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STUDIES ON RELATIVE PERFORMANCE OF CONVENTIONAL AND HYBRID RICE VARIETIES UNDER VARIOUS LEVELS OF NITROGEN, PLANT POPULATION AND PLANTING PATTERNS

By

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A thesis

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CERTIFICATE

This is to certify that the thesis entitled "**STUDIES ON RELATIVE PERFORMANCE OF CONVENTIONAL AND HYBRID RICE VARIETIES UNDER VARIOUS LEVELS OF NITROGEN, PLANT POPULATION AND PLANTING PATTERNS**", submitted to Post Graduate School, Indian Agricultural Research Institute, New Delhi in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Agronomy** is a record of *bona fide* research work carried out by **Ms. P. PADMAVATHI** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation has been duly acknowledged by her.

(Surendra Singh)
Chairman
Advisory Committee

New Delhi
Dated: 13th August, 1997

Dedicated to the Loving

Memory of My Mother

Late Smt. P. Pushpavathi

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1. INTRODUCTION

Rice contributes 35 to 65 per cent of total calorie requirement of nearly three billion people in Asia where 90 per cent of the world rice is grown and consumed. India and China together produce more than 50 per cent of the world rice. India has the largest area under rice among cereals and in 1995-96 produced 79.46 million tonnes of rice from 42.2 million hectares with an average production of 1.9 t ha^{-1} (FAI, 1995-96). By the turn of this century India will require nearly 100 million tonnes of rice. This means that India would require to add annually not less than 2.5 million tonnes of rice to sustain the present level of self sufficiency (Pillai, 1996). Projections based on population growth rates in countries where rice is the main food crop indicate that the world must produce 350 million tonnes more rice than it produced in 1992. The increase must come from increased production per unit area (Virmani, 1996).

Of the several approaches contemplated the use of hybrid rice technology is one of the strategies to meet this challenge. The technology has already made an impact on rice production in China during past 20 years where rice hybrids possessing 15-20 per cent yield advantage over inbred rices, are now cultivated in about 50 per cent of the total area under rice. The aforesaid yield advantage was harnessed without any significant difference in input use (He *et al.*, 1987). Commercial success of hybrid rice in China has clearly demonstrated the potential of this technology to meet the increased demands of rice. In India, the technology is yet to pick up its gear. About half a dozen hybrids have been made available for commercial use and about 50,000 hectares were planted with hybrid rice in

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various parts of the country during wet season 1996 (Siddiq *et al.*, 1996). However, for exploiting the full heterotic potential, it is indispensable to develop a suitable production packages for hybrid rice cultivation. So far, little attention has been paid in this direction.

The results of National Testing Programme revealed that the hybrids have great potential as compared to best inbred varieties of rice. A few hybrids have already been released and many are in the pipeline. The country is on the march towards a new rice revolution through hybrid rice. Since hybrid rice technology in India is only five years old, information on management aspects of hybrid rice needs to be generated because the full potential of hybrids can be realized only with the development of suitable agronomy for the hybrids. The present study was therefore taken up to determine the optimum level of nitrogen, plant population and suitable planting pattern for a hybrid rice variety NDHR 2 (New Delhi Hybrid Rice 2, developed at IARI recently). The Pusa 834 a conventional high yielding variety was taken as a check.

The objectives of the study were as follows:

Objectives

1. To compare the performance of hybrid and a conventional rice variety.
2. To determine the optimum plant population for hybrid rice.
3. To find out optimum nitrogen level for hybrid rice.
4. To study the effect of planting patterns on the yield and nitrogen utilization by hybrid and conventional rice.

2. REVIEW OF LITERATURE

Published information on the **"studies on relative performance of conventional and hybrid rice varieties under various levels of nitrogen, plant population and planting patterns"** is presented under different sub-heads. Under each sub-head the data for conventional high yielding varieties are discussed first followed by data on hybrid rice. Information available on hybrid rice, however, is meagre.

2.1 Varieties

2.1.1 Growth characters

Most researchers have reported positive heterosis (better performance of a F_1 hybrid than its parents) in hybrid rice for growth characters such as plant height (Chang *et al.*, 1973; Singh and Riccharia, 1980; Paramasivan and Sreerangaswamy, 1988), tiller number (Craigmiles *et al.*, 1968; Virmani *et al.*, 1981; Sahai et al., 1987; Rangaswamy and Murthy, 1988), leaf area index (LAI) (Murthy et al., 1991), root growth (Raj and Siddiq, 1986; Sahai and Choudary, 1986) and dry matter production (Rao et al., 1985; Yen and Hu, 1986; Blanco et al., 1990).The profused tillering nature of the rice hybrids was found to be helpful under low planting densities (Craigmiles et al., 1968).

Sahai and Choudary (1986) reported that the superiority of hybrids in root growth over their parents helped in utilizing the applied nitrogenous fertilizer more efficiently. Hybrid rice has been found to have a stronger and more active root system resulting in more efficient utilization of applied fertilizers (Lin and Yuan, 1980). Yamauchi (1994) reported that the high dry matter accumulation in hybrid rice as compared to conventional rice is due to higher root activity of F1 hybrids but not higher root mass.

Several researchers (Jennings, 1967; Sunohara *et al.*, 1986; Song *et al.*, 1990) observed higher crop growth rates (CGR) in hybrid rice in early than in later stages. Growth analysis of six rice hybrids showed more heterosis for CGR than for relative growth rates (RGR) and net assimilation rates (NAR) (Jennings, 1967; Blanco *et al.*, 1986; Sunohara *et al.*,1986; Song *et al.*, 1990). Song et al (1990) recorded a higher CGR of 30 g m^{-1} day^{-1} at 30 days prior to heading in hybrid rice.

2.1.2 Yield attributes

Several studies showed that hybrids when compared to either of their parents or standard check varieties showed positive and significant heterosis for number of productive tillers (IRRI, 1984; Lokaprakash *et al.*, 1992; Srinivasulu, 1994), panicle length (IRRI, 1984; Subramanian and Sivasubramanian, 1986; Lokaprakash *et al.*, 1992), fertile spikelets per panicle (IRRI, 1984; Yen and Hu, 1986; Sahai *et al.*, 1987; Malik *et al.*, 1988; Lokaprakash *et al.*, 1992), test weight (IRRI, 1984; Reddy *et al.*, 1984; Rao *et al.*, 1985; Sahai *et al.*,1987; Lokaprakash *et al.*, 1992) and harvest index (IRRI, 1984; Lokaprakash *et al.*, 1992).

In contrast, some research workers (Rao *et al.*, 1985; Subramanian and Sivasubramanian, 1986; Prakash and Mahadevappa, 1987; Paramasivan and Sreerangaswamy, 1990) have reported 30 to 40 per cent negative heterosis for spikelet fertility. Yamauchi *et al.* (1985) reported lower harvest index in hybrids than in pure lines, and Rao *et al.* (1985) reported no significant heterosis for harvest index.

Heterosis for yield in hybrid rice was found to come mostly from vegetative growth (Yan, 1988) and also from simultaneous heterosis for number of productive tillers, panicle weight, panicle length, fertile spikelets, test weight and harvest index (IRRI, 1984; Lokaprakash *et al.*, 1992). Rao *et al.* (1985) reported a significant and positive heterosis with a yield advantage of 11-23% and this was due to more biomass production, panicle number $hill^{-1}$, spikelets $panilce^{-1}$ and test weight.

2.1.3 Yield

In general, hybrids were found to give 1.0 to 1.8 t ha^{-1} more yield than the inbreds in korea (IRRI, 1988). The yield advantage for heterosis reported by several workers (IRRI, 1980a; Rao *et al.*, 1985; Raj and Siddiq, 1986; Voc and Luat, 1987; Anand Kumar and Subramaniam, 1988; Blanco *et al.*, 1990; Shanmugasundaram *et al.*, 1990; Longping, 1993; Durga Rani and Murthy, 1994) ranged from 8 to 32 per cent. Chengxiu and Shangxian (1988) reported that hybrid rice gave 0.9 t ha^{-1} more yield than those of conventional varieties at the same level of fertilizer application. Similar superiority of hybrids over conventional varieties at same level of fertilizer N were also reported by Subramanian and Sivasubramanian (1986) and Siddiq (1993). From the Northern Jiangsu Province of China, Gui-Ting *et al.* (1987) reported higher heterosis of hybrid rice than Indica rice cultivars.

2.2 Levels of Nitrogen

Literature available on the affect of fertilizer nitrogen on rice is enormous and beyond the scope of this review. The present review is restricted to pertinent references bringing out the main points.

2.2.1 Growth characters

In general, the research reports on rice indicated an increase in growth parameters such as plant height (Kalyanikutty and Morachan, 1974; Pandey and

Singh, 1985; Karel Marx, 1986; Singh *et al.*, 1991; Bhattàcharya and Singh, 1992; Thakur, 1993a), tiller number (Kumara, 1956; Manickam and Ramaswami, 1985; Karel Marx, 1986; Ramesh, 1989; Schnier *et al.*, 1990; Singh *et al.*, 1991; Bhattacharya and Singh, 1992; Pradeep *et al.*, 1994) only upto 80 kg N ha^{-1} and dry matter production (Upadhyaya and Pathak, 1981; Agasimani *et al.*, 1983; Ramasamy *et al.*, 1985; Karel Marx, 1986; Schnier *et al.*, 1990; Udaya Bhaskar, 1990; Thakur, 1993a) upto 120-180 kg ha^{-1}.

2.2.2 Yield attributes

As in the case of growth characters most workers reported increase in number of productive tillers m^{-2} with increasing levels of fertilizer N (Sharma and Prasad, 1982; Ghobrial, 1983; Raju and Rao, 1984; Ramasamy *et al.*, 1985; Karel Marx, 1986; Raju *et al.*, 1990; Bhattacharya and Singh, 1992; Thakur, 1993b; Kanungo and Roul, 1994; Pandey and Tripathi, 1994; Pradeep *et al.*, 1994; Singh *et al.*, 1994). Some workers, however, reported no change in productive tillers m^{-2} with an increase in the level of fertilizer N (Chau and Deshmukh, 1991; Robinson, 1992). Nitrogen application decreased days to 50 per cent flowering (Chatterjee and Maiti, 1985; Karel Marx, 1986; Udaya Bhaskar, 1990).

A significant increase in panicle length with an increased level of fertilizer N was reported by Sharma and Prasad (1982); Karel Marx (1986); Dalai and Dixit (1987); Raju *et al.* (1990); Udaya Bhaskar (1990); Singh *et al.* (1991); Thakur (1993a); Kanungo and Roul (1994).

Though the number of grains $panicle^{-1}$ and number of filled grains $panicle^{-1}$ were more at higher rates of fertilizer N (Manickam and Ramaswami, 1985; Karel Marx, 1986; Dalai and Dixit, 1987; Saikia *et al.*, 1988; Udaya Bhaskar, 1990; Thakur, 1993a), per cent filled grains were less (Ramesh, 1989; Chau and

Deshmukh, 1991; Deshmukh and Chau, 1992). Balasubramanian and Palaniappan (1991a, b) and Kanungo and Roul (1994), however, reported decreased filled grains panicle^{-1} with corresponding increase in unfilled grains due to increased fertility levels.

An increase in test weight with increased level of fertilizer N was reported by several workers (Dalai and Dixit, 1987; Saikia *et al.*, 1988; Udaya Bhaskar, 1990; Chau and Deshmukh, 1991; Thakur, 1993a; Kanungo and Roul, 1994). However, Gowda *et al.* (1987) reported no change in test weight with increasing level of fertilizer N.

2.2.3 Yield

An increase in grain yield with an increase in fertilizer N level was reported by a large number of researchers (Yogeswara Rao *et al.*, 1980; Sharma and Prasad, 1982; Raju and Rao, 1984; Murali *et al.*, 1985; Karel Marx, 1986; Dalai and Dixit, 1987; Rao and Raju, 1987; Saikia *et al.*, 1988; Ramesh, 1989; Raju *et al.*, 1990; Schnier *et al.*, 1990; Rai *et al.*, 1991; Bhattacharya and Singh, 1992; Deshmukh and Chau, 1992; Murthy *et al.*, 1992; Dhal and Misra, 1993; Shukla *et al.*, 1993; Pandey and Tripathi, 1994). Though many research workers reported (Srinivasulu Reddy, 1986; Chengxiu and Shangxian, 1988) response to fertilizer N upto 120 kg N ha^{-1}, some research workers did notice response upto 180 kg N ha^{-1}. Chengxiu and Shangxian (1988) reported response of some rice hybrids to the application of N as high as 180-225 kg N ha^{-1}. Whereas, Chandra *et al.* (1990) and Kanungo and Roul (1994) observed linear response in grain yield with increasing level of N upto 240 kg N ha^{-1}.

Straw yield also increased with an increase in the level of N upto 120 to 180 kg N ha^{-1} by different researchers (Prasad *et al.*, 1982; Rao and Raju, 1987;

Gulati *et al.*, 1987; Udaya Bhaskar, 1990; Rai *et al.*, 1991; Mongia, 1992; Murthy *et al.*, 1992; Robinson, 1992; Shukla *et al.*, 1993; Thakur, 1993b; Kanungo and Roul, 1994). A reduction in harvest index was reported with an increase in fertilizer N level from 0 to 100 kg N ha^{-1} by Biswas and Bhattacharya (1987), Gulati *et al.* (1987), Chau and Deshmukh, (1991) and Panda and Rao (1991).

2.2.4 Nutrient uptake

Several research workers reported an increase in N uptake and N content with the increased fertilizer N application upto 120 kg N ha^{-1} (Sharma and Prasad, 1980; Patnaik *et al.*, 1982; Tanaka *et al.*, 1984; Reddy and Sreeramamurthy, 1985; Biswas *et al.*, 1987; Thorat and Patil, 1987; Dubey and Bisen, 1989; Hamissa *et al.*, 1989; Chau and Deshmukh, 1991; Sreedevi and Thangamuthu, 1991; Krishnakumar and Subramonian, 1992; Thakur, 1993b; Pande *et al.*, 1993; Pradeep *et al.*, 1994).

The uptake of N was rapid between early tillering to rapid tillering (Hamissa *et al.*, 1989), which in general, contributes to one third of the total N uptake in rice (Thorat and Patil, 1987). In contrast Yang *et al.* (1987) reported a different pattern of N uptake in hybrid rice. Of the total N uptake, 8-13 per cent was during transplanting to tillering, 48-53 per cent during tillering to heading and 33-44 per cent during heading to ripening.

In general, uptake of P and K also increased with increasing level of fertilizer N (Biswas *et al.*, 1987; Sharma and Mittra 1990; Sreedevi and Thangamuthu, 1991), and P uptake was further enhanced with high basal and more split applications of fertilizer N (Sreedevi and Thangamuthu, 1991). Nayar *et al.* (1980) found that increase in N application upto 150 kg N ha^{-1} significantly increased zinc content of straw of rice variety Supriya under flooded conditions. Chengxiu and Shangxian (1988) reported that rice hybrids have higher N, P and K uptake by 3.2, 7.8 and 12.7 per cent respectively as compared to conventional varieties.

High yielding cultivars had comparatively higher translocation of phosphorus to grain (Raju and Rao, 1984). Similarly, Alam *et al.* (1989) found that mutants had high mineral uptake than their parents. Another study reported that uptake of ammonical N and phosphorus was more in Indica cultivars, while K uptake was more in Japonica cultivars, however, nitrate-N uptake was similar in both the types (Ichii and Tsumura, 1989).

The amount of nutrients absorbed by hybrid rice to yield 7.5 t ha^{-1} were 208 kg N ha^{-1}, 24 kg P ha^{-1} and 190 kg K ha^{-1} (Chengxiu and Shangxian, 1988).

2.2.5 Apparent recovery or Recovery of applied nitrogen

Considering the wide range of soil and climatic conditions, fertilizer N recovery, in general, was reported to be in the range of 20 to 60 per cent (Prasad and De datta, 1979; Matsushima, 1980; Hamissa and Mahrous, 1989; Cassman *et al.*, 1994; Pandey and Tripathi, 1994).

Nitrogen use efficiency in wet land rice is only 30-50% (Prasad and De Datta, 1979; Prasad, 1982a). Katyal *et al.* (1985) found a recovery of 23-31% with ^{15}N labelled urea, while Reddy *et al.* (1990) estimated 11.2-19.5 % apparent recovery of applied urea.

George and Prasad (1989) found a decrease in recovery with an increase in the rate of nitrogen, the apparent recovery was 31, 26.7 and 25.9 per cent at 50, 100 and 150 kg N ha^{-1} respectively. Similar trends in apparent recovery with increased levels of N were reported by Racho and De Datta (1968) and Rajale and Prasad (1975).

Nevertheless, besides soil and climatic factors, management factors also influence fertilizer N recovery. Rate, time and amount of fertilizer N application are the major management practices influencing the fertilizer N recovery. Fertilizer N recovery was high at low levels of fertilizer N (Yoshida, 1981; Manickam and Ramaswami, 1985; Cassman *et al.*, 1994), and with more number of split applications (Prasad and De Datta, 1979; Yoshida, 1981, Mongia, 1992).

From the above literature it is evident that increasing levels of N increased N content and NPK uptake. However, recovery of applied N decreased with an increase in the level of N.

2.3 Plant Population

2.3.1 Growth characters

Proper plant population generally adjusted by row spacing is an important non-monetary agronomic input which governs the optimum plant population of crop. Optimum plant population is one that gives maximum economical yield of a crop per unit area. Plants get almost equal conditions of growth and derive nutrients from the soil in the presence of proper spacing. Both intra and inter row spacing influence the growth and development of the plants. There is considerable variation in the literature on the effect of planting density on plant height probably because of the variations in soil and weather conditions, and the cultivars used in different studies.

Vachhani *et al.* (1961) working on rice recorded that the plant height was increased when the spacing was increased from 6" x 6" to 12" to 12" beyond which no further increase in plant height was noticed. Relwani (1963) conducted an experiment on rice with different spacings (i.e. 6" x 6", 8" x 8", 10" x 10", 5" x 20" and 6" x 18") and found an increase in plant height with an increase in spacing upto 10" x 10" beyond which the height is decreased. Sahu and Lenka (1966) reported an increase in plant height with the wider spacing. In general, closer spacings (10 x 10 cm or 15 x 10 cm) resulted in taller plants than wider spacings (30 x 30cm or 15 x15cm) (Kalyankutty *et al.*, 1969; Reddy, 1978; Sahu and Lenka, 1986; Gulati *et al.*, 1987; Shah *et al.*, 1991). Some researchers, however, did not find any marked effect of planting density on plant height (Shahi *et al.*, 1976; Satyavarma, 1988; Singh *et al.*, 1991).

Vachhani *et al.* (1961) further reported that too close spacing affects the tillering while too wide spacing appreciably increases tillering. A spacing of 6" to 9" appears to be optimum. Both the maximum and ear bearing tillers/clump significantly increased with wider spacings, which showed a linear trend. The survival of effective tillers was higher with wider spacings as compared to close spacings.

Many research workers (Relwani, 1962; Shahi *et al.*, 1976; Venkateswarulu and Singh, 1980; Venugopal and Singh, 1985; Kanade and Kalra, 1986; Satyavarma, 1988) reported an increase in tillering with an increase in spacing plant^{-1}. Tillers m^{-2} were, however, found to decrease, with an increase in plant spacing. Because number of hills planted m^{-2} were lower at wider spacings (Murthy and Murthy, 1980; Lin and Lin, 1985; Venugopal and Singh, 1985; Ramesh, 1986; Satyavarma, 1988; Reddy and Reddy, 1992 ; Kanungo and Roul, 1994; Sharma, 1994). Krishnan *et al.* (1994) and Padmaja Rao (1995) reported highest number of tillers m^{-2} at 20 x 10 cm spacing.

Higher tiller number m^{-2} in closely spaced crop may produce higher LAI as compared to that found in the wider spaced crop. Lin and Lin (1985) reported higher LAI from the closer spaced (300 cm^2 per hill) crop than from the wider spaced (500 cm^2 per hill) crop.

Wagh and Thorat (1987) reported significantly higher dry matter at closer spacing (15 x10 cm). The physiological parameters of growth such as CGR and RGR increased with an increase in spacing when these rates were expressed per plant or hill (Agasimani *et al.*, 1983), but decreased when they were expressed per unit area (Agasimani *et al.*, 1983; Das *et al.*, 1988).

