling percentage and was significantly higher than all other sources and control. Variety Taraori Basmati recorded highest value of hulling percentage under Press-mud which was statistically at par with FYM.

4.6.1.6.4. Milling percentage

The difference in milling percentage of rice among various nutrient sources was not significant. Highest value in milling percentage was recorded under green manuring. Variety HKR 126 had significantly higher milling percentage than Taraori Basmati.

The data from Table 4.16 indicate that differences due to interaction effect of various sources with varieties were not significant.

4.6.1.6.5. Head rice recovery (%)

Data from Table 4.16 and Fig. 8 show that effects of various nutrition sources was significant on HRR and the highest HRR was recorded under RF + 5 tons FYM. It was significantly higher than control and RF but similar to green manuring, Press-mud and FYM. Difference in HRR between two varieties was not significant. Data from Table 4.16 further reveal that interaction between various sources and varieties was not significant.

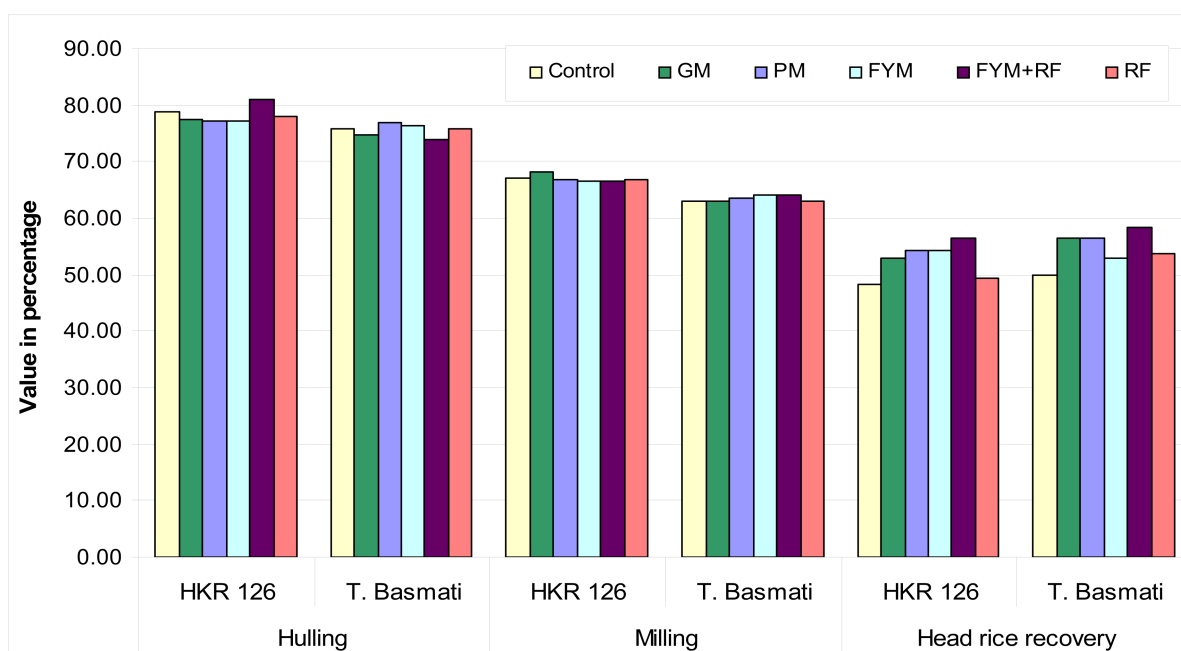


Fig. 8. Effect of nutrition sources on hulling, milling and HRR of rice varieties

4.6.1.6.6. Kernel length/kernel breadth ratio (L/B ratio)

Effect of various sources on L/B ratio were recorded and presented in Table 4.16 and Fig. 8. Application of RF + FYM gave highest value of L/B ratio but was statistically at par with press-mud, RF and GM. Similar effect was observed between GM and FYM. GM and FYM alone were also at par with control. Variety Taraori Basmati recorded significantly higher L/B ratio of rice grain than HKR 126. The interaction effect of nutrition sources and varieties on L/B ratio was not observed to be significant.

4.6.1.6.7. Density

The data from Table 4.16 show that application of nutrition sources had no significant effect on density of rice. Highest density of rice was recorded under RF + 5 tons FYM. Variety Taraori Basmati produced significantly higher rice density than HKR 126. Interaction effect of nutrition sources and varieties on density of rice was not significant.

Table 4.16: Effect of nutrition sources on grain quality characteristics of rice varieties

Treatment	Hulling (%)			Milling (%)			HRR (%)			L/B ratio			Density (g cm ⁻³)		
	HKR 126	T. Basma ti	Mean (A)	HKR 126	T. Basma ti	Mean (A)	HKR 126	T. Basma ti	Mean (A)	HKR 126	T. Basma ti	Mean (A)	HKR 126	T. Basma ti	Mean (A)
Nutrition sources (A)															
Control	78.81	75.85	77.33	67.16	62.97	65.06	48.40	49.80	49.10	2.77	3.56	3.16	0.84	0.89	0.86
GM	77.43	74.82	76.12	68.17	63.03	65.60	53.03	56.43	54.73	2.71	3.77	3.24	0.81	0.92	0.86
PM	77.31	77.01	77.16	66.91	63.42	65.16	54.31	56.52	55.42	2.94	3.78	3.36	0.81	0.87	0.84
FYM	77.17	76.47	76.82	66.59	64.21	65.40	54.28	52.86	53.67	2.71	3.71	3.21	0.88	0.85	0.87
RF+ 5 t FYM	81.00	74.04	77.52	66.55	64.05	65.30	56.45	58.39	57.42	2.83	3.94	3.38	0.86	0.89	0.88
RF	77.93	75.89	76.91	66.73	63.08	64.90	49.38	53.65	51.52	2.91	3.73	3.32	0.86	0.87	0.86
Mean (B)	78.27	75.68		67.02	63.46		52.64	54.61		2.81	3.75		0.84	0.88	
CD at 5% for nutrition sources (A)			N.S.				N.S.			4.62			0.15		
CD at 5% for varieties (B)			0.76				1.91			N.S.			0.10		
CD at 5% for A at same level of B			1.90				N.S.			N.S.			N.S.		
CD at 5% for B at same level of A			1.88				N.S.			N.S.			N.S.		