On red loamy soils of Bhavanisagar, Chandragiri and Iruthayaraj (1991) Studied NAR and CGR of cultivated varieties IR-50 and CO-41 from four planting geometries viz., uniform planting, paired-row planting, Strip-row planting and random planting. Out of these four planting geometries, the uniform planting geometry recorded higher NAR, while the strip-row planting geometry recorded higher CGR.

2.3.2 Yield attributes

Hedayetullah *et al.* (1947) stated that the number of effective tillers increases as spacing becomes wider, whereas, Gulati *et al.* (1987) reported a significant increase in the effective tillers m^{-2} with the decreased spacing. Krishnan *et al.* (1994) reported more productive tillers m^{-2} with 20 x 10 cm than with 15 x 10 cm spacing

Mandal and Mahapatra (1968) studied the performance of two cultivars, T_{41} and T_{90} at three different plant spacings, 7.5 x 15 cm, 15 x 15 cm and 22.5 x 15 cm and indicated that number of panicles per hill increased but number of panicles per unit area decreased significantly as the planting spacing increased from 7.5 x15 cm to 22.5 x 15 cm. Similarly an increase in panicles m^{-2} with a decrease in spacing was reported by many researchers (Venkateswarulu and Singh, 1980; Thorat *et al.*, 1983; Reddy and Ghosh, 1984; Singh *et al.*, 1985; Wei and Lin,1986; Jones and Snyder, 1987; Singh *et al.* 1987; Tsai, 1987; Aragones and Wada 1989; Sharma and Singh, 1992). In contrast, Venugopal and Singh (1985) and Shah *et al.* (1991) observed no significant influence of plant spacing on the number of panicles m^{-2}.

Padmaja Rao (1995) found highest number of panicles m^{-2} with 20 x 10 cm spacing, whereas Wagh and Thorat (1987) observed significantly more panicles

m^{-2} and heavier panicles at closer spacing (15 x 10 cm). In contrast, Sharma (1994) reported that panicles m^{-2} decreased with an increase in row spacing but reverse was observed in panicle weight.

On laterite soils, Thorat *et al.* (1983) and Liou (1987) recorded lesser panicle length and weight at closer spacing (15 x 10 cm) than at wider spacing (15 x 15 cm and 15 x 20 cm). A few other researchers (Singh *et al.*, 1985; Venugopal and Singh, 1985; Shah *et al.*, 1991) reported no significant effect of plant density on panicle length. Gulati *et al.* (1987) recorded significant increase in panicle length with an increase in spacing. Similar results were reported by Nguu and De Datta (1979).

Significant reduction in no. of grains per panicle with an increase in spacing was reported by Gulati *et al.* (1987) and Rao and Raju (1987). Padmaja Rao (1995) reported the highest number of grains m^{-2} at 20 x 10 cm spacing.

Number of grains per panicle was more with wider (30 x 30 cm) and normal (22.5 x 22.5) spacing than that with closer (15 x 15 cm) spacing (Rathi *et al.*, 1984; Reddy and Ghosh, 1984; Jones and Snyder, 1987; Singh *et al.*, 1987). Similarly, Ramesh (1986), Satyavarma (1988) and Raju *et al.* (1989) found higher number of filled grains per panicle from widely spaced plants as compared to closer spaced plants. Verma (1972) did not observe any increase in test weight of the cvs. TNI and NST-98. Similar results were also reported by Shahi *et al.* (1976), Singh *et al.* (1985), Ramesh (1986) and Satyavarma (1988).

Krishnan *et al.* (1994) reported highest filled grains m^{-2} at 20 x 10 cm spacing compared to 15 x 10 cm, whereas, Kanungo and Roul (1994) reported more filled grains $panicle^{-1}$ and less unfilled grains at 15 x 10 cm spacing.

The 1000-grain weight was significantly higher with 15 x 10 cm spacing as compared to that of 15 x 20 cm spacing (Wagh and Thorat, 1987; Nair and George, 1973 and Sewaram *et al.*, 1973).

Kanungo and Roul (1994) reported significantly higher 1000-grain weight with lower plant density 15 x 15 cm as compared to that of 15 x 10 cm spacing. In contrast, Reddy and Ghosh (1984) observed decreased test weight with increasing plant population.

2.3.3 Yield

Grain yield of F_1 rice hybrids were found to be higher when planted at a spacing of 20 x 20 cm or 30 x 30 cm than at a spacing of 40 x 40 cm (IRRI, 1984). In another study at (IRRI, 1987) three spacings 30 x 15 cm, 25 x 15 cm and 20 x 15 cm did not differ significantly in respect of grain yield. Though the information on the effects of planting density on yields of hybrid rice is meagre, it appears that rice hybrids need wider spacing than that needed for conventional cultivars probably because of their profused tillering nature (Craigmiles *et al.*, 1968).

Bains and Singh (1967) conducted an experiment on varying row spacing (15 cm, 22.5 cm and 30 cm) at the Agricultural Research Station, Dhaula Kuan (H.P.). The yield per row increased from 6.19 kg ha^{-1} at 15 cm row spacing to 10.60 kg ha^{-1} at 30 cm row spacing. Bathkal and Patil (1970) conducted a trial on varying row spacings (15 cm, 20 cm, 30 cm and 37.5 cm) at Kolhapur during *kharif* of 1967-68 and 1968-69and observed that the yield per row increased from 7.44 kg ha^{-1} at 15 cm row spacing to 17.87 kg ha^{-1} at 37.5 cm row spacing. Similarly Kumar *et al.* (1975) carried out similar studies during *kharif* 1967 and 1968 at Bichpuri, Agra where the yield per row increased from 8.28 kg ha^{-1} at 15 cm to 12.09 kg ha^{-1} at 25 cm, although, the highest grain yield of paddy (44.2 q ha^{-1}) was obtained at the narrowest row spacing of 15 cm. Patil *et al.* (1979) reported that yield per row was 11.59 kg ha^{-1} at 15 cm which increased to 20.36 kg ha^{-1} at 30 cm, while, the highest (61.8 q ha^{-1}) yield of paddy was obtained at 15 cm with lowest (54.3 q ha^{-1}) at 35 cm row spacing. Chandrakar and Khan (1981) tested three row spacings (10, 15 and 20 cm) with a fixed hill spacing of 10 cm at Raipur (M.P.) during wet season of 1977 and 1979. The yields per row increased with an increase in row spacing, while the reverse was true in case of grain yield per hectare. Varshney (1986) conducted experiments during wet season of 1978 and 1979 under upland terrace system of cultivation in Meghalaya and found that grain yield of rice increased with an increase in row spacing from 10 to 15 cm, while with further increase in row spacing, there was a significant reduction in grain yield. Similar results were reported by Singh and Singh (1973) and Thorat *et al.* (1983). Sewaram *et al.* (1973) at Karnal and Singh and Singh (1973) at Kanpur observed that plant spacings of 15 x 10 cm proved to be good compared to wider spacing.

In contrast, Shahi *et al.* (1976) reported that in Kappurthala of Punjab, plant spacings closer than 20 x 20 cm were not helpful in augmenting grain yield of rice. Singh and Modgal (1977) and Venkateswarulu and Singh (1980) reported no significant difference in grain yield due to varied plant densities.

Transplanting of seedlings with a spacing of 15 x 10 cm produced significantly higher grain yield than that of 20 x 15 cm (Wagh and Thorat, 1987). Singh *et al.* (1989) also reported significantly higher grain yield with 15 x 10 cm spacing than that with 15 x 15 and 20 x 10 cm spacing.

Raju *et al.* (1989) reported that wider spacings (20 x 20 cm, 20 x 15 cm and 15 x 10 cm) gave significantly higher yields than a closer spacing of (10 x 10 cm) with cv. MTU-5293 at Maruteru. On sandy loam soils of Pattambi, Sreedevi and Sreedharan (1991) reported increased grain yields of rice with an increase in planting density upto 33 hills m^{-2} but not beyond. Similarly, Raghuwansi *et al.* (1986) and crop. In this seeding and fertilizing was done in three rows and skip-row effect was provided to the two side rows in a group of three transplanted rows by leaving every fourth row vacant. This method is based on world wide observation on skip-row effect which has been defined by Gomez (1972) as "the difference in the growth and yeild of the plants adjacent to borders than those in the centre of the plot". The obsevations on skip-row effect are, however, available since 1910 (Smith, 1910 and wheeler, 1910). Numerical evidences of increase in the yeild of skip-rows have been produced by Barber (1914), Hayes and Arny (1917) and Arny and Hayes (1918) for the first time. There after a number of other research workers have shown positive evidences of skip-row effect in a number of crops irrespective of soil and climatic conditions (John and Hallsted, 1926; Mc. Rostie and Hamilton, 1927; Stringfield, 1927, Mc. Clelland, 1919 and 1934; Ayyangar *et al*, 1939; Richmond, 1943, Hartwig *et al.*, 1951; Green, 1956; Brown and weibel, 1957; Shear and Miller, 1960; Drapala and Johnson, 1961 and Bhalli *et al.*, 1964 Sharma and Singh, 1971 and Gomez, 1972) in different crops. But in case of rice, the first available reference is from (Anonymous, 1954-55). Later on the work on skip-row effect in rice was done by Gomez and De Datta (1971), Gomez (1972), Zimmermann (1980) and Sato and Takahashi (1983).

Keeping these observations and evidences in view the new system of sowing/ transplanting was developed in the department of Agronomy, Agrilcultural University, Kanpur, which was termed as 'skip-row method'. In case of rice, first field experiment was conducted by Rathi and Verma (1975) during 1972 to 1975 and the studies were further continued on this method by Singh (1980), Bhaskar (1980), Kumar (1981), Singh (1981a), Singh (1981b), Shahi (1982), Singh (1983a), Singh (1983b), Gupta (1985), Singh (1985), and Singh (1990) in dwarf paddy at Kanpur.

All these workers obtained equal grain yield of rice to that of transplanting and fertilizing every row with a saving of 25% nursery, 25% fertilizer and 25% labourer in transplanting and harvesting. A compensation of the yield of fourth missed row was made by increase in tillering, more grain filling and better development of grains and consequently in higher yield of all the three rows in new method particularly the side rows.

Although the skip-row method of planting is known to the scientists since 1910 but opinion differ to a great extent about the causes of skip-row effect.

In the opinion of Drapala and Johnson (1961) high yield of the row bordering the skip-row was more because of more absorption of nutrients by the roots. while Pendleton and Seif (1962); Sharma and Singh (1971) and Gomez and De datta (1971) attributed that the skip-row effect is due to more availability of light to the border rows.

Papadakis (1979) was of the opinion that skip-row effect is due to more expansion of roots as a result of more availability of the soil for neutralising/ absorbing/oxidising chemicals secreted by the roots and that more uptake of nutrients more absorption of water and better utilization of solar radiation by the skip-row rows are the after effects of root expansion.

Manna *et al.*, (1980) observed that planting in strips of three rows spaced at 15 cm each (15 cm plant to plant) and provision of gap of 30 cm between strips led to economise fertilizer, seeds and cost of planting by 25% over conventional planting without any such skips. No such advantage was observed with paired-row method of planting.

2.4.1 Growth characters

Manna *et al.*, (1981) conducted experiment with an object to find out the advantage of skip-row planting. They reported that border rows in skip-row planting recorded higher number of tillers than the central row and this attributed finally to grain yield comparable to conventional planting with 100% input of fertilizers and crop stand. However, no such advantage could occur from the paired-row method of planting.

Manna *et al.*, (1982) conducted experiments at Cuttack since 1980 to find out the effect of direction of strips besides the advantage of skip-row planting over the conventional practice. They observed that the border rows in skip planting recorded higher number of tillers over the central rows and this attributed finally to grain yields comparable to conventional planting with 100% inputs of fertrilizers and crop stand. Such advantage was not apparent in rabi season when crop responded more to the level of fertilizer use than planting geometry, confirming the earlier findings. The direction of strips North-South or East-West did not make any difference in the grain yield in both the seasons.

2.4.2 Yield attributes and yield

A study was conducted at Parbhani (Indore) in deep black soils and indicated that grain yield of upland *kharif* rice under regular method of sowing (14.4 q ha^{-1}) and in skip-row method of sowing with 75% seed rate and 75% fertilizer dose (12.7 q ha^{-1}) was at par (Anonymous 1983-84).

De *et al.* (1984) conducted an experiment in wet (kharif) and dry (boro) seasons at Kalyani (W.B) and reported that the dry matter of rice (oryza sativa L.) accumulated per unit area was slightly high (5%) in plots having one (1) skip-row after every two (2) rows planted 20 cm apart. When free from major incidences of pest and diseases, the increase in grain yield in plots with one (1) skip-row after every 2, 3, 4, or 5 rows in dry season were 8.2, 6.5 3.2 and 1.1 per cent. The corresponding increases in wet season were 8.8, 7.2, 3.4 and 2.0 per cent. The row bordering the skip-row produced more filled grains panicle^{-1} and heavier grains than the central plants compensating for the missing rows under skip-row planting.

At Shalimar, the yield of *kharif* rice, was not significantly affected by method of sowing and levels of fertilizers (Anonymous, 1986-87). At Rewa, yield of *kharif* rice was not significantly influenced by method of sowing and seed rate. However, reduction in fertilizer dose significantly reduced the yield both under regular and skip-row method of sowing and with both recommended and reduced seed rates (Anonymous, 1986-87).

Sharma and Warsi (1987) conducted experiment on four planting patterns (Normal) 20 x 10 cm, 20 x 15 cm, 27 x 10 cm and skip-row planting (skipping every fourth row) and two N doses 90 kg N ha^{-1} (75% of the normal) and 120 kg N ha^{-1} (normal) in a randomised block design during *kharif*, 1981 and 1982 at Kumarganj, Faizabad. They observed that planting pattern affected the grain yield of rice only in 1982. Skip-row planting with 90 kg N ha^{-1} gave yield at par with regular method with 120 kg N ha^{-1}. Thus an economy in seedlings and N fertilizer by 25% in skip-row technique could be achieved without any reduction in grain yield. The skip-row method manifested skip-row effect when every fourth row was skipped.

Taylor *et al.* (1987) conducted experiment on rice-fish culture involving skip-row method in Thailand where they reported equal grain yield of rice in skip-row planting as compared to conventional planting.

Field trail conducted at Shalimar during *kharif*, 1982-83 to exploit the skip-row effect in a crop to save fertilizer and/or seed requirement and found that, reduction in fertilizer significantly reduced the yield although, the results were not significant (Anonymous, 1987-88). Skip-row method of sowing resulted in reduced yields at all levels of seed rate and fertilizer although the differences were not significant.

Majumdar *et al* .(1989) observed that the rice grown in 6 row spacing patterns and with rows oriented North South or East West. Spacing is significantly influenced by dry matter accumulation, LAI and yield components at flowering. Highest grain yield was obtained when the crops were grown with a skip-row after every 3 continuous rows.

Sharma and Singh (1989) conducted a field experiment on wheat and rice during 1984-86 at Palampur (H.P). They observed that the number of panicles $hill^{-1}$ was significantly higher in the crop transplanted by skip-row method where as the number of panicles m^{-2} was significantly higher in regular transplanted crop. But yield attributes increased significantly with the decrease in plant population to 75%. It indicates that the increase in panicle number $hill^{-1}$ due to skip-row effect or reduced population could not compensate the tillers in the skipped row or lower plant population. However, the number of spikelets $panicle^{-1}$, spikelet fertility per cent and 1000-grain weight were not influenced significantly by the method of transplanting or variation in plant population. Decrease in fertilizer dose to 50% significantly decreased the number of panicles $hill^{-1}$, panicles m^{-2} and spikelets $panicle^{-1}$. However, spikelet fertility per cent and 1000-grain weight were significantly higher at 50% fertilizer dose than at 100% fertilizer dose.

Sharma *et al.* (1990) reprted that skip-row planting with 90 kg N ha^{-1} gave similar grain yield (4.54 and 4.26 t ha^{-1} in 1983 and 1984, respectively) as that with regular planting.

Deshmukh and Borulkar (1993) coducted a field experiment during kharif, 1984-85 at Parbhani, Maharastra, rice cv. PBN-1 was sown at rates of 45 or 60 kg seeds ha^{-1} with (skip-row method) or without (control) every 4^{th} row left blank.

They reported that the grain and straw yield were not affected by different methods of sowing.

The above results revealed that in most the experiments, skip-row method (by skipping every 4th row) gave as much yield as obtained by continuous transplanting and fertilizing every row. But these studies clearly indicated that about 25% of seed/seedling and fertilizer can be saved by skip-row planting pattern.

2.5 Varieties and Nitrogen Interaction

2.5.1. Growth characters

The lower concentration of N in F_1 hybrids which showed high dry matter accumulation suggests that N limits the growth of F_1 hybrids. Yamauchi (1994) reports that the depression in dry matter accumulation at heading may be caused partly by lack of N fertilizer application. F_1 hybrids require more intensive N fertilizer application before heading than parental lines.

2.5.2 Yield attributes

In hybrid rices, higher per cent of unfilled grains is commonly seen unless soil nutrient supply can cope with crop demands. Thus, delayed application of N coinciding with flowering can help to realise the full potential of hybrid rice (Surekha *et al.*, 1996).

Hybrid rice relies mainly on tillers to obtain desirable population while inbred rices mainly rely on the number of seedlings planted. About 85-90% of productive panicles in hybrid rice come from tillers, while in inbred rice their production is 30-40 per cent (Yan, 1988). He also reported that tiller number can be increased to meet the optimum LAI by applying N 30-35 days before heading in hybrid rice, whereas for inbred rices, N must be applied 5-10 days earlier to make unproductive tillers productive. Fertilizer management in inbred rice should focus on spikelet initiation and for hybrid rice it should be focussed on spikelet filling (Yan, 1988) For high yield of hybrid rice, sink is not the limiting factor as it is in inbred rice (Yan, 1988).

2.5.3 Yield

Results from India (Anonymous, 1995) revealed that application of N at 120 kg ha^{-1} in 3 splits (50% basal + 25% tillering + 25% at booting) was the best with higher yields irrespective of the season.

Cheng and Cheng (1989) reported that at 135 kg N ha^{-1} rice grain yield, N uptake and N efficiency were the highest for hybrids when it was applied as 67% basal and 33% top dressing. In contrast, for conventional rice 135 kg N ha^{-1} with 33% basal and 67% as top dressing was best.

In a study Devaraju *et al.* (1996) showed that hybrid, KRH-2 outyielded IR-20 at all levels of N ranging from 0-200 kg N ha^{-1}, as the nitrogen is used for the production of unproductive tillers in IR-20 is better utilized in KRH-2 to increase the seed set, panicle weight and finally the yield.

Singh *et al.* (1996a) reported that higher N application upto 150 kg N ha^{-1} is required to realize higher grain yield in hybrid rice. In another study, Singh *et al.* (1996b) showed that hybrids responded linearly to applied N levels upto 120 kg ha^{-1} and more than 3 splits of N application are not required for higher production of hybrid rice in vertisols. Subbaiah *et al.* (1996) reported that hybrids failed to respond beyond 150 kg N ha^{-1} in most test locations in India.

Virmani (1996) concluded that the hybrid rice UTL-2 had a higher physiological efficiency (kg yield per kg N uptake) than inbred rice MTU-19 during the wet season.

2.5.4 N concentration, uptake and utilization pattern

A study by Cheng and Cheng (1989) concludes that the ratio of N in the grains to that in vegetative parts of hybrid rice was more than 2.0 compared with 1.3 in conventional cultivars. This also suggests for more direct N assimilation from soil during ripening stage.

At IRRI, studies on N management of hybrids IR 64616H and IR-72 showed a significantly higher response of hybrid to late season N application than IR-72 (IRRI, 1993).

N uptake pattern

Shoji *et al.* (1986) and Wada *et al.* (1989) described the pattern of N absorption by rice plants as biphasic. The amount of N in the plant increased exponentially during the early growth stages and linearly during the middle and late growth stages. The transition point between the two phases coincided with maximum tillering for 20 x 20 cm plant spacing.

The rate of N absorption by rice plants increased after transplanting and shows a maximum at the maximum tillering stage. Another maximum is mostly observed at young panicle formation stage. However, the uptake pattern may be altered by both native soil fertility and cultural practices (Wada *et al.*, 1989).

The F_1 hybrids have higher N uptake compared to their inbred parents particularly at 3rd week after transplanting (WAT). At 5 weeks after transplanting differential N uptake diminished except for the hybrid with medium growth duration (125 days). The medium growth duration hybrids have consistently higher N uptake until maturity (Sta *et al.*, 1994). It was found that the uptake by hybrid Non you 3 was 29.1% more of the total, from seedling to tillering and 34.3% more from tillering to panicle initiation compared to inbred rice. N uptake at 40 days after transplanting was found to be 71.2%. Hence for hybrid rice more fertilizers should be applied at early stages Yan (1988), because more than half of the total nutrients were absorbed during the middle growth stages (Chengxiu and Shangxian, 1988). Yan (1988) suggested that if 160 kg ha^{-1} is to be used in a cropping season, 80 kg ha^{-1} be applied basally, 50 kg N ha^{-1} during tillering and remainder after panicle initiation. For inbred rice, more N should be applied during the middle and late stages than during early stages.

So for as the forms of N is concerned, although the NH_4^+-N has generally been accepted as a better source of nitrogen for rice (Surekha *et al.*, 1996). Some workers have concluded that NO_3-N is as effective as NH_4^+-N (Yang and Sun, 1991). They also reported that uptake of NO_3 in the late stages of growth by hybrid rice was greater than that of conventional rice.

Luo *et al.* (1993) reported that at all levels of N supply the conventional rice cultivar absorbed more NH_4^+ than NO_3. In contrast, the hybrid rice absorbed more NH_4^+ than NO_3 at the low levels of N supply (5.40 mg N/L) but more NO_3 than NH_4 at the high levels (80 and 120 mg N/L).

Nitrogen uptake by hybrid rice was also more than conventional rice, and large part of fertilizer should be applied during early stages. It also absorbed more K than conventional rice (Yan, 1988).

N utilization pattern

Schnier *et al.* (1990) reported that plant N status perse beginning at panicle initiation influences spikelet differentiation, and thus yield potential. In rice, prior to panicle emergence most of the N is found in the leaves. Following anthesis there is a rapid transfer of leaf N to the developing panicle (Guindo *et al.*, 1994). Research conducted on N utilization and partitioning by rice (Wada *et al.*, 1986) has given valuable insight; however literature providing comparisons between hybrid rice and conventional rice is limited. Differences in N utilization among rice cutivars of genotypes have been reported by several workers (Alam and Azmi, 1990).

In Huai Bei region Jiangsu province traditional tall variety Da-che-king responded upto 85 kg N ha^{-1}; short statured variety Nong-ken 57 responded upto 80 kg N ha^{-1},while Hybrid Ganga-Hua 2 showed highest response to N and gave highest grain yield (Yan, 1988).

In India National trials conducted during 1992-93 reveal varied response of rice to nitrogen in different regions. At Hyderabad response to N was observed upto 120 kg N ha^{-1}, while at Karnal and Coimbatore, hybrids responded to 180 and 200 kg N ha^{-1} respectively. At Maruteru, there was no difference in the yields obtained at 40 and 80 kg N ha^{-1} (DRR, 1992-93).

2.6 Plant Population and Nitrogen Interaction

Many researchers have observed that nitrogen uptake is not affected by spacing (Nair, 1975; Thorat *et al.*, 1983; Raju and Rao, 1984).

Papadakis (1970) has reported the results of a trial carried out for a decade during 1930-39 in which two pots of 40 and 80 cm deep were compared for yield under 4 treatments (humid and dry, unfertilized and adequately fertilized). Ten years average results indicated the higher yield from deeper pots under all treatments and that shallow pots with adequate irrigation and fertilizer could not give equal yield to deeper pots with neither irrigation nor fertilizer. These results make it clear that there was independent effect of soil and fertilizer and soil didn't act merely as a supplier of nutrients or moisture but it did something more. The independent effect of soil and fertilizer on the growth and yield of paddy has been clearly shown by number of research workers (Chowdhary and Raheja, 1962; Bains and Singh, 1967; Bathkal and Patil, 1970; Pillai *et al.*, 1972 and Lal *et al.*, 1986).

In the studies of Chowdhary and Raheja (1962) there was a linear increase in grain yield per row with an increase in the hill spacing, which was not affected by fertility levels. Similar results have been reported by Relwani (1963); Srinivasan *et al.* (1968); Yadav *et al.* (1976) and Agasimani *et al.* (1980).

Balasubramanian (1985) obtained significant interaction between spacing and nitrogen application. He reported significant increase in grain yield with an increase in N both at 15 x 10 cm and 20 x 10 cm spacing.

2.7 Varieties and Row Spacing Interaction

Yan (1988) recommended lower planting densities for hybrid rice (15-25 kg seed ha^{-1}) compared to that for conventional rice (110-180 kg seed ha^{-1}). Hybrid rice requires 4-5 times more space as compared to conventional rice plants. Singh *et al.* (1996b) showed that plant population of 3.3 to 5.0 lakh hills ha^{-1} is required to realise higher grain yield in hybrid rice.

2.8 Economics

Profuse tillering nature of hybrids was found to compensate for reduced plant densities, as a result lowered the seeding cost (Craigmiles *et al.*, 1968). Which led to higher net returns and benefit cost ratio with hybrids than with conventional cultivars because of higher grain yields obtained with the hybrids. In general, net returns depend on prevailing input costs and output prices, however, seed costs make much difference in net returns between hybrids and conventional cultivars.

3. MATERIALS AND METHODS

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

3.1 Plan of Research Work

Field experiments were conducted during *Kharif* season of 1995 and 1996 to study the "**RELATIVE PERFORMANCE OF CONVENTIONAL AND HYBRID RICE VARIETIES UNDER VARIOUS LEVELS OF NITROGEN, PLANT POPULATION AND PLANTING PATTERNS**".

3.2 Details of the Experimental Site

The trail was laid out at different sites during 1995 and 1996, in the Main Block 14-C of the Farm of Indian Agricultural Research Institute (IARI), New Delhi.

3.3 Climate and Weather Conditions

New Delhi is situated at $28^0 40'$ N latitude and $77^0 10'$ E longitude and at an elevation of 228.6 m above the mean sea level. The climate of this area is semi-arid and sub-tropical with hot and dry summers and cold winters. June is the hottest month with mean monthly temperature ranging from 41^0C to 46^0C, while January is the coldest month with monthly minimum temperature ranging from 5^0 to 7^0C. There is occasional frost during December and January.

The mean annual precipitation approximates to about 710 mm (average of past three years) and is mostly received during the period of July to September. The minimum number of agro-meteorological variables recommended for fundamental research in rice by World Meteorological Organization and the International Rice Research Institute (IRRI;1980) for the period of investigation recorded at the IARI observatory were collected and weekly averages were computed and are presented in Appendix 1 and Fig. 1.

3.4 Soil Characteristics

Before start of the experiment, a composite soil sample was collected from two sites and analyzed for mechanical composition and important characteristics, which are given in Table 3.1.The soil of experimental field was a sandy clay loam in texture with moderate water holding capacity. The soil was medium in organic carbon, low in total nitrogen content, medium in available phosphorus and high in available potassium and having 52.2%, 51.3% sand, 22.1%, 22.0% silt and 25.7, 26.7% clay respectively in two sites.

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

Particulars	Value	
	1995	1996
Mechanical Composition		
(Hydrometer method, Bouyoucos, 1962)		
Sand	52.2%	51.3%
Silt	22.1%	22.0%
Clay	25.7%	26.7%
Textural class	Sandy clay loam	
Chemical Composition		
pH (1:2.5 soil:water ratio)	8.10	8.00
(Elico pH meter, Piper, 1950)		
Electric Conductivity (ds m^{-1} at $25^{0}C$)	0.40	0.65
(Solubridge method, Piper, 1950)		
Cation exchange capacity (m.eq./100 g soil)	15.20	14.60
(Bower *et al.*, 1952)		

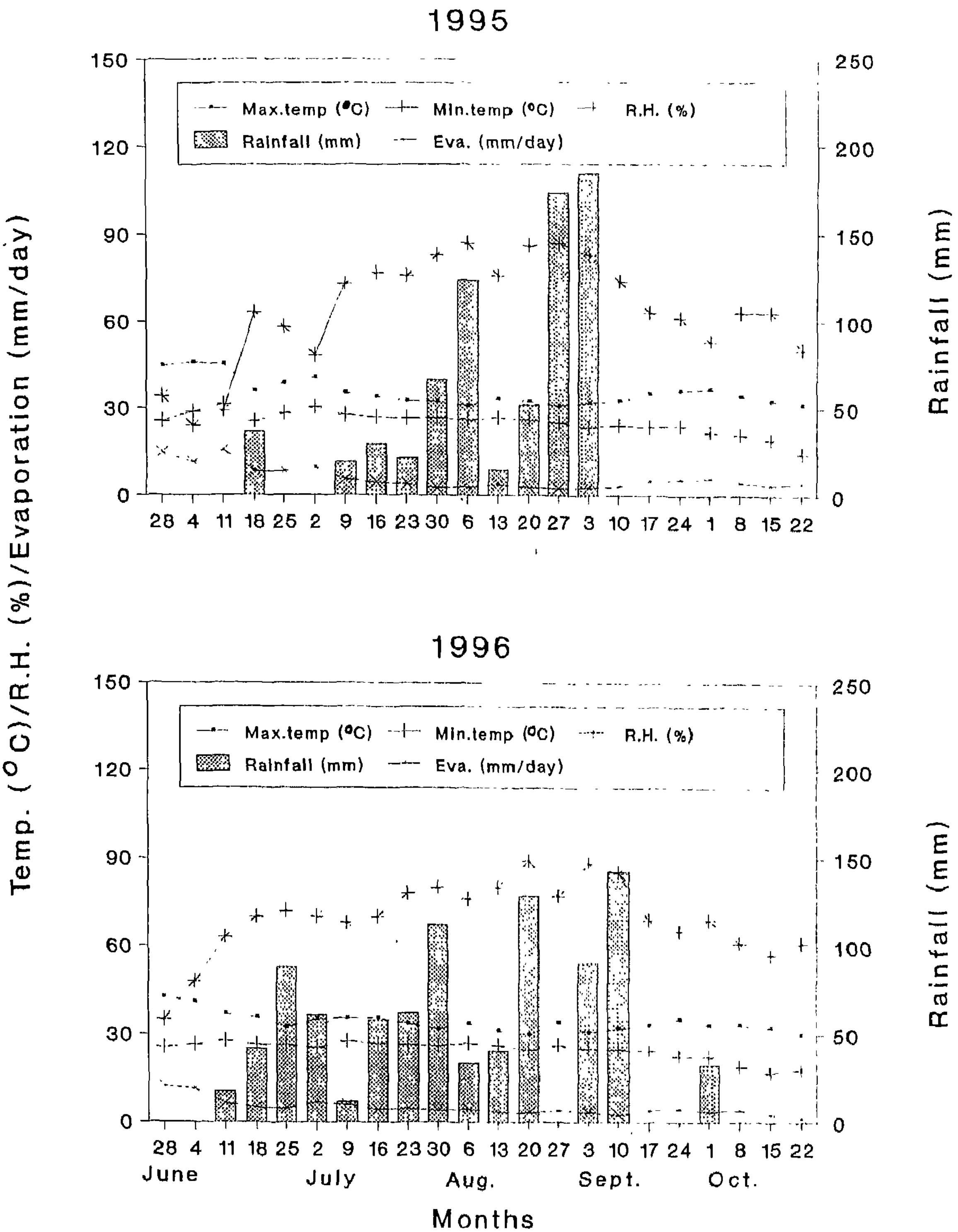

Fig. 1. Weekly meteorological data for crop season

Organic Carbon (%) (Walkely and Black Method, Piper, 1950)	0.51	0.55
Available N (kg ha^{-1}) (Bajaj and Singh, 1976)	186.90	170.00
Available P (kg ha^{-1}) Olsen's Method (Olsen's *et al.,* 1954)	21.60	20.20
Available K (kg ha^{-1}) (Ghosh *et al.*, 1983)	318.10	280.00

3.5 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	Kharif crop	Rabi crop
1989-90	Rice	Wheat
1990-91	Rice	Fallow
1991-92	Rice	Wheat
1992-93	Rice	Wheat
1993-94	Rice	Wheat

3.6 Experiment Details

The experiment was laid out in split plot design with three replications. The treatments consisted of eight combinations of two varieties (a conventional high yielding rice variety Pusa 834 and a hybrid rice variety NDHR 2), two plant populations which were obtained with row spacings of 20 cm and 15 cm with a uniform intra row distance of 10 cm and two planting patterns (conventional planting and skip-row planting -- skipping one row after each two rows) in main plots and three nitrogen levels 0, 60 and 120 kg N ha^{-1} in sub plots. The allocation of various treatments to different plots was done by randomization using Fisher and Yates random tables (Fisher and Yates, 1963).

3.6.1 Layout

The plan of the lay out is shown in Fig. 2 and the details are given as under

	1995	1996
Experimental Design	Split plot	Split plot
Replications	3	3
Gross plot size	3.6 m x 2.4 m	3.6 m x 2.4 m
Net plot size	2.4 m x 2.0 m	2.4 m x 2.0 m

3.5.2 Treatments

Main plot: The main plot treatments were all 8 combinations of the following factors

Varieties (V_1 , V_2)

V_1 Pusa 834

V_2 NDHR 2 (New Delhi Hybrid Rice)

Plant Population (Row Spacings)

5.00 lakhs (20 cm x 10 cm)

6.66 lakhs (15 cm x 10 cm)

Planting Patterns

Conventional planting

Skip-row planting

(Skipping one row after every two rows)

Sub Plot : Sub plot treatments were following 3 levels of nitrogen (N_0, N_1, N_2).

R-I	R-I	R-II	R-II	R-III	R-III
$V_1S_4N_0$	$V_2S_2N_2$	$V_2S_3N_0$	$V_1S_2N_2$	$V_2S_4N_0$	$V_2S_2N_2$
$V_1S_4N_1$	$V_2S_2N_0$	$V_2S_3N_1$	$V_1S_2N_0$	$V_2S_4N_2$	$V_2S_2N_0$
$V_1S_4N_2$	$V_2S_2N_1$	$V_2S_3N_2$	$V_1S_2N_1$	$V_2S_4N_1$	$V_2S_2N_1$
$V_2S_3N_0$	$V_1S_1N_0$	$V_2S_1N_2$	$V_1S_3N_1$	$V_2S_3N_1$	$V_1S_2N_0$
$V_2S_3N_2$	$V_1S_1N_2$	$V_2S_1N_0$	$V_1S_3N_2$	$V_2S_3N_2$	$V_1S_2N_2$
$V_2S_3N_1$	$V_1S_1N_1$	$V_2S_1N_1$	$V_1S_3N_0$	$V_2S_3N_0$	$V_1S_2N_1$
$V_2S_4N_2$	$V_2S_1N_2$	$V_1S_1N_0$	$V_1S_4N_0$	$V_1S_1N_0$	$V_1S_4N_0$
$V_2S_4N_0$	$V_2S_1N_1$	$V_1S_1N_2$	$V_1S_4N_1$	$V_1S_1N_2$	$V_1S_4N_1$
$V_2S_4N_1$	$V_2S_1N_0$	$V_1S_1N_1$	$V_1S_4N_2$	$V_1S_1N_1$	$V_1S_4N_2$
$V_1S_3N_0$	$V_1S_2N_2$	$V_2S_2N_0$	$V_2S_4N_0$	$V_2S_1N_0$	$V_1S_3N_2$
$V_1S_3N_2$	$V_1S_2N_1$	$V_2S_2N_2$	$V_2S_4N_1$	$V_2S_1N_1$	$V_1S_3N_0$
$V_1S_3N_1$	$V_1S_2N_0$	$V_2S_2N_1$	$V_2S_4N_2$	$V_2S_1N_2$	$V_1S_3N_1$

←2.4 m→ ← 3.6 m → R-I R-II R-III

ROAD TO GARDEN

RICE NURSERY THIS SIDE

Treatments

Main plot : (Variety x row spacing)

Variety

(i) Pusa 834 (V_1) (ii) NDHR 2 (V_2) (New Delhi Hybrid Rice) 2

Plant population (Row spacing)

(i) 20 cm - Conventional (S_1)

(ii) 20 cm - Skip-row (S_2)

(Skiping one row after every two rows)

(iii) 15 cm - Conventional (S_3)

(iv) 15 cm - Skip-row (S_4)

Sub-plot : (Levels of N)

(i) 0 kg ha^{-1} (N_0)

(ii) 60 kg ha^{-1} (N_1)

(iii) 120 kg ha^{-1} (N_2)

Fig. 2. Plan of layout of the experiment

Levels of Nitrogen (N_0, N_1, N_2)

N_0 0 Nitrogen

N_1 60 kg N ha^{-1}

N_2 120 kg N ha^{-1}

3.6.3 Important characteristics of the varieties

3.6.3.1 Pusa 834

It is a medium duration (110 days) variety developed at IARI, New Delhi in 1994 from cross of IR 50 x Pusa 33. It has an average potential of 5.0-7.0 t ha^{-1} and has long slender white grains with good cooking quality. It is moderately resistant to major pests and diseases. It is widely adaptable and has good performance under transplanting and direct seeding. It has an yield advantage of 5-37% over the best check and is tolerant to zinc deficiency and sodicity. It is resistant to blast (Pyricularia oryzae Cav.), RTV (Rice Tungro Virus), and stem borer (Scirpophaga incertulus (Walk.)). It is a fertilizer responsive, non-lodging, non shattering, photo-insensitive, profuse tillering variety; the plants attain a height of 100-110 cm. It is adopted to assured irrigated wet land conditions of Haryana, Punjab, Bihar, Western Uttar Pradesh, West Bengal and Karnataka.

3.6.3.2 NDHR 2 (New Delhi Hybrid Rice 2)

It is medium duration (110-115 days) hybrid developed at IARI, New Delhi in 1994 season and is the cross of IR 58025A x PRR 22. It has an average yield potential of 5.0-7.0 t ha^{-1} and has long slender fine grains with good cooking quality.

3.6.4 Details of cultural operations

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

Table 3.3 Schedule of cultural operations done in the rice field

Operations	Date 1995	1996
Nursery		
Nursery preparation	07-06-95	19-06-96
Sowing	09-06-95	20-06-96
Weeding and N dressing	24-06 95	06-07-96
Main Field		
Ploughing with a country plough	01-07-95	15-07-96
Puddling	03-07-95	18-07-96
Puddling	04-07-95	19-07-96
Layout and bunding	05-07-95	20-07-96
Transplanting	07-07-95	20-07-96
	08-07-95	24-07-96
Fertilizer application as basal	08-07-95	24-07-96
(SSP, MOP, Zn SO_4)		
1st dose of N application	16-07-95	02-08-96
Herbicide application/ Weeding	20-07-95	04-08-96
(Butachlor)	10-08-96	18-08-96
1st Biometric observations	15-08-95	25-08-96
2nd dose of N application	16-08-95	18-09-96
Weeding	18-08-95	20-09-96
2nd Biometric observations	19-09-95	25-09-96
3rd Biometric observations	09-10-95	17-10-96
Harvesting of border row	10-10-95	20-10-96
Harvesting of net plot	12-10-95	22-10-96
Threshing	18-10-95	28-10-96

3.6.4.1 Raising of nursery

The nursery was grown on a puddled raised beds of 10 x 1 m leaving a half meter wide irrigation cum drainage channel all around the beds. A fertilizer dose of 250 g urea + 300 g of single superphosphate + 100 g of muriate of potash were applied to each 10 m^2 bed. Sprouted seeds were broadcast uniformly on the wet nursery at the rate of 300 g per bed of 10 m^2, the seeds were covered with a thin layer of FYM. The beds were irrigated at alternate day. Fifteen days after sowing, the beds were weeded and a nitrogen dressing @ 250 g urea / 10 m^2 was given. The seedlings were grown to an age of 30 days during both the years..

3.6.4.2 Major field operations

Preparatory cultivation: The field was ploughed using a tractor driven disc harrow and puddled twice using victory and country plough and was levelled and the bunds and channels were made as per the experimental layout.

Transplanting: Two to three 30 days old seedlings were transplanted per hill as per the treatments in the 2-3 cm deep water.

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

Intercultural operations: In rice two hand weedings are done at 25-30 and 60 days after transplanting.