4.6.1.6.8. Optimum cooking time

The data on optimum cooking time of rice as influenced by various treatments are presented in Table 4.17.

The data from Table 4.17 show that application of 15 tons FYM has lower optimum cooking time compared to control. All other sources had significantly higher cooking time than control. Taraori Basmati had significantly lower optimum cooking time as compared to HKR 126.

Interaction effect of nutrition sources and varieties on cooking time was significant. Application of 15 tons FYM in Taraori basmati significantly reduced cooking time compared to control and remaining treatments. But in HKR 126 all sources had more cooking time than control.

4.6.1.6.9. Swelling index

Swelling index of Taraori Basmati and HKR 126 as influencing by nutrition sources is included in Table 4.17.

The data from table 4.17 reveal that no significant difference were caused by nutrition sources to swelling index. Highest swelling index was observed under green manuring, closely followed by control, RF + 5 tons FYM and Press-mud. Lowest swelling index was recorded under FYM and RF, respectively. The differences between Taraori Basmati and HKR 126 on swelling index was not significant.

The data from Table 4.17 further indicated that interaction effect of nutrition sources and varieties was not significant.

Table 4.17: Effect of nutrition sources on cooking quality of rice varieties

Treatment	Optimum cooking time (mins)			Swelling index			Water uptake ratio			Cooking coefficient			Volatile substance residue		
	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)	HKR 126	T. Basmati	Mean (A)
Nutrition sources (A)															
Control	13.12	12.56	12.84	2.06	2.02	2.04	2.59	2.42	2.50	3.35	5.07	4.21	27.59	61.70	44.64
GM	15.32	14.25	14.78	2.05	2.07	2.06	2.59	2.46	2.53	3.91	4.54	4.22	32.75	63.20	47.95
PM	14.64	12.58	13.61	2.03	2.00	2.02	2.59	2.48	2.54	2.95	5.03	3.99	31.85	64.70	48.28
FYM	14.05	11.43	12.74	2.11	1.87	1.99	2.51	2.48	2.50	2.96	5.16	3.99	28.59	61.19	44.95
RF+ 5 t FYM	13.64	14.30	13.97	1.94	2.12	2.03	2.52	2.49	2.50	2.85	3.32	3.08	30.10	65.71	47.90
RF	14.00	12.81	13.40	1.91	1.82	1.87	2.56	2.50	2.53	2.66	4.13	3.40	33.10	64.20	48.65
Mean (B)	14.28	12.99		2.02	1.98		2.56	2.47		3.11	4.52		30.66	63.45	
CD at 5% for nutrition sources (A)			0.17	N.S.			N.S.			0.72			1.40		
CD at 5% for varieties (B)			0.16	N.S.			0.02			0.47			1.07		
CD at 5% for A at same level of B			0.32	N.S.			0.06			N.S.			N.S.		
CD at 5% for B at same level of A			0.39	N.S.			0.06			N.S.			N.S.		

4.6.1.6.10. Water uptake ratio

The perusal of the data in Table 4.17 reveal that the application of different nutrition treatment had no significant positive effect on water uptake ratio of rice. Taraori Basmati had significantly lower value as compared to HKR 126.

Interaction effect of sources of nutrient and varieties on water uptake ratio was significant. Application FYM alone or in combination with RF to HKR 126 had significant decrease the water uptake ratio in comparison to control and remaining treatments. Highest value of water uptake ratio was observed under green manuring, Press-mud and control which was at par with RF. Application of FYM gave significantly lowest value of water uptake ratio. Water uptake ratio in Taraori Basmati was recorded the highest under RF. However, it was significant to control only and at par with other sources in this respect.

4.6.1.6.11. Cooking coefficient

Data in the Table 4.17 reveal that highest cooking coefficient was recorded under GM which was at par with control, Press-mud and FYM treatments. Taraori Basmati had significantly higher cooking coefficient than HKR 126.

Interaction effect between various treatments and varieties had no significant.

4.6.1.6.12. Volatile substances residue (VSR)

The volatile substances residue responsible for aroma flavor characteristic was estimated and presented in Table 4.17.

The data from Table 4.17 indicate that application of recommended dose of fertilizes (RF) gave highest value of VSR, which was significantly higher than control and FYM but at par with green manuring, Press-mud and RF + 5 tons FYM. Volatile substances residue in variety Taraori Basmati was significantly higher to HKR 126 which was almost double in Basmati than high yielding variety.

Interaction effect between varieties and nutrition sources was not significant.

DISCUSSION

The results of experiment obtained during one year of investigation are presented in Chapter 4. In this chapter, the effect of different treatments are discussed and explained in the light of information obtained by other workers:

5.1. Growth studies

Growth and development of a crop is affected by several factors including nutrients availability in the soil. In the present experiment also nutrients supply to crop through various sources had marked effect on all growth parameters. However, both varieties responded to various sources differently. In variety HKR 126 application of combined RF and FYM significantly increased the plant height at all stages but in Taraori Basmati maximum plant height was recorded under GM (Table 4.1 and Fig. 2). Manguiat *et al.* (1992) also reported that rice plant height increased with *Sesbania* green manuring. Similar results were reported by Singh and Singh (2003). Application of Press-mud produced minimum plant height among various nutrient sources. Taraori Basmati due to genetic character of tall growing nature, had significantly taller plants than HKR126 during all growth stages.

Number of tillers at harvest is a very important growth parameter which is highly associated with number of panicles per square meter. Application of nutrients by any source had significantly increased the number of tillers at all stages in both varieties. But higher amount of nutrient supply by RF alone or in combination with FYM had better effect on number of tillers in Taraori Basmati than in HKR 126. HKR 126 though is a high yielding dwarf variety but gave better response to green manuring in producing tillers (Table 4.3 and Fig. 4). Das *et al.* (2003) also reported that highest number of effective tillers were obtained by application of 100% NPK. The beneficial effect of nitrogen on tiller number was also reported by Ram *et al.* (1995) and Mehla and Panwar (2001). Taraori Basmati being a tall growing variety, cannot tolerate higher level of fertility, however, is profusely tiller producing variety and so was able to produce more tillers under higher fertility level. In general, at all stages, Taraori Basmati produced more tillers than HKR 126 and particularly at harvest the number of tillers per hill of Taraori Basmati (9.26) was significantly more over HKR 126 (5.86).

From the results presented in Chapter 4, it is clear that dry matter accumulation increased progressively upto harvest stage of growth under all treatments. Variety HKR 126 was superior in producing dry matter at all stages as compared to Taraori basmati. This could be due to high yielding characteristic of variety HKR 126. All nutrition sources had significantly higher dry matter accumulation as compared to control. It is clear from Table 4.3 and Fig. 4 that at early

stage, green manuring gave higher dry accumulation, however, at later stages, RF alone or in combination with FYM was superior to FYM or Press-mud alone. Kundu *et al.* (2004) also reported that 100% NPK + 5 tons FYM recorded highest dry matter accumulation in rice at harvest stage. Both varieties behaved differently to dry matter production under variable nutrient supply. Taraori Basmati produced maximum dry matter under GM but HKR 126 accumulated highest dry under RF alone or in combination with FYM.

The leaf area and leaf area index (LAI) are the most important growth parameters, which are directly related to the photosynthetic activities of the plant. LAI in all the treatments was maximum at 60 DAT and decreased thereafter (Table 4.4. and Fig. 5). At this stage, RF+ 5 tons FYM recorded maximum LAI in HKR 126 and 15 tons FYM gave highest LAI in Taraori Basmati but at par to other organic sources. Kundu *et al.* (2004) also reported that RF + 5 tons FYM gave significantly highest LAI in rice. Taraori Basmati continued to produce green leaf upto later stages and so had significantly more LAI than HKR 126 at 90 DAT. Mhaskar *et al.* (2005) also reported similar variations in leaf area index due to variety and different nutrient levels.

Taraori Basmati is a tall variety and highly susceptible to lodging under high fertility conditions with plant height more than 140 cm. At flowering stage, lodging appeared in this variety due to rain and wind under GM, RF and RF+FYM treatments (Table 4.5). At this stage maximum lodging percentage of about 35 % was estimated under GM. This could be one of the reasons that caused maximum loss in yield under GM treatment in this variety. During grain filling and ripening stages, heavy lodging continued under RF + FYM but under GM, FYM and RF with lower intensity. Lodging had adverse affect on productivity of this variety which is reflected in grain yield data (Table 4.7). No lodging appeared in HKR 126 at any stage under any treatment.

5.2. Yield components

Yield of a crop is directly related to various yield attributes, viz; number of panicles, grains per panicle, panicle weight and test weight. All these parameters were significantly affected by various treatments. Application of GM to HKR 126 produced significantly more panicles per square meter than control and other treatments, but Taraori Basmati gave more response to RF + FYM with 342.2 panicles per square meter. Application of FYM alone gave better results in Taraori Basmati producing 319.3 panicles m⁻² than lowest in HKR 126 (243.5). A number of workers reported an increase in productive tillers due to N fertilization (Sharma and Mitra, 1988; Patra and Padhi, 1989, Ram *et al.*, 1995 and Mehla and Panwar, 2001). Taraori

Basmati produced more numbers of panicles (320.7) than HKR 126 (260.5).

It is interesting to note that recommended dose of fertilizers alone or in combination with FYM produced highest number of filled grains per panicle in HKR 126 but number of filled grain per panicle in Taraori Basmati was highest under FYM treatment (Table 4.6 and Fig. 6). Singh *et al.* (2003) also reported similar results. Number of filled grains per panicle of HKR 126 was significantly more than Taraori Basmati.

Weight per panicle was significantly affected by various treatments. All nutrition sources gave significantly higher weight of panicle than control treatment. Both varieties showed variable response to sources of nutrients and it was noticed that in variety HKR 126, recommended dose of fertilizers alone or in combination with FYM had better effect than other sources in producing panicles weight (Table 4.6 and Fig. 6). On the other hand, tall growing variety Taraori Basmati had better weight of panicle under organic sources of nutrients than fertilizers applied alone or with FYM. A number of workers reported an increase in panicle weight due to organic and inorganic fertilization (Pandey *et al.*, 2001, Singh and Singh, 2003).

Applications of various sources of nutrients significantly affected 1000-grain weight in both varieties (Table 4.6 and Fig. 6). HKR 126 performed better under fertilizers alone or in combination with FYM, but Taraori Basmati gave better test weight under organic treatments. In general, application of different organic sources (FYM and GM) either separately or in combination with inorganic fertilizers significantly increased 1000-grain weight over control and the highest being recorded under GM. The results are in consistent with the reports of Mehla and Panwar (2001). Variety HKR 126 produced heavier weight than Taraori Basmati.