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

Fertilizer application: Nitrogen was applied through urea (46%N). Of the total, half nitrogen was applied 10 days after transplanting (DAT) and the remaining half was given at 40 DAT, according to the treatments. Phosphorus as single super phosphate (60 kg ha^{-1}), potassium as murate of potash (40 kg ha^{-1}), and zinc as $ZnSO_4$ (25 kg ha^{-1}) were applied basal during transplanting as per recommendations during both the years.

Plant protection measures: Endosulfan 35 EC @ 3 ml lt^{-1} of water was applied against rice gundhi bug (Leptocorisa acuta (Thumb.)) during 1995 and it was not needed during 1996.

Harvesting and threshing: The net plots after removing the crop from border rows were harvested and left to dry for 3-4 days in the field. The threshing was done with the help of pullman thresher.

3.6.5 Details of collection of data

Details of data collected during the experimental period are given below.

3.6.5.1 Biometric observations

Five plants in each plot from 4th and 6th row were randomly selected and tagged for recording plant height and tiller number per hill, at 30, 60 DAT and at harvest (90 DAT), panicles m^{-2}, panicle length, panicle weight and number of grains per panicle and thousand grain weight at harvest. For dry matter determination five plants were cut from ground level from the second row at 30, 60 DAT and at harvest (90 DAT) and dried in a hot air oven at 60^0 to a constant weight. Then the dry samples were weighed and dry matter yield quintals per hectare was computed. These dried samples were ground and kept for NPK analysis. The details for each character are discussed below.

3.6.5.2 Growth, yield and yield attributes

The following growth characters and yield attributes were recorded during the course of investigation.

Plant height (cm): The height of the five sample plants was measured from the ground level upto the tip of the longest leaf at 30 and 60 DAT and from ground level to the tip of the longest panicle at harvest (90 DAT) and the mean values were computed.

Tiller per hill: Number of tillers per hill for the sample plants were counted at 30, 60 and at harvest (90 DAT) and average number of tillers per hill were computed.

Dry matter production: Five plants were collected by cutting at the ground level from the second row onwards, leaving border rows on all sides. These plants were oven dried at 60-65^{0}c and dry weight was recorded in grams at 30, 60 and at harvest (90 DAT). Dry matter production in Q ha^{-1} was computed from the averages at 30, 60 DAT and at harvest (90 DAT).

Panicles m^{-2}: Five hills of sample plants were selected from net plots and the total number of panicles were counted and the average number of panicles m^{-2} was found out.

Panicle length (cm): The length of the panicle was measured from a sample of ten panicles drawn at random from the marked five hills. The length was measured from the neck to the tip of the panicle and the mean panicle length was computed.

Panicle weight (g): From the selected panicles, weight of the panicles was taken and the mean panicle weight was computed.

Spikelets per panicle: From the selected panicles, grains were separated and both filled and unfilled were added to get total grains per panicle and mean value was determined.

Number of filled and unfilled grains per panicle: From the selected ten panicles, grains were separated, cleaned and filled and unfilled grains were separated. The filled grains were counted with the help of a grain counting machine and unfilled grains were counted manually. The mean value of filled and unfilled grains were computed separately.

Per cent sterile spikelets: From the number of total spikelets and unfilled spikelets per panicle, the sterility per cent was worked out.

$$\% \text{ Sterile spikelets} = \frac{\text{Number of sterile spikelets}}{\text{Total spikelets}} \times 100$$

Test weight: The 1000 filled grains, counted from sample panicles were weighed and weight recorded in grams .

3.6.6 Grain and straw yield : The net plots (leaving 2 border rows on each side and 0.2 m at each end of the plot) were harvested and sun dried for four 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. Yields were expressed in quintals per hectare.

3.6.7 Harvest index: Harvest index was calculated by using the following expression (Singh and Stoskofif, 1971).

Harvest index = 100 (Economic yield / Biological yield)

Or

= 100 (Grain yield / Grain + Straw yield)

3.6.8 Chemical analysis

3.6.8.1 Soil analysis

Soil samples were collected from each plot after harvest of each crop from a depth of 0-15 cm and were analyzed for organic carbon, available phosphorus, available potassium and pH, as per methods given in Table 3.1

3.6.8.2 Plant analysis

The plant samples were dried, ground, sieved and analyzed for total nitrogen content in the plant samples at 30, 60 DAT and at harvest (90 DAT) by modified kjeldhal method (Prasad, 1982). Total phosphorus and potassium were estimated by vandomolybdo phosphoric acid yellow method and flame photometer method, respectively (Prasad, 1982) on a tri-acid digest of plant material (Johnson and Ulrich, 1959). The NPK content in straw and in grain were expressed in percentage.

Protein content in grain: Protein content in grain was obtained by multiplying N content in per cent with a factor 6.25.

Nutrient uptake: Nitrogen, phosphorus and potassium uptake by rice was calculated by multiplying their respective chemical concentrations with dry matter yields in q ha^{-1}.

Agronomic and Physiological efficiency and Apparent recovery:
Agronomic efficiency and Physiological efficiency were determined by the following expressions.

$$\text{Agronomic efficiency (AE)} = \frac{Yt - Yo}{At} \text{ kg grain / kg nutrient applied}$$

where Yt = Yield under test treatment (kg ha^{-1})

Yo = Yield under control (kg ha^{-1})

At = Units of nutrient applied in the test treatment (kg ha^{-1})

$$\text{Physiological efficiency (PE)} = \frac{Yt - Yo}{Ut - Uo}$$

where Yt = Yield under test treatment (kg ha^{-1})

Yo = Yield under control (kg ha^{-1})

Ut = Uptake of nutrient in test treatment (kg ha^{-1})

Uo = Uptake of nutrient in control plot (kg ha^{-1})

$$\text{Apparent recovery (\%)} = \frac{Nt - No}{Na}$$

where Nt = Amount of nutrient taken from tested plot (kg ha^{-1})

No = Amount of nutrient taken from the control plot (kg ha^{-1})

Na = Amount of nutrient added (kg ha^{-1})

Nutrient harvest index (%)

Nutrient harvest index (%) was given by (Austin et al.,1977)

Nutrient harvest index = 100 (N_s / N_t)

N_s = Nutrient uptake by grain at harvest

N_t = Nutrient uptake by (grain+straw) by whole plant at harvest

3.6.9 Statistical analysis

The data relating to each character were analyzed statistically by applying the technique of Analysis of Variance and the significance was tested by 'F' test (Cochran and Cox, 1957). Standard error of mean (SEm $\pm$) and critical difference (CD) at 5% level of significance were worked out for each character. The data have been illustrated graphically too, wherever needed.

4. RESULTS AND DISCUSSION

The experimental results obtained during the two years of investigation are presented in this chapter. Mean data on varieties, plant population, planting patterns and nitrogen levels are given irrespective of their statistical significance. Also data are presented for significant interactions

4.1 Growth Characters

4.1.1 Plant height

The data on plant height as influenced by varieties, plant population, planting patterns and nitrogen levels at different stages of crop growth (30, 60 DAT and at harvest) are presented in Table 4.1.

Varieties: Traditional variety Pusa 834 and rice hybrid NDHR 2 did not significantly differ in respect of plant height during both the years of study at all stages of crop growth.

Plant population and Planting patterns: These factors also did not significantly affect the plant height during either year of study, at all stages of crop growth. In general, closer spacing tended to produce taller plants than wider spacing. These results are in conformity with the findings of Kalyankutty *et al.* (1969), Shahi *et al.* (1976), Reddy (1978), Sahu and Lenka (1986), Gulati *et al.* (1987), Shah *et al.* (1991), Moorthy and Saha (1996).

Nitrogen: During both the years of study plant height increased with increasing levels of N upto 120 kg N ha^{-1}. At 30 DAT, in 1995, application of 60 kg N ha^{-1} produced significantly taller plants than control, there being no significant increase when the

Table 4.1. Effect of varieties, row spacings, planting patterns and nitrogen levels on plant height (cm) of rice.

Treatments	1995			1996		
	30DAT	60DAT	At harvest	30DAT	60DAT	At harvest
Varieties						
Pusa 834	68.2	95.1	95.9	65.0	93.8	94.7
NDHR 2	69.3	96.2	97.5	67.7	93.7	94.3
SEm ±	1.61	0.99	0.82	1.17	1.46	1.41
CD 5%	NS	NS	NS	NS	NS	NS
Row Spacings (cm)						
20	69.2	95.0	95.8	65.9	92.0	93.4
15	68.2	96.2	96.6	66.7	95.4	95.6
SEm ±	1.61	0.99	0.82	1.17	1.46	1.4
CD 5%	NS	NS	NS	NS	NS	NS
Planting Patterns						
Conventional	67.8	94.4	95.8	65.7	94.3	95.0
Skip-row	69.7	96.8	96.6	66.9	93.2	93.9
SEm ±	1.61	0.99	0.82	1.17	1.46	1.4
CD 5%	NS	NS	NS	NS	NS	NS
N Levels (kg ha^{-1})						
0	64.6	92.9	94.1	64.3	91.3	92.2
60	69.5	96.0	96.2	66.0	94.3	94.9
120	72.1	98.0	98.3	68.9	95.7	96.3
SEm ±	1.47	0.70	0.53	0.76	0.66	0.75
CD 5%	4.24	2.02	1.53	2.19	1.91	2.17

DAT : Days After Transplanting

level of N was raised to 120 kg N ha^{-1} However, in 1996, a significant increase in plant height was observed only when 120 kg N ha^{-1} was applied. During either year of study, at 60 DAT the trend of results were same as 30DAT in 1995. At 90 DAT each successive level of N increased plant height significantly in 1995, while in 1996, 60 kg N ha^{-1} significantly increased rice plant height over control, there being no significant increase when the level of N was raised to 120 kg N ha^{-1}

An increase in plant height due to N application has been reported by a number of workers (Kalyanikutty and Morachan, 1974; Manickam and Ramaswami, 1985; Pandey and Singh, 1985; Karel Marx, 1986; Sharma and Mittra, 1988; Singh *et al.*, 1991; Bhattacharya and Singh, 1992; Dahatonde, 1992; Shukla *et al.*, 1993; Thakur, 1993a).

4.1.2 Number of tillers

The data on tillers $hill^{-1}$ at 30, 60 DAT and at harvest are presented in Table 4.2.

Varieties, Plant population, Planting patterns and Nitrogen levels: None of the factors studied significantly influenced number of tillers $hill^{-1}$ in the present study. Only at harvest in 1995, skip-row planting produced significantly more tillers than conventional planting. Even nitrogen application did not significantly increase the number of tillers $hill^{-1}$.

Thus these results differ from those reported by a number of researchers (Bathkal and Patil, 1970; Kupkanchankeel and Vergara, 1980, Sharma and Prasad, 1984; Manickam and Ramaswami, 1985; Karel Marx, 1986; Ramesh, 1989; Schnier et al. 1990; Udaya Bhaskar, 1990; Singh *et al.*, 1991; Bhattacharya and Singh, 1992; Rao *et al.*, 1993; Pradeep *et al.*, 1994), who have reported an increase in the number of tillers $hill^{-1}$ in rice due to N fertilization.

Table 4.2. Effect of varieties, row spacings, planting patterns and nitrogen levels on tillering in rice (number hill^{-1})

Treatments	1995			1996		
	30DAT	60DAT	At harvest	30DAT	60DAT	At harvest
Varieties						
Pusa 834	8.2	9.1	9.6	9.4	8.9	8.8
NDHR 2	7.9	8.3	9.3	8.5	8.8	8.8
SEm ±	0.44	0.48	0.66	0.43	0.34	0.33
CD 5%	NS	NS	NS	NS	NS	NS
Row Spacings (cm)						
20	8.1	9.5	9.8	8.9	8.9	9.1
15	7.5	8.3	9.2	8.5	8.6	9.1
SEm ±	0.44	0.48	0.66	0.43	0.34	0.33
CD 5%	NS	NS	NS	NS	NS	NS
Planting Patterns						
Conventional	7.9	8.3	8.3	8.0	8.1	8.8
Skip-row	8.5	8.8	10.6	9.3	9.4	9.4
SEm ±	0.44	0.48	0.66	0.43	0.34	0.33
CD 5%	NS	NS	2.00	NS	NS	1.01
N Levels (kg ha^{-1})						
0	7.4	7.7	9.2	8.5	8.6	8.9
60	9.0	9.0	9.9	8.8	8.8	8.9
120	8.3	8.8	9.3	9.4	8.8	9.0
SEm ±	0.32	0.28	0.44	0.26	0.18	0.17
CD 5%	NS	NS	NS	NS	NS	NS

DAT : Days After Transplanting

4.1.3 Dry matter production

The data on dry matter accumulation by the crop at various crop growth stages (30, 60 DAT and at harvest) are presented in Table 4.3 and Fig. 3a & b.

Varieties: At all stages of crop growth, rice hybrid NDHR 2 produced significantly more dry matter as compared to traditional variety Pusa 834 except at 60 DAT during 1995, when the differences were not significant. During 1996 traditional variety Pusa 834 and rice hybrid NDHR 2 did not differ significantly in respect of dry matter accumulation at different stages of crop growth, except at harvest when NDHR 2 produced significantly more dry matter. Thus in general heterosis was positive in respect of dry matter.

A number of earlier workers have reported positive heterosis in hybrid rice for dry matter production, which is due to higher root activity (Rao *et al.*, 1985; Yen and Hu, 1986; Blanco *et al.*, 1990; Yamauchi, 1994).

Plant population: Higher plant population (closer spacing of 15 cm) produced significantly more dry matter compared to lower plant population (wider spacing of 20 cm) at all stages of crop growth during both the years of study, except at harvest during 1996, when the differences were not significant. These results are as one would generally expect. Wagh and Thorat (1987) also reported significantly higher dry matter production in rice at closer spacing of 15 x 10 cm.

Planting patterns: Planting patterns did not differ significantly in respect of dry matter accumulation at all stages of crop growth except at 60 DAT during both the years of study, when skip-row planting produced significantly higher dry matter as compared to conventional planting.

These results are in accord from those reported by De *et al.* (1984) who observed that dry matter accumulated per unit area was slightly high (5%) in skip-row plots, planted 20 cm apart.

Table 4.3. Effect of varieties, row spacings, planting patterns and nitrogen levels on dry matter production (q ha^{-1}) of rice.

	1995			1996		
Treatments	30DAT	60DAT	At harvest	30DAT	60DAT	At harvest
Varieties						
Pusa 834	18.7	82.0	127.0	18.0	86.3	104.2
NDHR 2	23.1	88.7	141.7	18.4	86.5	115.3
SEm ±	1.17	4.49	3.22	1.12	1.83	3.62
CD 5%	3.56	NS	9.77	NS	NS	10.98
Row Spacings (cm)						
20	17.8	76.2	128.6	14.2	78.8	109.7
15	24.0	94.6	140.1	22.2	94.0	109.8
SEm ±	1.17	4.49	3.22	1.12	1.83	3.62
CD 5%	3.56	13.63	9.77	3.40	5.55	NS
Planting Patterns						
Conventional	20.1	74.4	136.1	16.9	82.6	111.6
Skip-row	20.7	96.4	132.6	19.4	90.1	107.9
SEm ±	1.17	4.49	3.22	1.12	1.83	3.62
CD 5%	NS	13.63	NS	NS	5.55	NS
N Levels (kg ha^{-1})						
0	15.4	65.2	114.5	12.5	76.0	92.6
60	21.4	88.7	137.0	18.1	86.1	110.2
120	26.0	102.2	151.6	23.8	97.0	126.4
SEm ±	0.82	2.95	1.44	0.73	0.93	2.22
CD 5%	2.49	8.94	4.36	2.21	2.83	6.73

DAT : Days After Transplanting

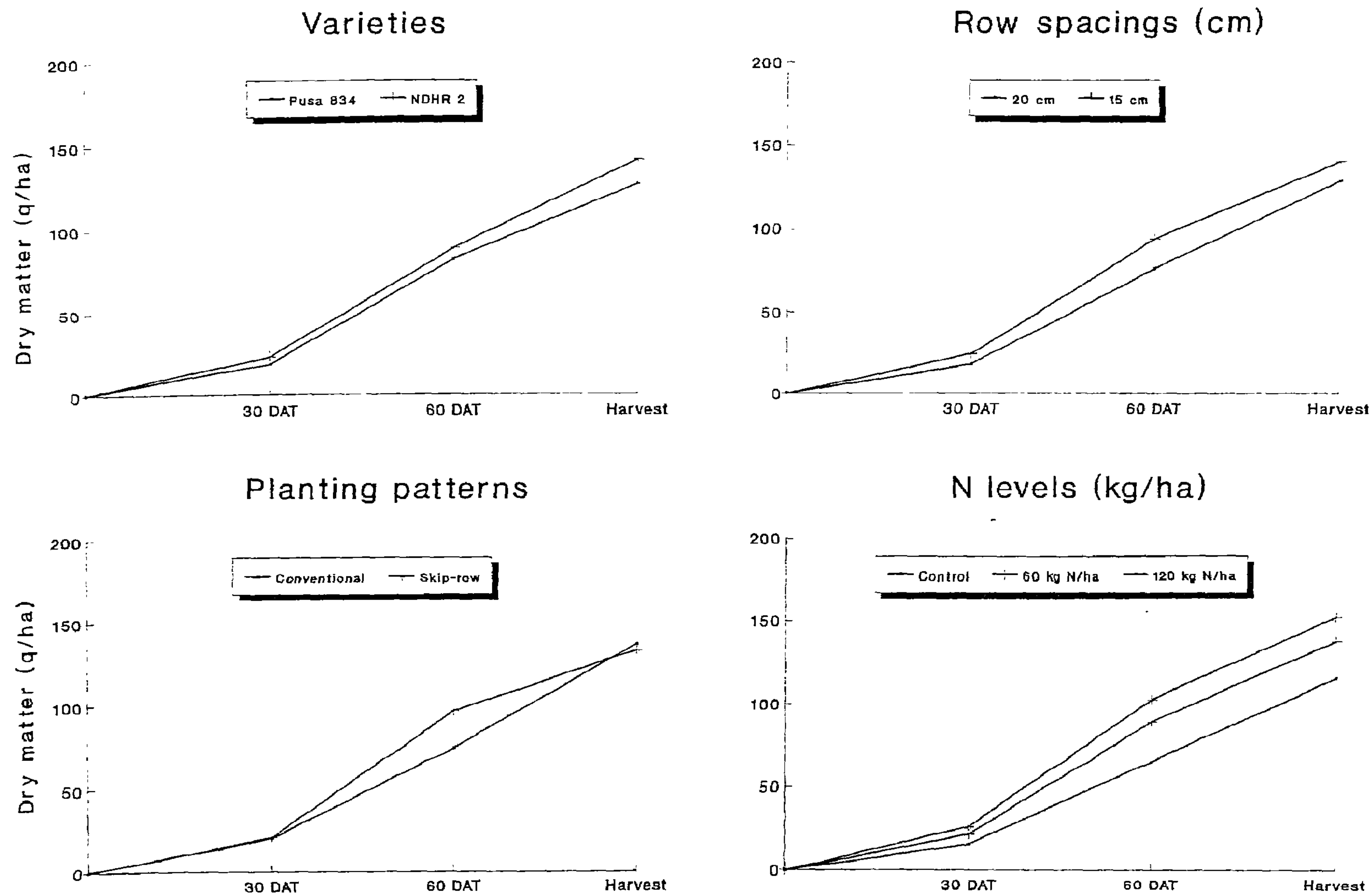

Fig. 3a. Dry matter production (q/ha) of *rice as influenceda by varieties*, row spacings, planting patterns and nitrogen levels during 1995