5.3. Yield

The ultimate effect of experimental variables is reflected in final yield of the crops and it is a major criterion to identify the efficiency of various treatments in a given situation. The data pertaining to grain yield presented in Table 4.7 indicate that grain yield of varieties was significantly higher due to any source when compared to control. On overall average basis of two varieties, among all these sources, RF + 5 tons FYM gave significantly highest grain yield. In high yielding variety HKR 126 maximum grain yield of 80.5 q ha⁻¹ was obtained under RF + 5 tons FYM but in scented tall variety Taraori Basmati maximum grain (38.88 q ha⁻¹) was recorded under 15 tons FYM. As discussed in previous paragraphs, application of sources of nutrients significantly increased the yield attributes which ultimately resulted in increase grain yield of rice varieties. Being a high yielding and dwarf variety, HKR 126 was able to give better response to higher level of fertility and therefore, recommended fertilizers alone or in combination with FYM gave maximum grain yield in this variety. On the other hand, Taraori

Basmati, being a tall growing weak stem variety could not tolerate high fertility level and as data on lodging indicate, this variety was highly susceptible to lodging under RF or RF + 5 tons FYM which supplied high amount of nutrients to the crop. Due to lodging in these treatments, this variety performed better in organically manured treatments of FYM alone, GM and Press-mud. HKR 126 gave grain yield of 80.5 q ha⁻¹ in RF + 5 tons FYM, which was 47.0, 28.8 and 15.6 % higher than FYM, Press-mud and GM, 74.25 q ha⁻¹ in RF which was 35.6, 18.8 and 6.6 % higher than FYM, Press-mud and green manuring, respectively. In Taraori Basmati, nutrients supply was higher than tolerance limit under RF + 5 tons FYM and so yield decreased significantly than Press-mud, FYM and RF alone. Later treatments gave 9.3, 4.3 and 9.8 % higher grain yield than RF + FYM treatment. These results clearly indicate that high yielding variety HRK 126 still needed more supply of nutrients than RF alone and Taraori Basmati needed low nutrient supply through organic manure or RF. These results are in accord with the findings of Sharma (1993) and Singh *et al.* (1996). Parihar (2004) also reported that 100% NPK along with 5 tons FYM gave highest yield of dwarf rice. Dhiman *et al.* (2002) also reported similar grain yield of Taraori Basmati under green manuring and recommended dose of fertilizers.

Straw yield is important parameter to evaluate the productivity index of a crop. The data in Table 4.7 and Fig. 6 show that highest straw yield (93.87 q ha⁻¹) of rice was obtained under recommended fertilizers along with FYM. Nitrogen supply increases net photosynthesis that has a favorable effect on various growth parameters resulting in higher straw yield with higher rates of N application. This was true in variety HKR 126 which gave highest straw yield under RF + 5 tons FYM. Such response to level of recommended dose of fertilizers in conjunction with FYM could be attributed to higher availability of nutrients to plant that improved plant height, number of tillers and dry accumulation, which ultimately result into higher straw yield of HRK 126. Similar results were obtained by other researchers (Ram *et al.*, 1995 and Mehla and Panwar, 2001). Green manuring was most effective in Taraori Basmati in producing significantly higher straw yield (102.25 q ha⁻¹) than other treatments. This variety behaved in the same way as in case of grain yield and due to lodging under high fertility environment, the variety lost biological as well as grain and straw yields.

Harvest index of rice decreased with increase in nutrient supply to crop. A decrease in harvest index with increase in nutrient was due to proportionate higher increase in straw yield than in grain yield with increasing level of fertilizer application. Similar findings were also reported by Narang *et al.* (1990). Application of different organic manures and their combination had no significant effect on harvest index of rice. Variety HKR 126 produced higher grain yield and lesser straw yield than Taraori Basmati so it gave significantly higher HI than tall scented

variety Taraori Basmati which was 46.77 and 32.20, respectively in two varieties.

5.4. Nitrogen, phosphorus and potash content and uptake

Application of various sources had no significant effect on nitrogen concentration in grain but in straw it differed significantly among various fertility treatments (Table 4.8). Application of recommended dose of fertilizers along with 5 tons FYM increased the N content in rice grain in Taraori Basmati. In straw of HKR 126, maximum concentration of nitrogen was recorded under GM treatment (0.58 %). Application of FYM alone, Press-mud and RF + 5 tons FYM had similar effect on nitrogen concentration in rice straw and it was significantly higher than control. Parihar (2004) also reported that incorporation of crop residues, FYM and fertilizers significantly increased N content in rice. Nitrogen uptake showed different pattern and data in Table 4.11 clearly spell out that high yielding variety HKR 126 recorded significantly highest N uptake in RF + 5 tons FYM but in Taraori Basmati all sources recorded statistically at par nitrogen uptake in grain and RF + 5 tons FYM was also at par with GM in nitrogen uptake in straw. Hussain *et al.* (1989), Ghosh *et al.* (2004), Mhaskar and Thorat (2005) reported similar results.

Phosphorus concentration of rice grain was not affected significantly by various sources but P concentration in straw was significantly higher under GM followed by RF (Table 4.9). Taraori Basmati had more concentration of P in grain than HKR 126 but both varieties were at par in P concentration in straw. Similar findings were reported by Parihar (2004). P uptake in grain was recorded maximum under GM but in straw maximum P uptake was recorded with RF + 5 tons FYM. Similar trend in P uptake were observed for total P uptake also which was highest in RF + 5 tons FYM and green manuring treatments. The higher uptake of P under GM could be due to reasons: firstly, green manuring may have capacity to increase the available P status of soil because incorporation of GM converts unavailable P into available P form and absorbs more P in the deeper soil layer due to their developed root system (Meelu and Morris, 1984); secondly, they can supply more available N content in soil (Table 4.15) which resulted in increased in P uptake (Table 4.12) and finally increased grain yield of rice (Table 4.7). Ghosh *et al.* (2004), Mhaskar and Thorat (2005) also reported similar effect on NPK uptake caused by different nutrient treatments in Basmati rice.

Concentration of K was highest under RF but at par with other sources of nutrients. However, in straw there was no significant effect of nutrient sources on K concentration. The uptake of K in grain, straw and total was increased by various sources of nutrients than control. But various sources were at par in uptake in grain except RF which recorded significantly highest uptake. RF alone or in combination with FYM and GM recorded more uptake than other sources in straw. Similar trend was recorded for total uptake of K. Varieties had variable responses in this

regard and HKR 126 recorded maximum K uptake under RF alone or in combination with FYM. Taraori Basmati had higher total K uptake under GM. Parihar (2004) also reported an increase in K uptake due to FYM and NPK fertilizers.