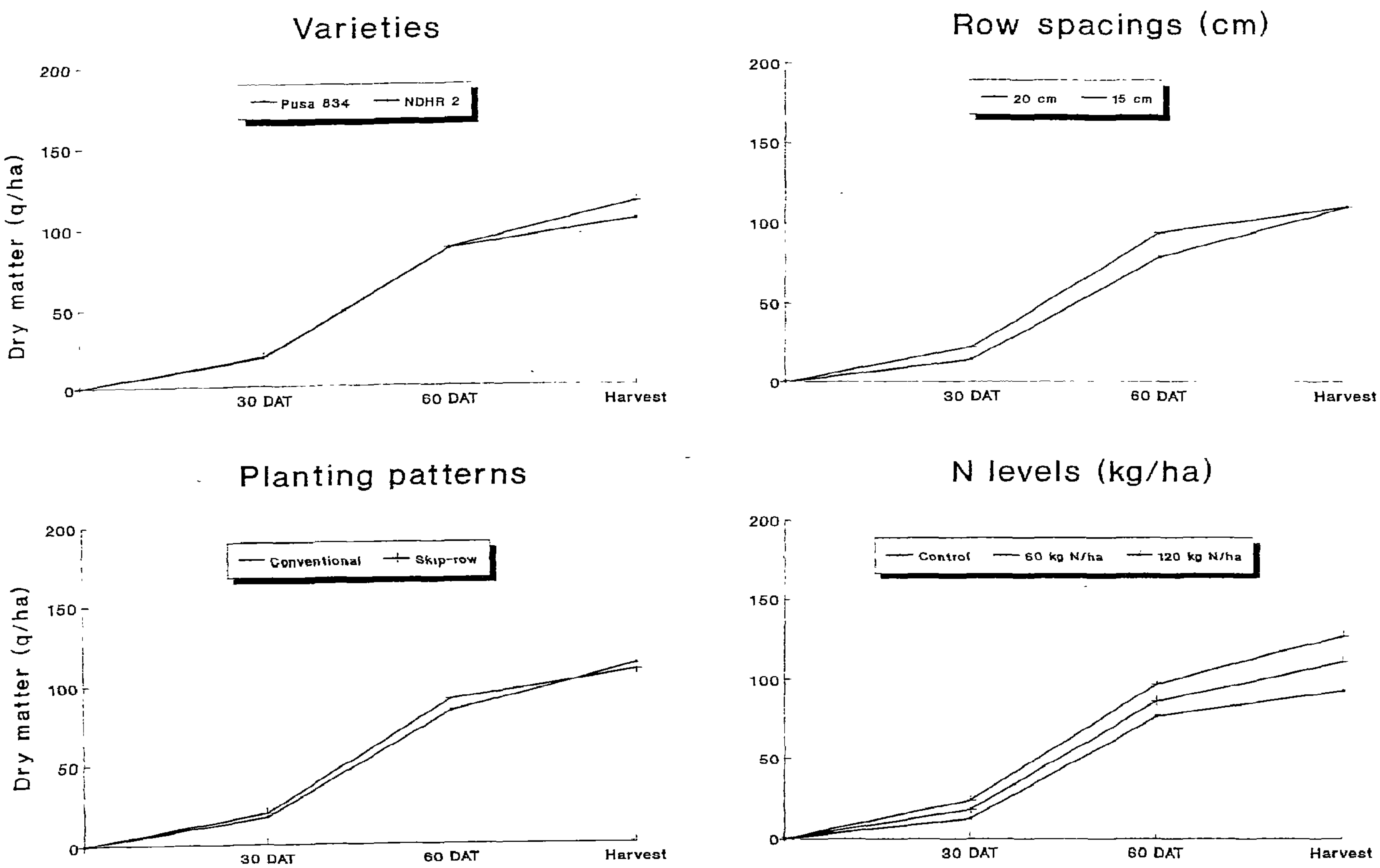

Fig. 3b. Dry matter production (q/ha) of rice as influenced by varieties, row spacings, planting patterns and nitrogen levels during 1996

Row spacings x Planting patterns Interaction: It was found significant at 60 DAT in 1996 (Table 4.4) and showed that in conventional planting, 15 cm spacing produced significantly more dry matter than 20 cm spacing, whereas skip-row planting did not.

Table 4.4 Effect of row spacings on dry matter production (q ha^{-1}) of rice as influenced by planting patterns at 60 days after transplanting (1996).

	Planting patterns	
Row spacings (cm)	Conventional	Skip-row
20	71.2	86.4
15	94.0	93.9
SEm ±	2.59	
CD 5%	7.85	

Nitrogen: During both the years of study, dry matter of rice significantly increased with each successive increase in nitrogen level upto 120 kg N ha^{-1} at all stages of crop growth. Several research workers (Sharma and Prasad, 1980; Upadhyaya and Pathak, 1981; Agasimani *et al.*, 1983; Ramasamy *et al.*, 1985, Karel Marx, 1986; Schnier *et al.*, 1990; Sharma *et al.*, 1990; Udaya Bhaskar, 1990; Thakur, 1993a; Padmaja Rao, 1995) reported an increase in dry matter production with increasing levels of nitrogen.

4.2. Yield Attributes

4.2.1 Panicles

The data on panicles m^{-2} as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.5.

Varieties: Traditional variety Pusa 834 produced significantly more panicles m^{-2} as compared to rice hybrid NDHR 2 during 1995, however, the differences were not significant during 1996.

Row spacings: Closer spacing of 15 x 10 cm resulted in significantly more panicles m^{-2} than with wider spacing of 20 x 10 cm during both the years of study.

Table 4.5 Effect of varieties, row spacing, planting patterns and nitrogen levels on yield attributes of rice.

Treatments	Panicles m^{-2} (No.)		Panicle weight (g)		Panicle length (cm)		Filled spikelets $panicle^{-1}$		Sterile spikelets $panicle^{-1}$		Total spikelets $panicle^{-1}$		Sterility (%)		Test weight (g)	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
Varieties																
Pusa 834	338.3	256.1	2.30	2.61	23.2	22.9	101.5	115.4	41.3	36.3	142.8	151.7	29.3	21.8	22.7	22.7
NDHR 2	321.6	257.3	2.90	3.19	25.0	23.9	130.8	140.4	57.3	40.8	188.1	181.2	30.1	23.7	22.2	23.1
SEm ±	4.00	2.99	0.04	0.08	0.18	0.40	1.55	3.26	1.86	3.32	2.96	4.70	0.92	1.52	0.08	0.10
CD 5%	12.20	NS	0.11	0.25	0.54	NS	4.70	9.90	5.64	NS	8.95	14.24	NS	NS	0.24	NS
Row Spacing (cm)																
20	316.1	246.9	2.61	2.90	23.9	23.2	117.1	135.7	49.3	40.4	166.4	176.1	29.5	23.1	22.3	22.9
15	343.7	266.4	2.58	2.91	24.3	23.6	115.2	126.1	49.3	36.6	164.5	162.7	29.9	22.5	22.5	23.0
SEm ±	4.00	2.99	0.04	0.08	0.18	0.40	1.55	3.26	1.86	3.32	2.96	4.70	0.92	1.52	0.08	0.10
CD 5%	12.20	9.07	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting Patterns																
Conventional	321.6	258.8	2.51	2.83	24.1	23.6	111.6	123.6	44.6	40.1	156.2	163.7	28.6	24.2	22.3	22.9
Skip-row	338.2	254.6	2.68	2.97	24.1	23.2	120.7	138.2	43.9	37.0	164.6	175.2	30.8	21.3	22.6	23.0
SEm ±	4.00	2.99	0.04	0.08	0.18	0.40	1.55	3.26	1.86	3.32	2.96	4.70	0.92	1.52	0.08	0.10
CD 5%	12.20	NS	0.11	NS	NS	NS	4.70	9.90	5.64	NS	8.95	NS	NS	NS	NS	NS
N Levels ($kg\ ha^{-1}$)																
0	296.5	228.3	2.48	2.73	23.9	23.0	111.5	125.6	48.6	45.5	160.1	171.1	33.2	27.2	22.3	22.8
60	337.0	255.2	2.60	2.94	24.0	23.4	115.1	134.3	50.4	37.8	165.5	172.1	30.5	22.7	22.6	22.9
120	356.2	286.6	2.70	3.04	24.4	23.7	121.8	132.8	48.8	32.3	170.6	165.1	25.4	18.4	22.3	23.2
SEm ±	2.20	3.11	0.07	0.08	0.23	0.33	3.25	4.00	1.83	1.99	4.54	4.69	0.68	0.85	0.10	0.12
CD 5%	6.70	9.43	0.21	0.25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

These results are in conformity with the findings of Venkateswarulu and Singh (1980), Thorat *et al.* (1983), Reddy and Ghosh (1984), Singh *et al.* (1985), Wei and Lin (1986), Jones and Snyder (1987), Tsai (1987), Wagh and Thorat (1987), Aragones and Wada (1989), Sharma and Singh (1992) and Sharma (1994).

Varieties x Row spacings: Varieties and row spacings interaction was found significant in 1996 (Table 4.6) and showed that traditional variety Pusa 834 produced significantly more number of panicles with closer spacing of 15 cm than with wider spacing of 20 cm, whereas, rice hybrid NDHR 2 did not.

Table 4.6 Effect of varieties on panicles m^{-2} of rice as influenced by row spacings (1996)

	Row spacings (cm)	
Varieties	**20**	**15**
Pusa 834	238.0	274.1
NDHR 2	255.9	258.8
SEm ±	4.23	
CD 5%	12.83	

Planting patterns: In 1995, skip-row method of planting produced significantly more panicles m^{-2} than conventional method, however, there was no significant difference between the two methods of planting in 1996.

Varieties x Planting patterns Interaction: Planting patterns interacted significantly with varieties in 1995 and 1996 (Table 4.7) and Pusa 834 had significantly lesser panicles m^{-2} in skip-row planting than in conventional planting. These results are in conformity with the findings of De *et al.* (1984) and Moorthy and Saha (1996).

Table 4.7 Effect of varieties on panicles m^{-2} of rice as influenced by planting patterns

Varieties	Planting patterns Conventional		Skip-row
		1995	
Pusa 834	358.7		317.8
NDHR 2	325.4		317.7
SEm ±		5.70	
CD 5%		17.20	
		1996	
Pusa 834	262.8		249.3
NDHR 2	254.8		259.8
SEm ±		4.23	
CD 5%		12.83	

Nitrogen: With each successive increment in the level of nitrogen there was significant increase in the number of panicles m^{-2} in both the years of study. Similar results were reported by several research workers (Raju and Rao, 1984; Varshney, 1986).

Varieties x Nitrogen: This interaction was significant only in 1995, when at no nitrogen varieties did not differ significantly, whereas at 60 and 120 kg N ha^{-1} Pusa 834 produced significantly more panicles than NDHR 2 (Table 4.8).

Table 4.8 Effect of varieties on panicles m^{-2} of rice as influenced by nitrogen levels (1995)

Varieties	Nitrogen levels (kg N ha^{-1}) 0	60	120
Pusa 834	300.6	351.8	362.3
NDHR 2	292.5	322.5	350.1
SEm ±		3.10	
CD 5%		8.95	

Row spacings x Nitrogen: As already discussed closer spacing (15 cm) produced significantly more panicles than wider spacing (20 cm) in both the years (Table 4.5). Furthermore in 1995 the number of panicles produced with 15 cm row spacing even at 60 kg N ha^{-1} were significantly more than with 20 cm row spacing at 120 kg N ha^{-1} (Table 4.9).

Table 4.9 Effect of row spacings on panicles m^{-2} of rice as influenced by nitrogen levels (1995)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	287.9	320.4	340.1
15	305.2	353.6	372.3
SEm ±		3.10	
CD 5%		8.95	

Planting patterns x Nitrogen Interaction: As in the case of closer spacing, in 1995 in skip-row planting significantly more panicles were produced in control and at 120 kg N ha^{-1} but at 60 kg N ha^{-1} the differences were not significant. Furthermore the number of panicles produced at 60 kg N ha^{-1} with skip-row planting were on par with the number of panicles produced at 120 kg N ha^{-1} with conventional planting. In 1996 a significant difference between the two planting patterns was found only in control plots, when conventional planting produced significantly more panicles m^{-2} (Table 4.10).

Table 4.10 Effect of planting patterns on panicles m^{-2} of rice as influenced by nitrogen levels

	Nitrogen levels (kg N ha^{-1})		
Planting patterns	**0**	**60**	**120**
		1995	
Conventional	284.2	333.2	347.6
Skip-row	308.9	340.8	364.8
SEm ±		3.10	
CD 5%		8.95	
		1996	
Conventional	237.4	256.1	283.0
Skip-row	219.2	254.3	290.3
SEm ±		4.40	
CD 5%		12.70	

4.2.2 Panicle weight

The data on panicle weight (g) in rice as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.5.

Varieties: Rice hybrid NDHR 2 produced heavier panicles than Pusa 834. Similar results of positive heterosis for panicle weight were reported by IRRI (1984), Lokaprakash *et al.* (1992).

Plant population and Planting patterns : Plant population had no significant influence on panicle weight of rice during both the years of study Skip-row planting produced heavier panicles than conventional planting, however, the differences were significant only during 1995.

Plant population x Planting patterns Interaction: It was found significant during 1995, which showed that 15 cm row spacing with skip-row planting produced significantly heavier panicles as compared to conventional planting with either spacings (Table 4.11).

Table 4.11 Effect of row spacings on panicle weight (g) of rice as influenced by planting patterns (1995)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	2.61	2.61
15	2.41	2.76
SEm ±	0.050	
CD 5%	0.150	

Nitrogen: Significantly heavier panciles over control were obtained only when 120 kg N ha^{-1} was applied during both the years of study.

4.2.3 Panicle length

The data on panicle length (cm) as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.5.

Varieties: Traditional variety Pusa 834 and rice hybrid NDHR 2 did not significantly differ in respect of panicle length of rice, except in 1995, when NDHR 2 produced significantly longer panicles than Pusa 834.

Several researchers showed that hybrids when compared to standard check varieties showed positive and significant heterosis for panicle length (IRRI, 1984; Subramanian and Sivasubramanian, 1986; Lokaprakash *et al.*, 1992).

Varieties x Planting patterns: This interaction was found significant during 1995 (Table 4.12) and showed that NDHR 2 with either of the planting patterns produced significantly longer panicles than Pusa 834.

Table 4.12 Effect of varieties on panicle length (cm) of rice as influenced by planting patterns (1995)

	Planting patterns	
Varieties	**Conventional**	**Skip-row**
Pusa 834	22.9	23.5
NDHR 2	25.3	24.7
SEm ±	0.25	
CD 5%	0.76	

Plant population, Planting patterns and Nitrogen levels: None of these factors studied significantly influenced panicle length of rice in the present study. A few earlier research workers (Singh *et al.*, 1985; Venugopal and Singh, 1985; Shah *et al.*, 1991) have also reported significant effect of plant population on panicle length.

On the other hand number of workers have reported increase in panicle length due to N fertilization (Srivastava and Singh, 1971; Sharma and Prasad, 1982; Sharma and Prasad, 1984; Karel Marx, 1986; Dalai and Dixit, 1987; Thakur, 1989; Raju *et al.*, 1990; Udaya Bhaskar, 1990; Singh *et al.*, 1991; Shukla *et al.*, 1993; Kanungo and Roul, 1994).

4.2.4 Filled spikelets panicle^{-1}

The data on filled spikelets panicle^{-1} as influenced by varieties, plant population, planting patterns and nitrogen levels are presented in Table 4.5.

Varieties: Rice hybrid NDHR 2 produced significantly more filled spikelets per panicle than Pusa 834, during both the years of study. These results are in conformity with the findings of several workers (IRRI, 1984; Yen and Hu, 1986; Sahai *et al.*, 1987; Malik *et al.*, 1988; Lokaprakash *et al.*, 1992).

Plant population: Plant population had no significant effect on filled spikelets panicle^{-1}, however, lower plant population (wider spacing of 20 cm) had a tendency to produce more filled spikelets panicle^{-1} than higher population (closer spacing of 15 cm) during both the years of study. These results are in conformity with the findings of Padmaja Rao (1995).

Planting patterns: Skip-row planing produced significantly more filled spikelets than conventional planting, during 1995 and 1996. Similar results are reported by De *et al.* (1984).

Varieties x Planting patterns: Varieties and planting patterns interaction was found significant during 1995 (Table 4.13) and showed that rice hybrid NDHR 2 produced significantly more fillled spikelets panicle^{-1} than Pusa 834 in either of the planting patterns studied.

Table 4.13 Effect of varieties on filled spikelets panicle^{-1} of rice as influenced by planting patterns (1995)

Varieties	Planting patterns: Conventional	Planting patterns: Skip-row
Pusa 834	98.7	104.3
NDHR 2	124.4	137.1
SEm ±	6.64	
CD 5%	9.22	

Nitrogen: With each successive incrément in the level of nitrogen, number of filled spikelets per panicle increased, but differences were not significant during both the years of study.

A number of earlier workers reported an increase in filled spikelets with an increase in N fertilization (Manickam and Ramaswami, 1985; Karel Marx, 1986; Dalai and Dixit, 1987; Saikia *et al.*, 1988; Udaya Bhaskar, 1990; Thakur, 1993a).

4.2.5 Sterile spikelets panicle^{-1}

Varieties: Rice hybrid NDHR 2 produced significantly more sterile spikelets than traditional variety Pusa 834 during 1995, however, the differences were not significant during 1996.

Similar results were reported by number of earlier workers (Rao *et al.*, 1985; Subramanian and Sivasubramanian, 1986; Prakash and Mahadevappa, 1987; Paramasivan and Sreerangaswamy, 1990).

Plant population and Planting patterns: Plant population and planting patterns had no significant influence on number of sterile spikelets panicle^{-1} during both the years of study, except in 1996 when skip-row planting produced significantly more sterile spikelets than conventional planting.

Nitrogen: With an increase in the level of nitrogen, number of sterile spikelets panicle^{-1} decreased, however, the differences were not significant except during 1996, where control plot produced significantly higher number of sterile spikelets panicle^{-1}.

Row spacings x Nitrogen: This interaction was found significant during 1996 (Table 4.14) and showed that control plot produced significantly more sterile spikelets with 20 cm row spacing than with 15 cm row spacing.

Table 4.14 Effect of row spacings on sterile spikelets panicle^{-1} of rice as influenced by nitrogen levels (1996)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	0	60	120
20	51.7	36.4	33.3
15	39.3	39.2	31.3
SEm ±		2.82	
CD 5%		8.10	

4.2.6 Total spikelets panicle^{-1}

The data on total spikelets panicle^{-1} as influenced by varieties, plant population, planting patterns and nitrogen levels are presented in Table 4.5.

Varieties: Rice hybrid NDHR 2 produced significantly more spikelets panicle^{-1} than traditional variety Pusa 834, during both the years of study.

Row spacings: Wider spacing of 20 cm produced more spikelets panicle^{-1} than closer spacing of 15 cm, however, the differences were significant only during 1996.

Several researchers reported more spikelets panicle^{-1} with wider spacing (Rathi *et al.* 1984; Reddy and Ghosh, 1984; Jones and Snyder, 1987; Singh *et al.*, 1987; Padmaja Rao, 1995).

Planting patterns: Planting patterns studied did not differ significantly in number of total spikelets panicle^{-1}, except in 1995 when skip-row planting produced significantly more spikelets panicle^{-1} than conventional planting.

Varieties x Planting patterns Interaction: It was found significant during 1995 (Table 4.15) and showed that NDHR 2 produced significantly more spikelets panicle^{-1} than Pusa 834 in either of the planting patterns studied.

Table 4.15 Effect of varieties on total spikelets of rice as influenced by planting patterns (1995)

Varieties	Planting patterns	
	Conventional	Skip-row
Pusa 834	136.1	145.4
NDHR 2	171.8	199.7
SEm ±	4.17	
CD 5%	12.66	

Nitrogen: With an increase in the level of nitrogen spikelets panicle^{-1} increased with 60 kg N ha^{-1}, thereafter, it decreased with 120 kg nitrogen application, however, the differences were not significant during both the years of study.

A number of workers have obtained increase in number of spikelets panicle^{-1} due to N fertilization (Srivastava and Singh, 1971; Singh *et al.*, 1979; Sharma and Prasad, 1984; Manickam and Ramaswami, 1985; Karel Marx, 1986; Dalai and Dixit, 1987; Saikia *et al.*, 1988; Thakur, 1989; Udaya Bhaskar, 1990; Shukla *et al.*, 1993; Thakur, 1993a).

4.2.7 Per cent Sterile Spikelets

The data on per cent sterile spikelets as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.5.

Varieties: Traditional variety Pusa 834 and rice hybrid NDHR 2 did not significantly differ in respect of per cent sterile spikelets during both the years of study. However NDHR 2 produced more percentage of sterile spikelets than Pusa 834 during both years of study.

Row spacings and Planting patterns: These two factors also did not significantly influenced the percentage sterile spikelets during both the years of study.