5.5. Economics

Gross and net income followed the trend of grain yield under various treatments. The high yielding variety HKR 126 gave maximum net return under RF + FYM (Rs. 20925/-) followed by RF (Rs. 17985/-). This was due to relatively more increase in yield than cost of cultivation in these treatments than other nutrients sources. Due to better performance of Taraori Basmati under organic sources and RF, highest return of this variety was observed under FYM followed by RF and Press-mud with Rs. 21586/-, 20558/- and 19013/-, respectively. Overall highest net income was recorded with Taraori Basmati under FYM treatment (21586/-) which was due to better price fetched by this variety when grown organically. Almost similar trend was observed for benefit cost ratio in both varieties.

5.6. Soil fertility status

Soil fertility status after harvest of crop was compared with initial status of soil at start of experiment (1998-1999). Organic carbon content in soil increased significantly under GM, FYM and RF + FYM (Table 4.15). The increase in organic carbon content of the soil under these treatments might be due to addition of organic matter from outside sources. Incorporation of GM gave significantly highest organic carbon (0.53%) into soil. The similar results have also been reported by Upadhyay *et al.* (2003). Data from the International Rice Research Institute on long-term experiment also showed a significant increase in organic carbon content due to N fertilizers (Blair and Lefroy 1998). Almost a trend similar to organic carbon was observed in available N content in soil under various treatments (Table 4.15).

The available P content in soil after harvest decreased in the control compared to initial value. Application of GM to soil gave slightly higher P content than initial value. It could be due to that Dhaincha (*Sesbania aculeata*) bring the nutrients from the lower layer of the soil to upper layer in soluble form, thus availability of nutrients like nitrogen, phosphorus, potassium and another micro-nutrients increases. The pH of the soil is also decreased which enhances the availability of nutrients, particularly P availability (Yadav *et al.*, 2003). Effect of Press-mud, FYM and RF in soil P availability was at par with RF + 5 tons FYM, but in all these treatments P status decreased than initial value of soil.

The available K status of the soil in the manured plots increased in comparison to initial value, but slightly decreased in the control. The highest value of available K was recorded with RF + 5 tons FYM. Other sources of nutrients also improved the K content in soil compared to

initial value. The increase in available K content in the soil due to application of FYM or GM were also reported by Sharma and Sharma, (1993) and Prasad *et al.* (1995).

5.7. Grain quality characteristics

Application of different treatments did not have significant effect on hulling percentage of rice. However, HKR 126 gave significantly higher hulling percentage compared to Taraori Basmati. It can be explained that HKR 126 had thinner husk and a awnless spike than Taraori Basmati. Application of RF + 5 tons FYM to HKR 126 gave maximum hulling percentage while Taraori Basmati gave highest hulling percentage under Press-mud.

The difference in milling percentage of rice among various nutrient treatments was not significant. However, due to higher hulling percentage, HKR 126 had significantly higher milling percentage over Taraori Basmati with 67.02 and 63.46 %, respectively. These observations are in close agreement with the findings expressed by Dhiman *et al.* (1999).

Head rice recovery (HRR) or head rice yield is very important parameter, which depends on variety characteristics and cultural conditions. Data from Table 4.16 show that highest head rice recovery was recorded under RF + 5 tons FYM (57.42 %) which was significantly higher than control but similar to GM, Press-mud and FYM. Addition of 5 tons FYM has given significantly higher HRR as compared to RF applied alone. A number of workers had reported the effect of different nutrients treatments on HRR in Basmati and non-basmati rice (Mehla and Panwar, 2001; Satheesh and Balasubramanian, 2003; Ghosh *et al.*, 2004 and Elaine, 2005).

Both Taraori Basmati and HKR126 had slender grain with higher value of L/B ratio. Application of RF + FYM gave highest value of L/B ratio (3.38) but it was at par with Press-mud, RF and GM (Table 4.16). Similar effect was observed between GM and FYM. Scented variety Taraori Basmati (3.75) had significantly higher L/B ratio compared to HKR 126 (2.81).

Application of nutrition sources did not have any significant effect on rice density. However, highest density of rice was recorded under RF + 5 tons FYM, closely followed by FYM. Variety Taraori Basmati had significantly higher rice density than HKR 126. It can be explained on the fact that Taraori Basmati has more slender grain so it has less pore space between grains. It is desirable characteristic and attracts consumers.

5.8. Rice cooking characteristics

Optimum cooking time is very important characteristic. Lower optimum cooking time can convince the consumers more because it saves time and energy. Taraori Basmati had significantly lower optimum cooking time than HKR 126. Application of 15 tons FYM in Taraori Basmati significantly reduced cooking time as compared to control and all other sources.

The breadth wise expansion of rice after cooking is not desirable trait in high quality rice. The value was obtained from 1.87 to 2.06 but no significant difference was observed among nutrition sources in swelling index of rice varieties (Table 4.17). However, the value of swelling index observed in present study was slightly higher in value than earlier reported by Ahuja *et al.* (1995) in Basmati rice and Sankar (1998) in Basmati and high yielding varieties.

Lower water uptake ratio is a desirable characteristic of high quality of rice. Taraori Basmati had significantly lower water uptake ratio (2.47) as compared to HKR 126 (2.56). This result was inconsistent with Sankar (1998) but it could be explained that both varieties increased length and breadth after cooking but grain of HKR 126 increased more in breadth. Water uptake values vary between 205 and 338 per cent in Basmati rice was also reported by Ahuja *et al.* (1995).

One of the three most important characteristics of high quality rice is kernel elongation during cooking. High quality rice, in general, and Basmati in particular, required cooking coefficient bigger than 2.5. Data in the Table 4.17 reveal that all treatments had cooking coefficient bigger than 2.5. Highest cooking coefficient was recorded under GM but was at par with control. The results are similar to reports obtained by Battan *et al.* (2003). Being a slender grain rice variety, Taraori Basmati had significantly higher cooking coefficient (4.52) than HKR 126 (3.11).

Basmati is globally reputed aromatic group of rice, having three distinct quality features: pleasant aroma, super-fine grain (> 6.5 mm long) along with extremely kernel elongation and soft texture of cooked rice. The volatile substances residue (VSR) responsible for this characteristic (aroma flavor) was estimated and presented in Table 4.17. Taraori Basmati is strong scented (Mehla and Panwar, 2001). Taraori Basmati had significantly higher volatile substances residue with 63.45 (mg KMnO₄ per 100g white rice) than HKR 126 (non-scented variety) with 30.66. These results are in agreement with Sankar (1998). Various nutrition sources increased the volatile substance residue, maximum being recorded under RF in HRK 126 and under RF + 5 tons FYM in Taraori Basmati.

CHAPTER VI

SUMMARY AND CONCLUSION

6.1. SUMMARY

The experimental trial was laid out in the field No. 79/17 of the research farm of Rice Research Station, Kaul (Kaithal), Haryana during *kharif* season of 2005 to study the effect of

various organic and inorganic sources of nutrients (Green manuring, press-mud, FYM) and fertilizers (N, P, K, Zn) on growth, yield, nutrient uptake, grain quality of HKR 126 and Taraori Basmati varieties of rice, soil health and to find out the economics of different nutrition sources for sustainable rice production. The experiment was laid out in split-plot design with four replications. The treatments were comprised of six main plot treatments; nutrition sources (Control, Green manure, Press-mud (7.5 tons ha⁻¹), FYM 15 tons ha⁻¹, RF + 5 tons FYM and RF) and two sub-plot varieties; Taraori Basmati (scented rice) and HKR126 (high yielding variety). Thus, there were 12 treatments in all.

The important findings of the experiment are summarized below:

1. Plant height, number of tillers and dry matter accumulation of rice increased significantly with either by application of RF + 5 tons FYM or by Green manuring. Taraori Basmati produced maximum dry matter accumulation under GM treatment while HKR 126 produced highest dry matter accumulation under RF alone or RF + 5 tons FYM.
2. Leaf area index (LAI) increased up to 60 DAT and decreased thereafter. Maximum LAI was recorded under RF + 5 tons FYM but at par with GM and FYM. Taraori Basmati recorded maximum LAI under FYM and variety HKR 126 recorded maximum LAI under RF + 5 tons FYM at 60 DAT.
3. Lodging in Taraori Basmati appeared during flowering which was highest in GM and RF + 5 tons FYM at this stage and continued heavily in later treatment. There was no lodging in Press-mud application during flowering and grain filling. No lodging appeared in HKR 126.
4. Application of GM gave significantly highest panicles per square meter in HKR 126 and gave highest weight of 1000-grains of Taraori Basmati. Number of panicles per square meter in Taraori Basmati and number of filled grains per panicle in HKR 126 increased significantly with RF + 5 tons FYM.
5. In HKR 126 panicle weight, filled grains per panicle and weight of 1000-grain was recorded maximum under RF + 5 tons FYM. Variety Taraori Basmati produced highest number of filled grains per panicle and panicle weight under FYM.
6. Application of recommended dose of fertilizers gave maximum grain and straw yields as compared to all other sources. In Taraori Basmati, maximum grain yield was recorded under FYM but at par with GM, Press-mud and RF while straw yield of this variety was

highest under GM. Variety HKR 126 recorded both maximum grain and straw yields under RF + 5 tons FYM, followed by RF and both these produced significantly higher yields over other sources of nutrients. Maximum and minimum HI were recorded in control and GM treatments, respectively. HI decreased with increase in availability of nutrients to plants. HI was significantly higher in HKR 126 than Taraori Basmati.

7. Application of nutrition sources did not have significant effect on N and P concentration in grain, but it was significant in N and P concentration in rice straw. Green manuring gave significantly higher N and P content in rice straw. Recommended dose of fertilizers gave significantly highest K concentration in rice grain but was at par with all other sources.
8. N, P and K uptake was higher with applied RF + 5 tons FYM and GM. Variety HKR 126 recorded maximum N (grain and total uptake), P (straw and total uptake) and K (grain, straw and total uptake) under RF + 5 tons FYM. Taraori Basmati recorded significantly higher uptake of P (grain and total) and K (straw and total) under GM treatment.
9. In HKR 126, application of RF + FYM gave maximum hulling percentage and HRR (%) but milling percentage and cooking time were maximum in GM treatment. Density, swelling index and water uptake ratio were higher in other treatments.
10. In Taraori Basmati, maximum value of hulling was recorded under Press-mud, maximum density was recorded under GM, milling (%) under FYM, HRR, L/B ratio, optimum cooking time and swelling index under RF + 5 tons FYM and water uptake ration under RF.
11. Application of all sources improved soil fertility. Application of GM had maximum organic carbon and available P content of soil, whereas RF + 5 tons FYM recorded highest available N and available K content in soil.
12. Variety HKR 126 gave maximum return under RF + 5 tons FYM (Rs. 20925/-) followed by RF (Rs. 17985/-). Taraori Basmati gave highest return under FYM (Rs. 21586/-) followed by RF (Rs. 20558/-). Overall highest net return was recorded with Taraori Basmati under FYM treatment (21586/-).

6.2. CONCLUSION

Growth and yield parameters, grain and straw yields, nutrient uptake and income of rice increased significantly with nutrition sources but both varieties behaved differently to application of nutrients by various sources. Quality of grain was improved by organic sources alone or in combination with fertilizers. Growth parameters were superior in Taraori Basmati but yield attributes were higher in HKR 126. Taraori Basmati had superior quality traits than HKR 126.

In variety HKR 126, an application of the recommended dose of fertilizers ($150 \text{ kg N} + 60 \text{ kg P}_2\text{O}_5 + 60 \text{ kg K}_2\text{O} + 25 \text{ kg ZnSO}_4 \text{ ha}^{-1}$) + 5 tons FYM had positive effect on growth and yield parameters and gave 80.5 q ha^{-1} grain, Rs. 48300/- gross income, Rs. 20925/- net income and 1.76 benefit cost ratio, whereas in Taraori Basmati application of 15 tons FYM had positive effect on growth and yield parameters gave 38.88 q ha^{-1} grain, Rs. 47700/- gross income, Rs. 21586/- net return and also highest benefit cost ratio (1.83). The results of present study, thus, show that Basmati rice can be grown organically and soil can sustain production better with 15 tons of FYM but high yielding variety HKR 126 does better under high fertility environment by applying recommended dose of fertilizers along with 5 tons FYM or recommended fertilizers alone.