Nitrogen: With each successive increase in the level of nitrogen there was a significant decrease in the percentage of sterile spikelets, during both the years of study.

A number of earlier workers reported that per cent filled spikelets were less with higher rates of fertilizer-N (Ramesh, 1989; Chau and Deshmukh, 1991; Deshmukh and Chau, 1992).

4.2.8 1000-grain weight

The data on 1000-grain weight (g) as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.5.

Varieties: Rice hybrid NDHR 2 produced significantly higher 1000-grain weight than traditional variety Pusa 834 during 1995, however, the differences were not significant during 1996. Similar results of significant positive heterosis for 1000-grain weight (test weight) was reported by several workers (IRRI, 1984; Rao *et al.*, 1985; Lokaprakash *et al.*, 1992).

Plant population, Planting patterns and Nitrogen levels: These factors did not differ signfiicantly on 1000-grain weight during both the years of study, however, with an increase in the level of nitrogen, 1000-grain weight increased.

A number of workers obtained increase in 1000-grain weight due to N fertilization (Sharma and Prasad, 1984; Dalai and Dixit, 1987; Saikia *et al.*, 1988; Thakur, 1989; Reddy and Reddy, 1989; Udaya Bhaskar, 1990; Chau and Deshmukh, 1991; Thakur, 1993a; Shukla *et al.*, 1993; Kanungo and Roul, 1994). Gowda *et al.* (1989) however, reported no change in test weight with increasing levels of fertilizer nitrogen

4.3 Yield

4.3.1 Grain yield

The data on grain yield (q ha^{-1}) as influenced by varieties, plant population, planting patterns and nitrogen levels are presented in Table 4.16 and Fig. 4.

Varieties: Traditional variety Pusa 834 and rice hybrid NDHR 2 did not differ significantly in respect of grain yield during both the years of study.

Table 4.16. Effect of varieties, row spacing, planting patterns and nitrogen levels on grain, straw yield and harvest index of rice.

	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
Treatments	1995	1996	Pooled data	1995	1996	Pooled data	1995	1996	Pooled data
Varieties									
Pusa 834	49.9	39.6	44.8	89.6	66.3	78.5	40.3	38.3	39.3
NDHR 2	47.6	39.1	43.4	97.1	75.5	86.3	35.5	34.4	35.0
SEm ±	0.88	1.02	0.67	1.95	1.33	1.18	0.75	1.20	0.71
CD 5%	NS	NS	NS	5.91	4.03	3.42	2.27	3.63	2.04
Row Spacing (cm)									
20	47.3	39.0	43.2	87.3	70.3	78.8	37.6	36.6	37.1
15	50.2	39.8	45.0	99.4	71.5	85.5	38.2	36.1	37.2
SEm ±	0.88	1.02	0.67	1.95	1.33	1.18	0.75	1.20	0.71
CD 5%	2.66	NS	NS	5.91	NS	3.42	NS	NS	NS
Planting Patterns									
Conventional	49.0	40.4	44.7	94.1	70.0	82.1	36.9	36.8	36.8
Skip-row	48.5	38.3	43.4	92.6	71.8	82.2	38.9	35.9	37.4
SEm ±	0.88	1.02	0.67	1.95	1.33	1.18	0.75	1.20	0.71
CD 5%	NS	NS	NS	NS	NS	3.42	NS	NS	NS
N Levels (kg ha^{-1})									
0	44.2	31.1	37.7	77.2	56.5	66.9	39.1	34.7	36.9
60	48.8	39.9	44.4	95.0	71.6	83.3	38.0	36.8	37.4
120	53.2	47.2	50.2	107.9	84.6	96.3	36.6	37.7	37.2
SEm ±	0.42	0.75	0.65	1.29	1.02	1.24	0.63	1.04	0.92
CD 5%	1.27	2.28	1.89	3.90	3.09	3.59	NS	NS	NS

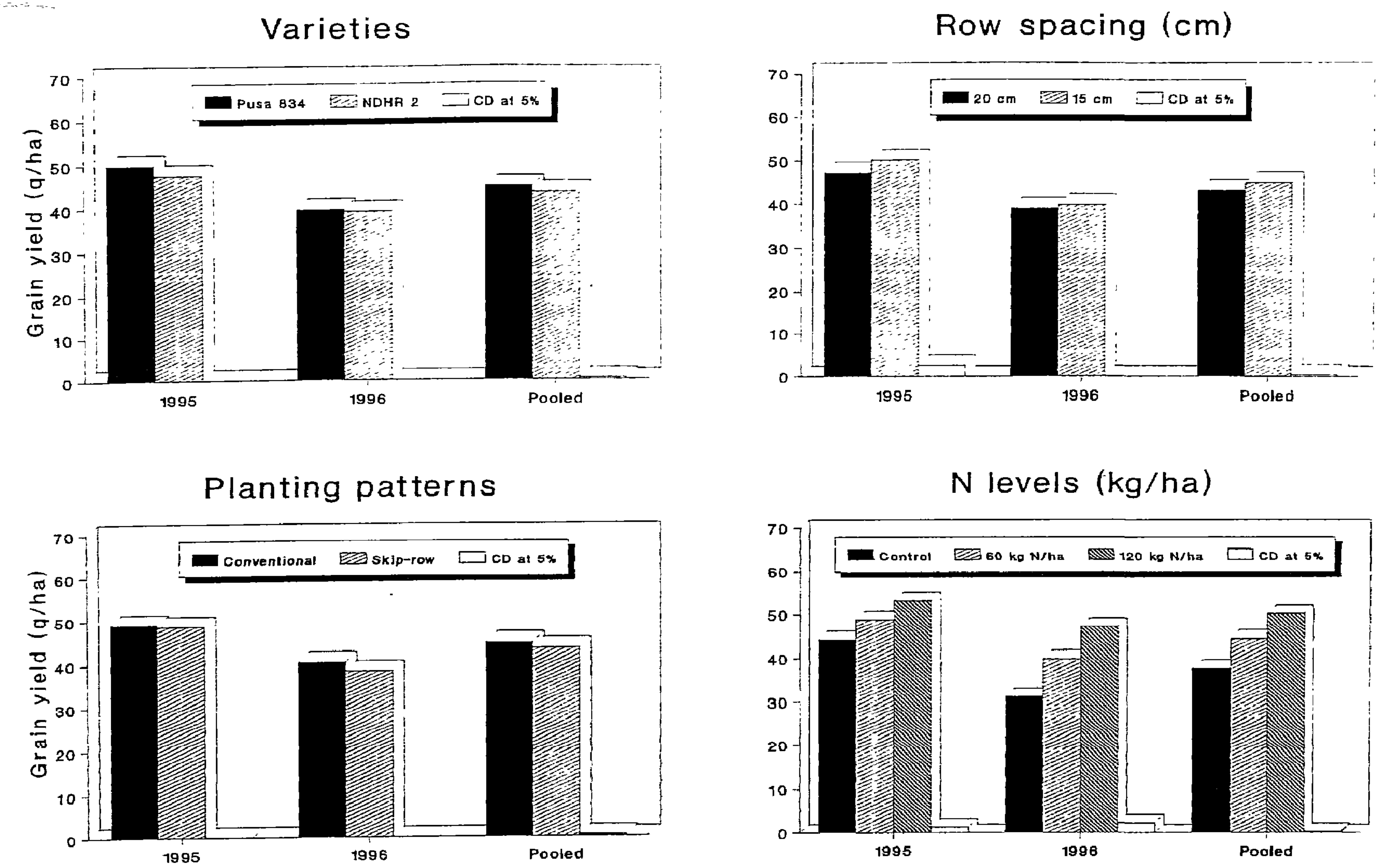

Fig. 4. Grain yield of rice (q/ha) as influenced by varieties, row spacings, planting patterns and nitrogen levels

Plant population: Higher plant population obtained with a closer spacing of 15 x 10 cm significantly increased grain yield during 1995, however, the differences were not significant during 1996.

A number of earlier workers obtained increased grain yields due to narrow spacing of 15 x 10 cm over wider spacing of 20 x 10 cm (Sewaram *et al.*, 1973; Singh and Singh, 1973; Kumar *et al.*, 1975; Patil *et al.*, 1979; Varshney, 1986; Wagh and Thorat, 1987; Raju *et al.*, 1989; Singh *et al.*, 1989).

Planting patterns: Planting patterns did not significantly differ in respect of grain yield, during both the years of study.

Plant population x Planting patterns: This interaction was found significant during 1995 (Table 4.17) and showed that in conventional planting, 15 cm spacing produced significantly higher grain yield than 20 cm spacing, whereas the skip-row planting did not.

Table 4.17 Effect of row spacings on grain yield (q ha^{-1}) of rice as influenced by planting patterns (1995)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	46 2	48.4
15	51.9	48.6
SEm ±	1.24	
CD 5%	3.77	

Varieties x Planting patterns Interaction: It was found significant during 1996 and was given in Table 4.18 and showed that traditional variety Pusa 834 produced significantly more grain yield with conventional planting than with skip-row planting, whereas NDHR 2 did not.

Table 4.18 Effect of varieties on grain yield (q ha^{-1}) of rice as influenced by planting patterns (1996)

Varieties	Planting patterns	
	Conventional	Skip-row
Pusa 834	42.6	36.7
NDHR 2	38.3	40.0
SEm ±	1.45	
CD 5%	4.39	

Nitrogen: There was a significant increase in grain yield of both the varieties of rice with each successive increment in the level of nitrogen, highest grain yield being obtained at 120 kg N ha^{-1}.

Similar increase in grain yield due to nitrogen (Vlek *et al.*, 1979; Fagi and De Datta, 1981; Sharma *et al.*, 1990; Narang *et al.*, 1990; Dhal and Misra, 1993; Pandey and Tripathi, 1994; Devaraju *et al.*, 1996; Singh *et al.*, 1996a), potassium (Pande *et al.*, 1993; Sagwal and Vijay Kumar, 1994; Singh *et al.*, 1994) fertilization had been reported.

Varieties x Nitrogen interaction was not found significant during both the years of study.

Plant population x Nitrogen Interaction: It was found significant during 1996 (Table 4.19). As already discussed spacing did not significantly influenced the grain yield during both the years of study, but the application of 120 kg N ha^{-1} with 20 cm spacing was significantly superior to all levels, and also 15 cm spacing with 120 kg N ha^{-1} was being on par with it. Furthermore, 60 kg N ha^{-1} with 20 cm spacing produced significantly higher grain yield than 15 cm spacing with 60 kg N ha^{-1}.

Table 4.19 Effect of row spacings on grain yield (q ha^{-1}) of rice as influenced by nitrogen levels (1996)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	29.6	42.1	48.7
15	32.7	38.6	45.7
SEm ±		1.07	
CD 5%		3.09	

Balasubramaniyan (1985) obtained significant interaction between spacing and N application. He reported significant increase in grain yield with an increase in N both at 15 x 10 cm spacing and 20 x 10 cm spacing.

4.3.2 Straw yield

The data on straw yield (q ha^{-1}) as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.16 and Fig. 5.

Varieties: Rice hybrid NDHR 2 produced significantly more straw than Pusa 834 in both the years of study.

Plant population: Higher plant population produced significantly more straw than lower plant population during 1995, however, the differences were not significant during 1996.

Planting patterns: Planting patterns did not differ significantly in respect of straw yield during both the years of study.

Plant population x Planting patterns Interaction: It was found significant during 1996 and was given in Table 4.20. In skip-row planting, 20 cm row spacing gave significantly more straw yield than 15 cm spacing, whereas in conventional planting the tendency was reverse.

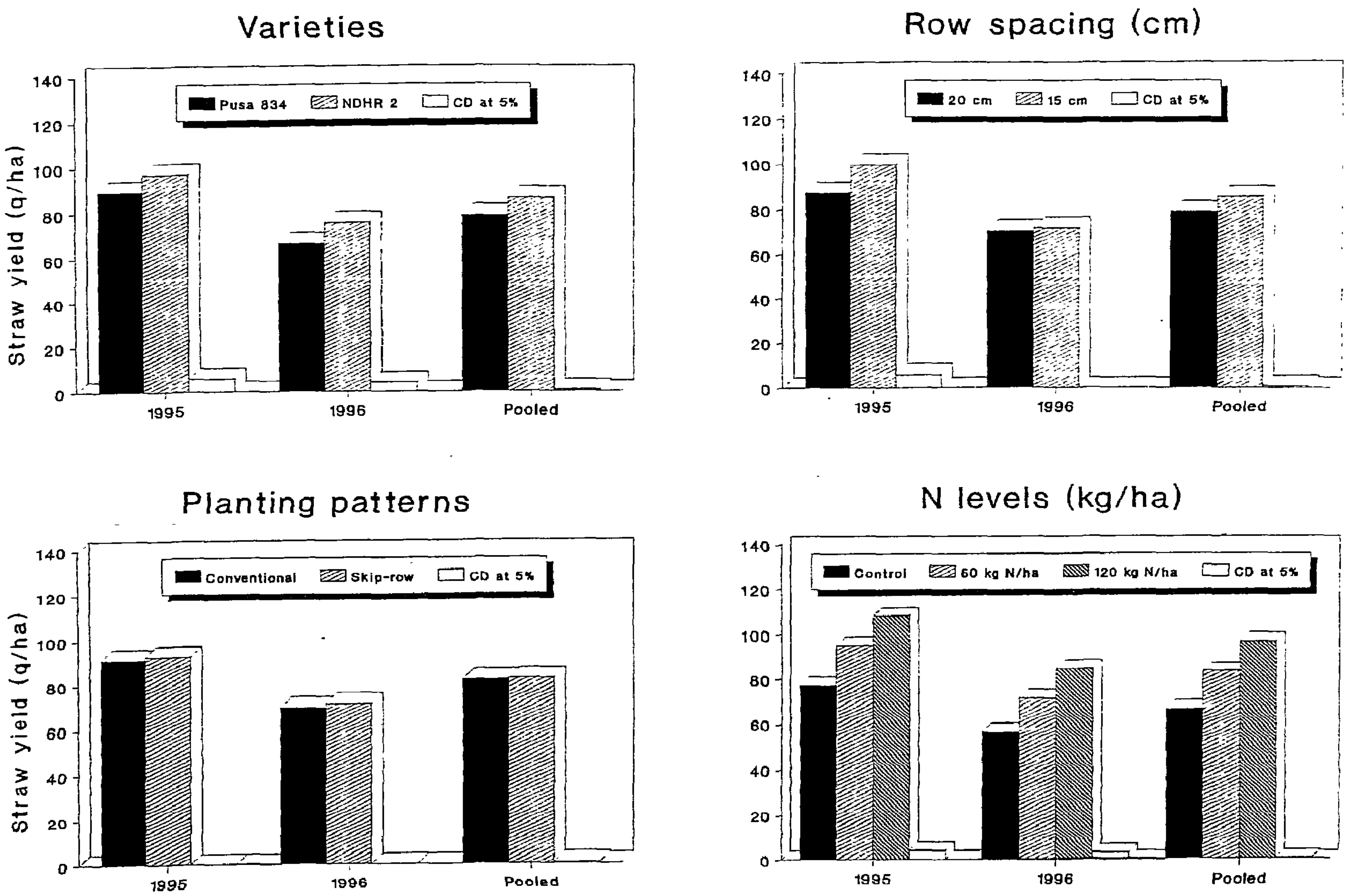

Fig. 5. Straw yield of rice (q/ha) as influenced by varieties, row spacings, planting patterns and nitrogen levels

Table 4.20 Effect of row spacing on straw yield (q ha^{-1}) of rice as influenced by planting patterns (1996)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	63.6	77.1
15	76.5	66.5
SEm ±	1.88	
CD 5%	5.70	

Nitrogen: There was a significant increase in straw yield of rice due to each successive increment of 60 kg N ha^{-1} upto 120 kg N ha^{-1} in both the years of study.

A number of workers have reported an increase in straw yield due to N (Rajale and Prasad, 1975; Singh *et al.*, 1979; Prasad and Prasad, 1980; Prasad *et al.*, 1982; Rao and Raju, 1987; Thakur, 1989; Udaya Bhaskar, 1990; Rai *et al.*, 1991; Mongia, 1992; Murthy *et al.*, 1992; Robinson, 1992; Shukla *et al.*, 1993; Thakur, 1993a; Kanungo and Roul, 1994), while others reported an increase in straw yield due to combined application of NP (Sharma and Mittra, 1990), NPK (Singh *et al.*, 1994).

Varieties x Nitrogen Interaction: It was found significant during 1995 (Table 4.21) and showed that rice hybrid NDHR 2 produced significantly more straw only with no nitrogen than Pusa 834 with same level of nitrogen, but did not differ significantly in their straw yield at 60 kg N ha^{-1} and at 120 kg N ha^{-1}.

Table 4.21 Effect of varieties on straw yield (q ha^{-1}) of rice as influenced by nitrogen levels (1995)

	Nitrogen levels (kg N ha^{-1})		
Varieties	**0**	**60**	**120**
Pusa 834	70.3	93.1	105.5
NDHR 2	84.1	96.8	110.3
SEm ±		1.82	
CD 5%		5.26	

Plant population x Nitrogen Interaction: It was found significant during 1995 (Table 4.22) and showed that 15 cm spacing produced significantly more straw yield at all levels of nitrogen except in control than 20 cm spacing. Furthermore straw yield produced with 15 cm row spacing even at 60 kg N ha^{-1} were being on par with 20 cm row spacing at 120 kg N ha^{-1}.

Table 4.22 Effect of row spacings on straw yield (q ha^{-1}) of rice as influenced by nitrogen levels (1995)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	74.6	87.6	99.8
15	79.8	102.3	116.0
SEm ±		1.82	
CD 5%		5.26	

4.2.3 Harvest index

The data on harvest index (%) as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.16.

Varieties: Traditional variety Pusa 834 gave significantly higher harvest index than rice hybrid NDHR 2 during both the years of study.

The results are in conformity with the findings of Yamauchi *et al.* (1985) who reported lower harvest index in hybrids than in pure lines and Rao *et al.* (1985) reported no significant heterosis for harvest index.

In contrast some researchers reported that hybrids have positive and significant heterosis for harvest index than compared to either of parents or standard check varieties (IRRI, 1984; Lokaprakash *et al.*, 1992).

Plant population, Planting patterns and Nitrogen levels: None of the factors studied significantly influenced harvest index during both the years of study. There was a decrease in harvest index with an increase in the level of nitrogen, which was due to an increase in biological yield without any increase in economic yield. A decrease in harvest index due to increase in N fertilizer have also been reported by Biswas and Bhattacharya (1987), George (1987), Gulati *et al.* (1987), Narang *et al* (1990), Chau and Deshmukh (1991) and Panda and Rao (1991).

4.4 Nutrient Content

4.4.1 Nitrogen concentration

The data on nitrogen concentration (%) of rice as influenced by varieties, plant population, planting patterns and nitrogen levels are presented in Table 4.23.

Varieties: At 30 DAT, during both the years of study rice hybrid NDHR 2 recorded significantly higher nitrogen content than Pusa 834. On the other hand at 60 DAT in 1996 and at harvest in straw in 1995, Pusa 834 recorded significantly higher N concentration than NDHR 2. The differences between the varieties were not significant at other stages of crop growth. Thus while in the initial stages of growth rice hybrid NDHR 2 recorded higher N content, later on Pusa 834 caught up it.

Row spacings: Nitrogen concentration was not significantly influenced by the row spacings studied with both the varieties of rice at all stages of crop growth, in either year of study except at 30 DAT during 1995 and at 30 and 60 DAT during 1996, when closer row spacing of 15 cm recorded higher nitrogen content than wider row spacing of 20 cm.

Varieties x Row spacings Interaction: It was found significant during 1995 at harvest in rice straw and at 60 DAT during 1996 (Tables 4.24 & 4.25) and showed that Pusa 834 recorded significantly higher N content than NDHR 2 at 15 cm row spacing in 1995, and at 20 cm row spacing in 1996.

Table 4.23 Effect of varieties, row spacings, planting patterns and nitrogen levels on nitrogen content (%) of rice.