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APPENDIX

Appendix I. Weekly meteorological data during crop growth

Month	Week	Temp. ($^{\circ}$ C)		Relative humidity (%)		Sunshine (hrs./day)	Rain fall	Evaporation
		Max	Min	at 07:22	At 14:22		(mm)	
June	01.06-05.06	40.5	22.8	50.8	20.6	11.0	0	46.3
	06.06-12.06	38.7	24.5	59.3	33.4	9.8	15.4	62.3
	13.06-19.06	40.0	24.9	59.9	24.9	9.7	0.0	59.4
	20.06-26.06	40.7	27.5	67.3	48.1	9.7	0.2	58.0
	26.06-03.07	32.1	25.7	78.6	73.6	4.2	102.8	32.9
July	04.07-10.07	31.1	26.0	88.0	74.3	4.6	7.0	19.7
	11.07-17.07	31.7	25.6	91.1	73.6	4.7	25.4	25.7
	18.07-24.07	34.3	26.3	84.0	65.4	7.0	24.8	30.4
	25.07-31.07	34.2	26.8	85.9	67.3	7.1	8.4	26.3
August	01.08-07.08	33.5	26.3	90.6	70.6	6.0	52.4	27.8
	08.08-14.08	34.0	26.3	88.4	64.4	7.7	8.3	30.3
	15.08-21.08	34.2	25.8	85.3	65.9	5.5	3.2	28.7
	22.08-28.08	35.2	26.3	85.4	54.9	9.4	0.0	30.6
	29.08-04.09	35.9	24.6	88.0	52.4	9.7	0.0	37.5
September	05.09-11.09	32.9	25.2	87.0	68.0	4.9	45.4	28.6
	12.09-18.09	30.1	22.9	93.4	77.1	1.5	105.6	20.3
	19.09-25.09	30.8	23.3	92.6	70.0	6.4	99.9	18.2
	26.09-02.10	31.9	22.3	91.3	57.6	8.0	0.0	20.0
October	03.10-09.10	33.7	19.8	91.6	38.6	8.4	0.0	25.1
	10.10-16.10	33.0	18.2	91.6	40.3	7.5	0.0	19.3

November	17.10-23.10	30.3	16.1	91.7	47.4	6.5	0.0	16.2
	24.10-30.10	29.9	13.9	93.7	40.4	6.9	0.0	15.4
	31.10-06.11	28.3	13.2	86.3	39.1	7.3	0.0	14.1
	07.11-13.11	28.2	11.7	86.6	32.9	8.0	0.0	15.4
	14.11-20.11	28.4	9.9	68.3	17.0	8.7	0.0	24.4
	21.11-27.11	27.8	8.4	90.0	28.6	8.1	0.0	12.2

Appendix II. Cost of cultivation of green manuring (*Sesbania*)

Operations	Inputs	Rate (Rs.)	Cost (Rs.ha)
Discing	1 Tractor for hrs	250 hr ⁻¹	250
Seed	13 Kg ha ⁻¹	5 kg ⁻¹ seed	65
Sowing	4 man days	105 day ⁻¹	420
Irrigations (4 irrig.)	1 Water charge	200 irrig. ⁻¹ ha ⁻¹	200
	4 man days	105 day ⁻¹	420
Incorporation	1 Tractor for 3 hrs.	250 hr ⁻¹	250
Irrigation in incorporated plots (1 irrig.)	1 Water charge	200 irrig. ⁻¹ ha ⁻¹	200
	1 man days	105 day ⁻¹	105
Land revenue	for 3 months	14512 ha ⁻¹ yr ⁻¹	2419
Grand Total			4329

Appendix III. Common cost of cultivation of rice for HRK 126

Operations	Quantity	Input	Rate (Rs.)	Units	Cost
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(Rs. ha⁻¹)**A. Raising nursery (1000 sq. m.)**

Land preparation and puddling

Ploughing	1	Tractor 4 hour.	250		250
Puddling	1	Tractor 4 hour.	250		250
Making beds and sowing	4	mandays	105	day	420
Seed	35	kg ha ⁻¹	13	kg seed	455
Nitrogen dressing and weeding	25	kg urea	4.8	kg	120
	1	manday	105	day	105
Irrigations (4 times)	0.6	Water charge	250	irrig. ha ⁻¹	150
	1	manday	105		105

B. Main field (1 hectare)

Tillage	4	Tractor for 4 hrs	250		1000
Ploughing with cultivators	4	Tractor for 4 hrs	250		1000
Puddling and planking	4	Tractor for 4 hrs.	250		1000
Bunding	4	mandays	105	day	420
Fertilizer application		As per treatment			
Uprooting the seedlings and transplanting	20	mandays	105	day	2100
Thinning and gap filling	4	mandays	105	day	420
Weeding	4	mandays	105	day	420
Irrigations	10	irrigation	250	irrig ha ⁻¹	2500
	5	mandays	105	day	525
Harvesting and threshing	15	mandays	105	day	1575
Including transportation					400
Management charge					1281.5
Interest for capital					640.75
Land rental value		for 6 months	13525	ha yr ⁻¹	6763
Grand total					21900

Appendix IV. Common cost of cultivation of Basmati rice

Operations		Input	Rate (Rs.)	Cost (Rs.ha ⁻¹)
A. Raising nursery (1000 sq. m.)				
Land preparation and puddling				
Ploughing	1	Tractor 4 hour.	250	250
Puddling	2	Tractor 4 hour.	250	500
Making beds and sowing	4	mandays	105	day 420
Seed	35	kg ha ⁻¹	29	kg seed 1015
Nitrogen dressing and weeding	25	kg urea	4.8	kg 120
	1	manday	105	day 105
Irrigations (4 times)	1	Water charge	250	Irrig. ha ⁻¹ 250
	1	manday	105	105

B. Main field (1 hectare)

Tillage	4	Tractor for 4 hrs	250		1000
Ploughing with cultivators	4	Tractor for 4 hrs	250		1000
Puddling and planking	4	Tractor for 4 hrs.	250		1000
Bunding	2	mandays	105	day	210
Fertilizer application		As per treatment			
Uprooting the seedlings and transplanting	20	mandays	105	day	2100
Thinning and gap filling	4	mandays	105	day	420
Weeding	4	mandays	105	day	420
Irrigations	10	irrigation	250	irrig. ha ⁻¹	2500
	5	mandays	105	day	525
Harvesting and threshing	20	mandays	105	day	2100
Including transportation					400
Management charge					1500
Interest for capital					750
Rental value of field	0.5000	for 6 months	14512	ha yr ⁻¹	7256
Grand total					23946

Appendix V. Influence of rates and sources of fertilizers on the cost of cultivation

Treatment	Applied	Amount (kg)	Rate (Rs. kg ⁻¹)	Cost (Rs. ha ⁻¹)	Total cost
HKR 126					
Control	(no fertilizer)				0.0
GM	Green manuring				2243.3
PM	Transport of press-mud			2000	2000.0
	mandays	1	105	105.0	2105.0
FYM	FYM	15000	0.12	1800.0	
	mandays	2	105	210.0	2010.0
RF + FYM	Urea	275	4.8	1320.0	
	DAP	130.5	9.35	1220.2	
	MOP	100	4.5	450.0	

	ZnSO ₄	25	15	375.0	
	FYM	5000	0.12	600.0	
	mandays	3	105	315.0	4280.2
RF	Urea	275	4.8	1320.0	
	DAP	130.5	9.35	1220.2	
	MOP	100	4.5	450.0	
	ZnSO ₄	25	15	375.0	
	mandays	2	105	210.0	3575.2
Taraori Basmati					
Control	Control (no fertilizer)				0.0
GM	Green manuring				2243.3
PM	Transport of press-mud			2000.0	2000.0
	mandays	1	105	105.0	2105.0
FYM	FYM	15000	0.12	1800.0	
	mandays	2	105	210.0	2010.0
RF + FYM	100Urea	65	4.8	312.0	
	DAP	105	9.35	981.8	
	MOP	50	4.5	225.0	
	ZnSO ₄	25	15	375.0	
	FYM	5000	0.12	600.0	
	mandays	3	105	315.0	2808.8
RF	100Urea	65	4.8	312.0	
	DAP	105	9.35	981.8	
	MOP	50	4.5	225.0	
	ZnSO ₄	25	15	375.0	
	mandays	2	105	210.0	2103.8

ABSTRACT

Title of Dissertation	: Response of rice to organic nutrition under rice-wheat cropping system
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Title of Degree	: Master of Science
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Year award of degree	: 2006
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Number of word in the abstract	: 553
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A field experiment was conducted during *kharif* 2006 on clay loam soil, medium in organic carbon, low in available nitrogen, high in available phosphorus and potash at Rice Research Station, Kaul, Kaithal districts of Haryana state. The experiment consisting of combinations of six main plot treatments *viz.*, Control (no fertilizer), Green manuring, 7.5 t ha⁻¹ Press-mud, 15 t ha⁻¹ FYM, RF + 5 t ha⁻¹ FYM and RF (recommended fertilizers) with two sub-plot treatment of varieties (HKR 126 and Taraori Basmati) was laid out in Split-plot design with four replications. The experiment was carried out with the objectives of to study the effect of nutrition sources on growth, yield and yield attributes, quality of rice and nutrient uptake in rice including the economics of different treatments and fertility status of soil. Plant height, number of tillers and dry matter accumulation of rice increased significantly with application of RF + 5 tons FYM and Green manuring. Taraori Basmati produced maximum dry matter accumulation under GM treatment while HKR 126 produced highest dry matter accumulation under RF + 5 tons FYM. LAI of two varieties increased up to 60 DAT and maximum LAI was recorded under RF + 5 tons FYM. Taraori Basmati experienced lodging with highest under GM and RF + 5 t FYM. The yield and yield attributes of HKR 126 were significantly affected by various sources with highest recorded in GM and RF. The yield and yield attributes of Taraori Basmati were significantly highest in 15 tons FYM and RF treatments. The maximum number of panicles per square meter and number of filled grains per panicle were recorded with the application of RF. The RF treatment produced significantly higher number of grains per panicle and maximum 1000-grains weight which was superior over control. On HKR 126, an application of N₁₅₀ P₆₀ K₆₀ Zn₂₅ + 5 tons FYM gave significantly higher grain, straw and biological yields. Application of nutrients sources did not affect the N and P concentration in grain, but affected significantly the N and P concentration in rice straw. N, P and K uptake was higher with applied RF + 5 tons FYM and GM. Variety HKR 126 recorded maximum N (grain and total uptake), P (straw and total uptake) and K (grain, straw and total uptake) under RF + 5 tons FYM. Taraori Basmati recorded significantly higher uptake of N (straw), P (grain and total) and K (straw and total) under GM treatment. Variety HKR 126 gave maximum return under RF + 5 tons FYM (Rs. 20925/-) followed by RF (Rs. 17985/-). Taraori Basmati gave highest return under FYM (Rs. 21586/-) followed by RF (Rs. 20558/-). Overall, highest net return was recorded with Taraori Basmati under FYM treatment (Rs. 21586/-). Application of all sources improved soil fertility. Application of GM had maximum organic carbon and available P content of soil, whereas RF + 5 tons FYM recorded highest available N and available K content in soil. In HKR 126, application of RF +

FYM gave maximum hulling percentage and HRR (%) but milling percentage and cooking time were maximum under GM treatment. In Taraori Basmati, maximum of hulling percentages and density were recorded under GM, milling (%) under FYM, HRR, L/B ratio, optimum cooking time and swelling index under RF + 5 tons FYM and water uptake ration under RF.

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