	1995				1996			
Treatments	30DAT	60DAT	Grain	Straw	30DAT	60DAT	Grain	Straw
Varieties								
Pusa 834	1.44	0.92	1.16	0.44	1.47	0.99	0.99	0.50
NDHR 2	1.57	0.90	1.14	0.40	1.59	0.93	1.00	0.49
SEm ±	0.020	0.045	0.019	0.008	0.009	0.016	0.010	0.007
CD 5%	0.061	NS	NS	0.024	0.026	0.047	NS	NS
Row Spacings (cm)								
20	1.46	0.85	1.16	0.43	1.51	0.93	1.01	0.50
15	1.55	0.96	1.15	0.41	1.55	0.99	0.98	0.49
SEm ±	0.020	0.045	0.019	0.008	0.009	0.016	0.010	0.007
CD 5%	0.061	NS	NS	NS	0.026	0.047	NS	NS
Planting Patterns								
Conventional	1.51	0.88	1.16	0.44	1.55	0.94	1.00	0.50
Skip-row	1.50	0.93	1.15	0.40	1.50	0.98	0.99	0.49
SEm ±	0.020	0.045	0.019	0.008	0.009	0.016	0.010	0.007
CD 5%	NS	NS	NS	0.024	0.026	NS	NS	NS
N Levels (kg Nha^{-1})								
0	1.42	0.86	1.06	0.37	1.49	0.88	0.91	0.48
60	1.50	0.87	1.16	0.43	1.53	0.97	1.02	0.49
120	1.59	0.99	1.24	0.46	1.56	1.03	1.04	0.51
SEm ±	0.014	0.021	0.011	0.006	0.009	0.009	0.010	0.007
CD 5%	0.042	0.063	0.032	0.019	0.027	0.026	0.030	0.023

DAT : Days After Transplanting

Table 4.24 **Effect of varieties on nitrogen content (%) of rice straw as influenced by row spacings (1995)**

Varieties	Row spacings (cm) 20		15
Pusa 834	0.43		0.44
NDHR 2	0.43		0.38
SEm +		0.011	
CD 5%		0.035	

Table 4.25 **Effect of varieties on nitrogen content (%) of rice as influenced by row spacings at 60 days after transplanting (1996)**

	Row spacings (cm)		
Varieties	20		15
Pusa 834	0 99		0.98
NDHR 2	0.88		0.99
SEm ±		0.022	
CD 5%		0.067	

Planting patterns: Planting patterns also did not differ significantly in respect of nitrogen content, at all stages of crop growth during both the years of study, except at harvest in rice straw during 1995 and at 30 DAT in 1996, when conventional planting recorded significantly higher nitrogen content than skip-row planting.

Varieties x Planting patterns Interaction: It was found significant during both years of study at 30 DAT (Table 4.26), where with conventional planting, rice hybrid NDHR 2 recorded significantly higher nitrogen content than Pusa 834.

Table 4.26 **Effect of varieties on nitrogen content (%) of rice as influenced by planting patterns at 30 days after transplanting**

	Planting patterns		
Varieties	Conventional		Skip-row
		1995	
Pusa 834	1.40		1.48
NDHR 2	1.63		1.51
SEm +		0.028	
CD 5%		0.086	
		1996	
Pusa 834	1.46		1.48
NDHR 2	1.65		1.53
SEm ±		0.012	
CD 5%		0.037	

Row spacings x Planting patterns Interaction: It was found significant at harvest in rice straw during 1995 and at 30 and 60 DAT during 1996 (Table 4.27, 4.28 and 4.29).

In 1995, nitrogen content in straw in conventional planting was significantly more with 20 cm spacing than with 15 cm spacing, while tendency was reverse in skip-row planting.

Table 4.27 Effect of row spacings on nitrogen content (%) of rice straw as influenced by planting patterns (1995)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	0.47	0.39
15	0.40	0.42
SEm ±	0.011	
CD 5%	0.035	

In 1996, N content in plant tissue at 30 DAT was significantly more with 15 cm spacing than with 20 cm spacing in conventional planting, there being no significant difference in the two spacings with skip-row planting. However, at 60 DAT the two spacings studied did not differ significantly in conventional planting, while in skip-row planting, 15 cm row spacing gave significantly higher N content than 20 cm row spacing.

Table 4.28 Effect of row spacings on nitrogen content (%) of rice as influenced by planting patterns at 30 days after transplanting (1996)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	1.50	1.51
15	1.61	1.49
SEm ±	0.012	
CD 5%	0.037	

Table 4.29 Effect of row spacings on nitrogen content (%) of rice as influenced by planting patterns at 60 days after transplanting (1996)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	0.95	0.92
15	0.94	1.04
SEm ±	0.022	
CD 5%	0.067	

Nitrogen: With each successive increment in the level of nitrogen there was a significant increase in the nitrogen content of both the varieties of rice at all stages of crop growth during both the years of study.

Sharma and Prasad (1980) and Patnaik *et al.* (1982) reported similar results that increased rate of N application resulted in increased N content of plants

Varieties x Nitrogen Interaction: This was found significant at 30 DAT during both the years of study and at 60 DAT in 1995 and are presented in Table 4.30 and 4.31.

Table 4.30 Effect of varieties on nitrogen content (%) of rice as influenced by nitrogen levels at 30 days after transplanting during 1995 and 1996.

	Nitrogen levels (kg N ha^{-1})		
Varieties	**0**	**60**	**120**
		1995	
Pusa 834	1.33	1.42	1.56
NDHR 2	1.50	1.59	1.63
SEm +		0.020	
CD 5%		0.060	
		1996	
Pusa 834	1.42	1.46	1.53
NDHR 2	1.57	1.59	1.61
SEm ±		0.013	
CD 5%		0.039	

During both years of study, N content in plant tissue at 30 DAT was significantly higher with rice hybrid NDHR 2 than Pusa 834 at all levels of nitrogen application. Furthermore, in 1995 N content recorded by rice hybrid NDHR 2 was significantly more even in control than Pusa 834 at 60 kg N application, however, in 1996, rice hybrid NDHR 2 at 60 kg N ha^{-1} also recorded significantly higher N content than Pusa 834 at 120 kg N ha^{-1}.

In 1995, at 60 DAT, Pusa 834 recorded significantly higher nitrogen content than NDHR 2 at 120 kg N application, however, the differences were not significant at other levels of nitrogen application.

Table 4.31 Effect of varieties on nitrogen content (%) of rice as influenced by nitrogen levels at 60 days after transplanting (1995)

	Nitrogen levels (kg N ha^{-1})		
Varieties	**0**	**60**	**120**
Pusa 834	0.89	0.83	1.04
NDHR 2	0.84	0.91	0.94
SEm ±		0.029	
CD 5%		0.084	

Row spacings x Nitrogen Interaction: It was found significant at 60 DAT during both the years of study and in rice straw in 1995 and in rice grain in 1996 and were given in Tables 4.32, 4.33 and 4.34.

During both the years of study, N content recorded at 60 DAT in 15 cm spacing was significantly more than in 20 cm spacing both in control and with 60 kg N application. However two spacings studied did not differ significantly at 120 kg nitrogen application.

Table 4.32 Effect of row spacings on nitrogen content (%) of rice as influenced by nitrogen levels at 60 days after transplanting

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
		1995	
20	0.79	0.78	0.98
15	0.94	0.95	1.00
SEm ±		0.029	
CD 5%		0.084	
		1996	
20	0.83	0.94	1.03
15	0.93	0.99	1.03
SEm ±		0.012	
CD 5%		0.035	

In straw, at both the levels of nitrogen, 20 cm spacing recorded significantly higher nitrogen content than 15 cm spacing, during 1995.

Table 4.33 Effect of row spacings on nitrogen content (%) of rice starw as influenced by nitrogen levels (1995)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	0.37	0.44	0.48
15	0.38	0.41	0.44
SEm ±		0.009	
CD 5%		0.026	

In 1996, nitrogen content in grain was significantly higher with 20 cm spacing than with 15 cm spacing in control, however the differences due to spacings were not significant when nitrogen was applied.

Table 4.34 Effect of row spacings on nitrogen content (%) of rice grain as influenced by nitrogen levels (1996)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	0.95	1.03	1.05
15	0.88	1.01	1.04
SEm ±		0.010	
CD 5%		0.029	

4.4.2 Phosphorus content

The data on phosphorus content (%) as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.35.

Varieties: Rice hybrid NDHR 2 recorded significantly higher phosphorus content than Pusa 834 at all stages of crop growth in both the years of study except at 30 and 60 DAT in 1995, when the differences were not significant. These results are in conformity with the findings of Chengxiu and Shangxian (1988).

Row spacings: Row spacings had no significant influence on phosphorus content at all stages of crop growth in 1995, but the differences were significant at all the stages of crop growth during 1996, when 15 cm row spacing recorded significantly higher phosphorus content.

Planting patterns: Planting patterns did not differ significantly in respect of phosphorus content during both the years of study, at all stages of crop growth, except at 30 DAT, when conventional planting recorded significantly higher P content than skip-row planting and at harvest in rice grain and straw during 1996, when skip-row planting recorded significantly higher phosphorus content than conventional planting.

Nitrogen: With each successive increase in the level of nitrogen, there was a significant increase in the phosphorus content in both the years of study, at all stages of crop growth except at 30 DAT in 1995, 60 DAT in 1995 and 1996 and in rice grain during 1996, when the differences were not significant.

Table 4.35. Effect of varieties, row spacings, planting patterns and nitrogen levels on phosphorus content (%) of rice.

	1995				1996			
Treatments	30DAT	60DAT	Grain	Straw	30DAT	60DAT	Grain	Straw
Varieties								
Pusa 834	0.248	0.226	0.184	0.074	0.257	0.227	0.196	0.085
NDHR 2	0.255	0.224	0.199	0.089	0.263	0.236	0.211	0.101
SEm ±	0.0003	0.0003	0.0005	0.0005	0.0010	0.0003	0.0005	0.0003
CD 5%	NS	NS	0.0014	0.0014	0.0020	0.0010	0.0014	0.0010
Row Spacings (cm)								
20	0.249	0.218	0.185	0.079	0.257	0.230	0.197	0.091
15	0.253	0.221	0.198	0.083	0.263	0.233	0.209	0.095
SEm ±	0.0003	0.0003	0.0005	0.0005	0.001	0.0003	0.0005	0.0003
CD 5%	NS	NS	NS	NS	0.002	0.0010	0.0014	0.0010
Planting Patterns								
Conventional	0.252	0.220	0.191	0.080	0.261	0.230	0.197	0.092
Skip-row	0.251	0.220	0.192	0.083	0.259	0.233	0.209	0.094
SEm ±	0.0003	0.0003	0.0005	0.0005	0.0010	0.0003	0.0005	0.0003
CD 5%	NS	NS	NS	NS	0.0020	NS	0.0014	0 0010
N Levels (kg ha^{-1})								
0	0.248	0.217	0.185	0.075	0.258	0.228	0.196	0.087
60	0.251	0.220	0.191	0.082	0.260	0.231	0.202	0.093
120	0.255	0.223	0.199	0.087	0.263	0.235	0.211	0.099
SEm ±	0.0003	0.0003	0.0007	0.0004	0.0010	0.0003	0.0007	0.0003
CD 5%	NS	NS	0.0021	0.0012	0.0020	NS	NS	0.0010

DAT : Days After Transplanting

Table 4.36. Effect of varieties, row spacings, planting patterns and nitrogen levels on potassium content (%) of rice.

Treatments	1995				1996			
	30DAT	60DAT	Grain	Straw	30DAT	60DAT	Grain	Straw
Varieties								
Pusa 834	1.83	1.31	0.27	1.31	1.85	1.28	0.27	1.37
NDHR 2	1.95	1.27	0.27	1.30	1.81	1.26	0.26	1.37
SEm ±	0.036	0.028	0.001	0.034	0.050	0.030	0.001	0.040
CD 5%	0.108	NS	NS	NS	NS	NS	NS	NS
Row Spacings (cm)								
20	1.84	1.30	0.28	1.30	1.84	1.27	0.27	1.38
15	1.93	1.29	0.27	1.32	1.82	1.26	0.26	1.36
SEm ±	0.036	0.028	0.001	0.034	0.050	0.030	0.001	0.040
CD 5%	NS	NS	0.004	NS	NS	NS	0.003	NS
Planting Patterns								
Conventional	1.90	1.26	0.27	1.30	1.83	1.25	0.26	1.37
Skip-row	1.87	1.32	0.27	1.30	1.84	1.28	0.27	1.38
SEm ±	0.036	0.028	0.001	0.034	0.050	0.030	0.001	0.040
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS
N Levels (kg ha^{-1})								
0	1.74	1.13	0.26	1.16	1.66	1.13	0.25	1.19
60	1.89	1.28	0.27	1.30	1.84	1.26	0.27	1.37
120	2.03	1.47	0.28	1.45	2.00	1.41	0.27	1.56
SEm ±	0.025	0.018	0.002	0.018	0.020	0.020	0.001	0.020
CD 5%	0.075	0.054	0.005	0.055	0.060	0.050	0.004	0.070

DAT : Days After Transplanting

4.4.3 Potassium content

The data on potassium content (%) as influenced by varieties, plant population, planting patterns and nitrogen levels are presented in Table 4.36.

Varieties: Traditional variety Pusa 834 and rice hybrid NDHR 2 did not differ significantly in respect of potassium content at all stages of crop growth, during both the years of study, except at 30 DAT during 1995, when rice hybrid NDHR 2 recorded significantly higher potassium content than Pusa 834.

Row spacings: Row spacings had no significant influence on potassium content of rice during both the years of study at all stages of crop growth except in rice grain, when 20 cm row spacing recorded significantly higher potassium content than 15 cm row spacing.

Planting patterns: Planting patterns did not differ significantly in respect of potassium content at all stages of crop growth during both the years of study.

Row spacings x Planting patterns Interaction: This was found significant at harvest in rice grain during both the years of study and data are presented in Table 4.37 which showed that in both years of study, 20 cm row spacing recorded significantly higher potassium content than 15 cm row spacing in conventional planting, whereas the skip-row planting did not.

Table 4.37 Effect of row spacings on potassium content (%) of rice grain as influenced by planting patterns

	Planting patterns		
Row spacings (cm)	Conventional		Skip-row
		1995	
20	0.28		0.27
15	0.27		0.27
SEm ±		0.002	
CD 5%		0.005	
		1996	
20	0.27		0.27
15	0.26		0.27
SEm ±		0.002	
CD 5%		0.005	

Nitrogen: With each successive increase in the level of nitrogen, there was a significant increase in the potassium content of both the varieties of rice at all stages of crop growth, during both the years of study.

Row spacings x Nitrogen Interaction: It was found significant at 60 DAT during 1995 (Table 4.38) and showed that with either of the spacings there was a significant increase in the K content upto 120 kg N ha^{-1}.

Table 4.38 Effect of row spacings on potassium content (%) of rice as influenced by nitrogen levels at 60 days after transplanting (1995)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	1.13	1.25	1.50
15	1.13	1.31	1.43
SEm ±		0.025	
CD 5%		0.072	

4.5 Nutrient Uptake

4.5.1 Nitrogen uptake

The data on nitrogen uptake (kg ha^{-1}) as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.39 and Fig. 6a & b.

Varieties: Traditional variety Pusa 834 and rice hybrid NDHR 2 did not differ significantly in respect of nitrogen uptake during both the years of study, at all stages of crop growth except at 30 DAT in 1995 and at harvest in rice straw during 1996, when rice hybrid NDHR 2 recorded significantly higher N uptake than Pusa 834. Whereas, in 1995 at harvest in rice grain Pusa 834 recorded significantly higher N uptake than NDHR 2 during 1995.

These results are in conformity with the findings of Sta *et al.* (1994) who reported that hybrids have higher N uptake compared to their inbred parents particularly at 30 DAT, however, this differential uptake was not observed at 60 DAT.

Table 4.38. Effect of varieties, row spacings, planting patterns and nitrogen levels on nitrogen uptake (kg ha^{-1}) of rice.

	1995				1996			
Treatments	30DAT	60DAT	Grain	Straw	30DAT	60DAT	Grain	Straw
Varieties								
Pusa 834	27.6	78.0	58.3	39.6	26.7	85.5	39.2	66.1
NDHR 2	36.5	77.7	54.5	39.3	29.4	80.9	38.8	75.0
SEm ±	1.91	5.29	1.03	1.27	1.98	1.71	1.14	1.47
CD 5%	5.79	NS	3.12	NS	NS	NS	NS	4.47
Row Spacings (cm)								
20	27.7	65.4	55.0	38.1	21.6	73.7	39.7	71.4
15	37.5	90.3	57.8	40.8	34.6	92.6	38.3	69.7
SEm ±	1.91	5.29	1.03	1.27	1.98	1.71	1.14	1.47
CD 5%	5.79	16.05	NS	NS	5.99	5.20	NS	NS
Planting Patterns								
Conventional	31.3	66.2	56.5	41.1	26.5	77.9	40.3	70.6
Skip-row	32.9	89.5	56.3	37.8	29.7	88.5	37.7	70.5
SEm ±	1.91	5.29	1.03	1.27	1.98	1.71	1.14	1.47
CD 5%	NS	16.05	NS	NS	NS	5.20	NS	NS
N Levels (kg ha^{-1})								
0	22.1	53.1	46.8	28.7	18.5	67.0	30.0	51.2
60	32.4	75.9	56.8	40.3	28.4	82.7	39.0	72.7
120	41.7	104.6	66.5	49.4	37.3	99.7	48.0	87.7
SEm ±	1.39	1.68	0.65	0.58	1.27	1.00	0.72	1.10
CD 5%	4.22	14.18	1.98	1.76	3.84	3.03	2.18	3.33

DAT : Days After Transplanting

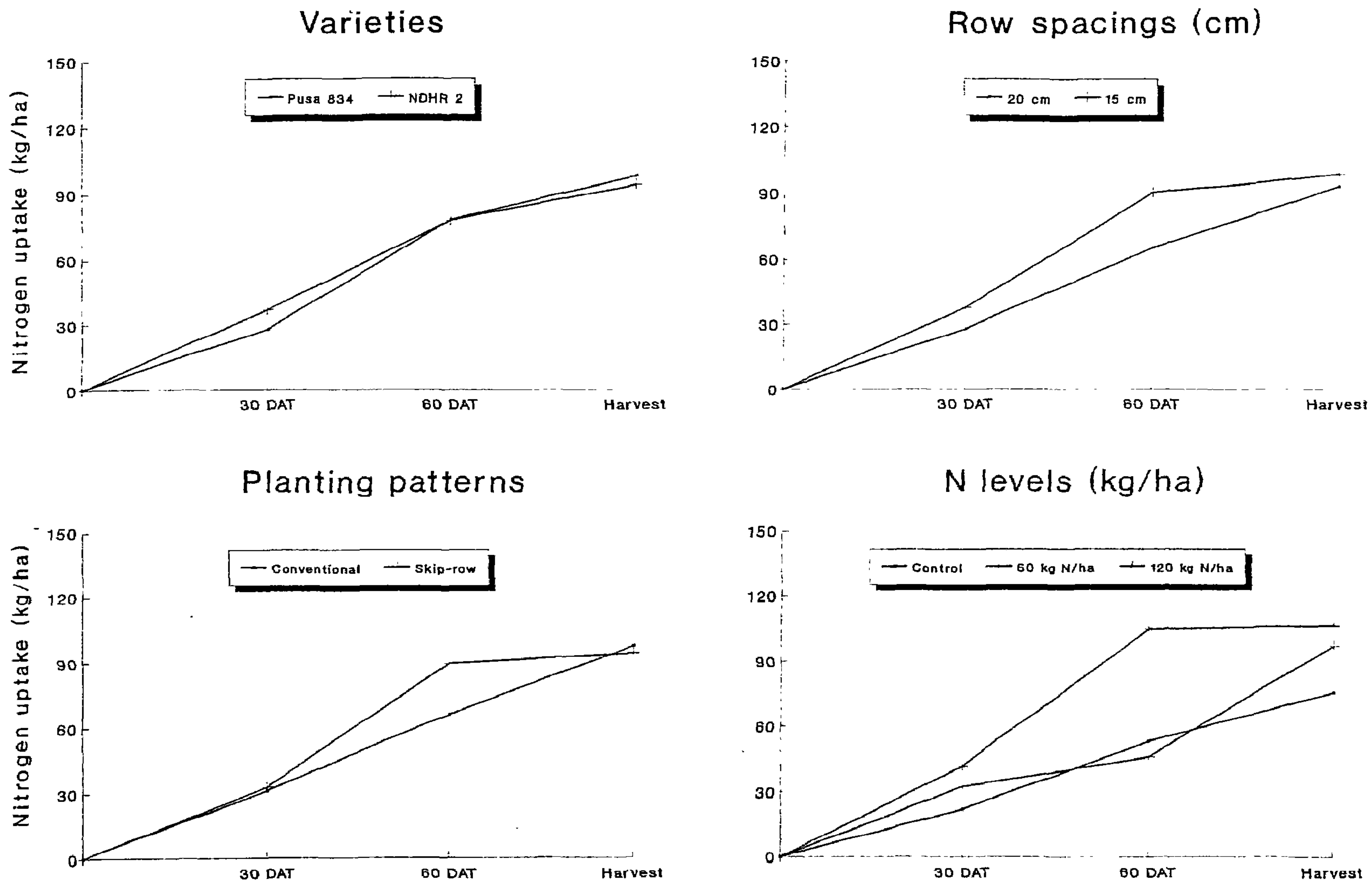

Fig. 6a. Nitrogen uptake (kg/ha) of rice as influenced by varieties, row spacings, planting patterns and nitrogen levels during 1995

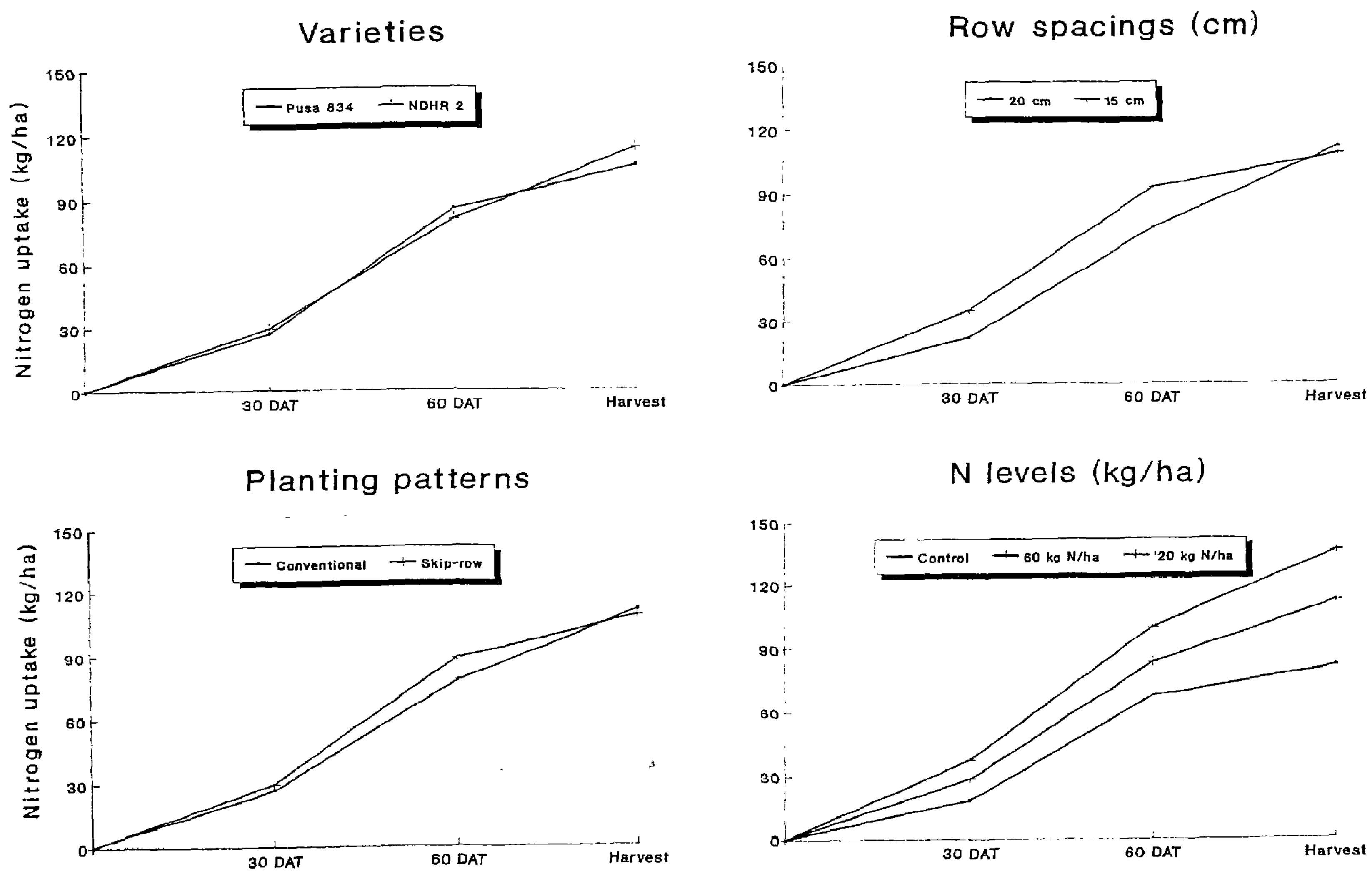

Fig. 6b. Nitrogen uptake (kg/ha) of rice as influened by varieties, row spacings, planting patterns and nitrogen levels during 1996

Row spacings: Row spacings had no significant influence on N uptake of rice during both the years of study at all stages of crop growth except at 30 and 60 DAT, when 15 cm row spacing gave significantly higher N uptake than 20 cm row spacing.

Varieties x Row spacings Interaction: This was found significant at harvest in rice grain during 1996 (Table 4.40) and showed that NDHR 2 recorded significantly more N uptake at 20 cm row spacing than at 15 cm row spacing, whereas Pusa 834 did not.

Table 4.40 Effect of varieties on nitrogen uptake (kg ha^{-1}) of rice grain as influenced by row spacings (1996)

	Row spacings (cm)		
Varieties	**20**		**15**
Pusa 834	37.8		40.7
NDHR 2	41.6		36.0
SEm ±		1.61	
CD 5%		4.88	

Planting patterns: Planting patterns did not differ significantly in respect of nitrogen uptake during both the years of study at all stages of crop growth except at 60 DAT during both years of study, when skip-row planting produced significantly more N uptake than conventional planting.

Row spacings x Planting patterns Interaction: It was found significant at harvest in rice straw during 1995 and 1996 and data are presented in Table 4.41. In 1995 at 20 cm row spacing, conventional planting recorded significantly higher N uptake than skip-row planting. Also in skip-row planting 15 cm row spacing recorded significantly higher N uptake than 20 cm row spacing.

In 1996, N uptake in plant tissue was significantly higher with skip-row planting than with conventional planting, at 20 cm spacing, however the trend was reverse at 15 cm spacing.

Table 4.41 Effect of row spacings on nitrogen uptake (kg ha^{-1}) of rice straw as influenced by planting patterns.

Row spacings (cm)	Planting patterns Conventional		Skip-row
		1995	
20	43.0		33.3
15	39.2		42.3
SEm ±		1.80	
CD 5%		5 46	
		1996	
20	63.6		77.1
15	76.1		66.5
SEm ±		1.89	
CD 5%		5.72	

Nitrogen: During both the years of study, nitrogen uptake increased significantly with each successive increase in the level of nitrogen upto 120 kg N ha^{-1}, at all stages of growth.

A number of workers have obtained increase in N uptake due to N fertilization upto 120 kg N ha^{-1} (Rajale and Prasad, 1975; Sharma and Prasad, 1980; Patnaik *et al.*, 1982; Tanaka *et al.*, 1984; Reddy and Sreeramamurthy, 1985; Biswas *et al.*, 1987; Dubey and Bisen, 1989; Hamissa *et al.*, 1989; Hussain *et al.*, 1989; Sharma and Mittra, 1990; Chau and Deshmukh, 1991; Sreedevi and Thangamuthu, 1991; Krishnakumar and Subramonian, 1992; Pande *et al.*, 1993; Thakur, 1993a; Pradeep *et al.*, 1994) while others reported increase in N uptake due to combined application of NP (Perumal *et al.*, 1986; Mohapatra and Jee, 1993), NPK (Palaniappan *et al.*, 1992) fertilization.

Row spacings x Nitrogen Interaction: It was found significant at harvest in rice grain during 1996 (Table 4.42) and showed that 20 cm spacing recorded significantly higher N uptake than with 15 cm spacing at 120 kg N ha^{-1}, however, differences were not significant at other levels.

Table 4.42 **Effect of row spacings on nitrogen uptake (kg ha^{-1}) of rice grain as influenced by nitrogen levels (1996)**

	Nitrogen levels (kg N ha^{-1})		
Row spacing (cm)	**0**	**60**	**120**
20	29.1	39.9	50.0
15	30.8	38.2	46.0
SEm ±		1.02	
CD 5%		2.95	

Planting patterns x Nitrogen : This interaction was found significant at harvest in rice grain during 1996 (Table 4.43) and showed that only when nitrogen was not applied conventional planting recorded significantly higher N uptake than skip-row planting, when N was applied the two planting systems did not differ significantly

Table 4.43 Effect of planting patterns on nitrogen uptake (kg ha^{-1}) of rice grain as influenced by nitrogen levels (1996)

	Nitrogen levels (kg N ha^{-1})		
Planting patterns	**0**	**60**	**120**
Conventional	32.9	40.2	47.8
Skip-row	27.1	37.8	48.2
SEm ±		1.02	
CD 5%		2.95	

4.5.2 Phosphorus uptake

The data on phosphorus uptake (kg ha^{-1}) as influenced by varieties, plant population, planting patterns and nitrogen levels are presented in Table 4.44 and Fig.7a & b

Varieties: Rice hybrid NDHR 2 recorded significantly higher phosphorus uptake than Pusa 834 at 30 DAT and in rice straw during 1995, however, the differences were not significant at 60 DAT and in rice grain in 1995. In 1996, both the varieties did not differ significantly in their phosphorus uptake. except in straw when rice hybrid NDHR 2 recorded significantly higher P uptake than traditional variety Pusa 834.

Table 4.44. Effect of varieties, row spacings, planting patterns and nitrogen levels on phosphorus uptake (kg ha^{-1}) of rice.

Treatments	1995				1996			
	30DAT	60DAT	Grain	Straw	30DAT	60DAT	Grain	Straw
Varieties								
Pusa 834	4.7	18.0	9.2	6.7	4.6	19.7	7.8	5.7
NDHR 2	5.9	19.1	9.5	8.7	4.9	20.3	8.3	7.6
SEm ±	0.30	0.75	0.17	0.14	0.31	0.41	0.20	0.15
CD 5%	0.91	NS	NS	0.44	NS	NS	NS	0.46
Row Spacings (cm)								
20	4.5	16.7	8.8	7.0	3.7	18.1	7.9	6.5
15	6.1	20.5	10.0	8.4	5.9	21.9	8.2	6.8
SEm ±	0.30	0.75	0.17	0.14	0.31	0.41	0.20	0.15
CD 5%	0.91	2.27	0.51	0.44	0.95	1.24	NS	NS
Planting Patterns								
Conventional	5 1	16 5	9 4	7 6	4.4	19.1	8.2	6 6
Skip-row	5.5	20.7	9.3	7.8	5.1	20.9	7.9	6 7
SEm ±	0.30	0.75	0.17	0.14	0.31	0.41	0.20	0.15
CD 5%	NS	2.27	NS	NS	NS	1.24	NS	NS
N Levels (kg ha^{-1})								
0	3.8	16.4	8.2	5 9	3.2	17.3	6 1	5.0
60	5.4	19.0	9.3	7.8	4.8	19.9	8.1	6.7
120	6.7	23 3	10 6	9.5	6.3	22.7	9.9	8.3
SEm ±	0.21	0 67	0.09	0.12	0.20	0.23	0.15	0 10
CD 5%	0.64	2.04	0.29	0.36	0.59	0.69	0.45	0 30

DAT . Days After Transplanting

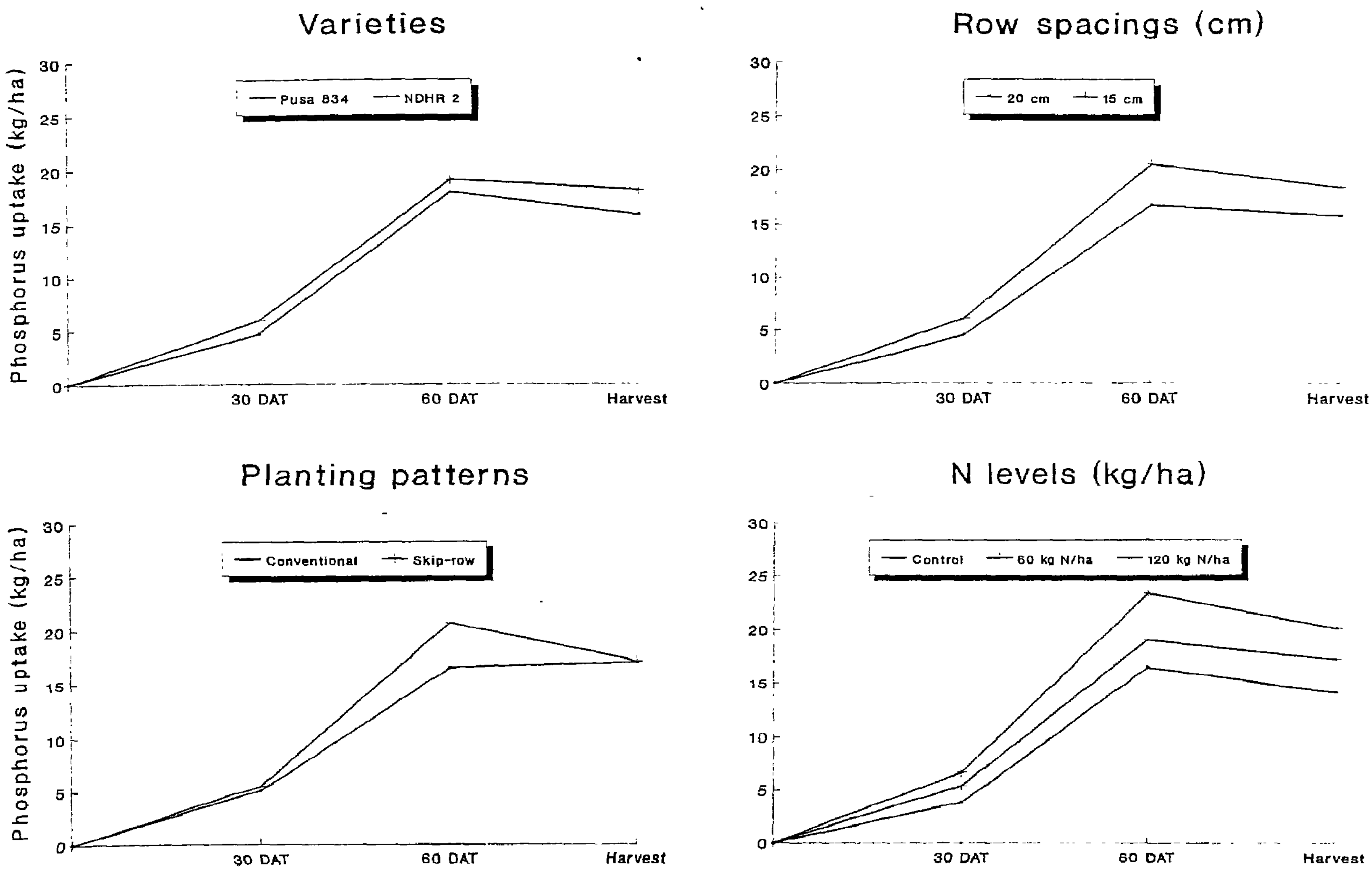

Fig. 7a. Phosphorus uptake (kg/ha) of rice as influenced by varieties, row spacings, planting patterns and nitrogen levels during 1995

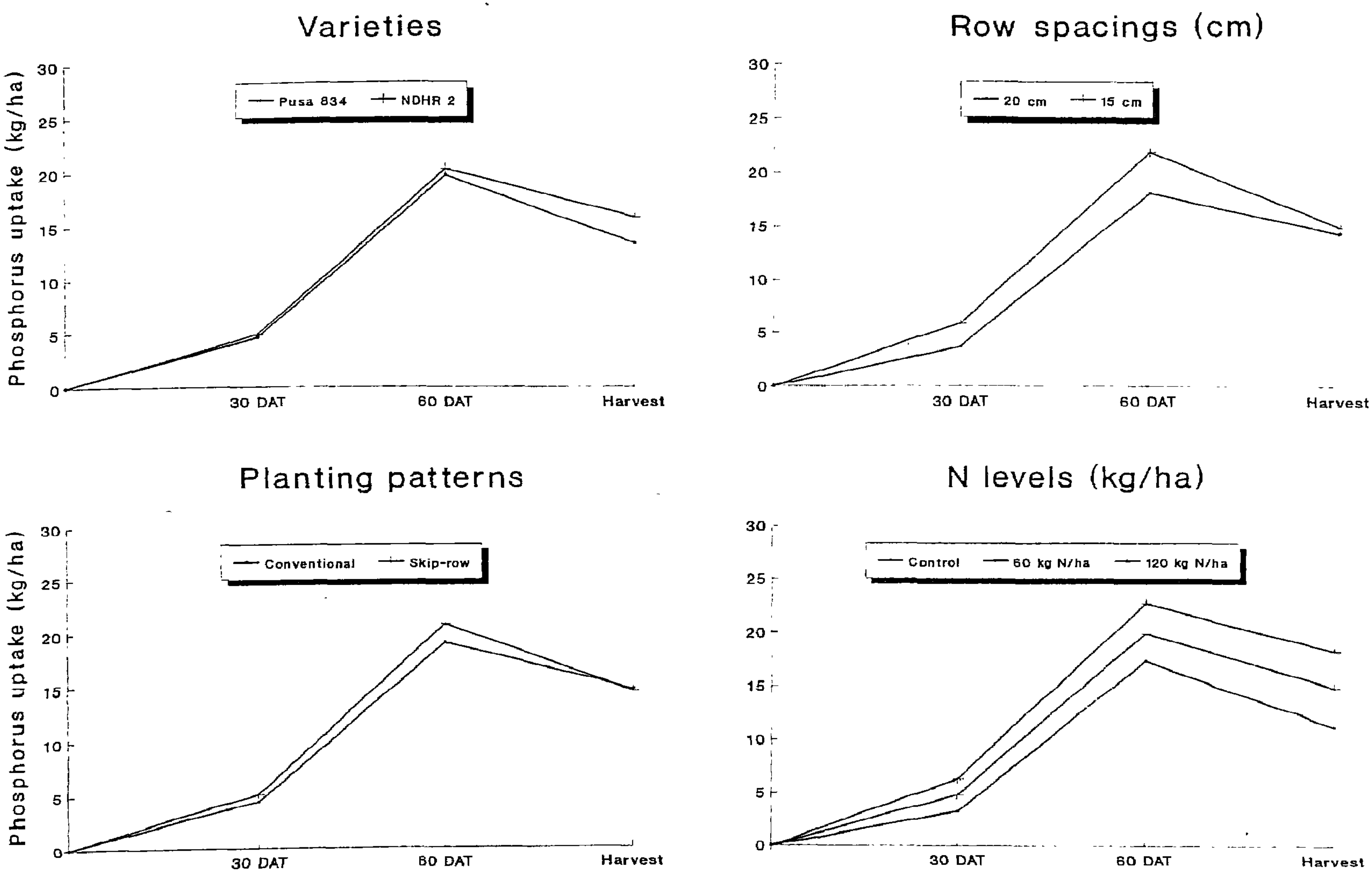

Fig. 7b. Phosphorus uptake (kg/ha) of rice as influenced by varieties, row spacings, planting patterns and nitrogen levels during 1996

Row spacings: 15 cm row spacing produced significantly more P uptake than 20 cm row spaicng in both the years of study at all stages of crop growth except at harvest in rice grain and straw during 1996, when the differences were not significant.

Varieties x Row spacings Interaction: This was found significant in rice grain during 1996 (Table 4.45) and showed that at 20 cm row spacing, rice hybrid NDHR 2 produced significantly more P uptake than Pusa 834, whereas 15 cm row spacing did not.

Table 4.45 Effect of varieties on phosphorus uptake (kg ha^{-1}) of rice grain as influenced by row spacings (1996)

	Row spacings (cm)		
Varieties	**20**		**15**
Pusa 834	7.2		8.3
NDHR 2	8.5		8.0
SEm ±		0.28	
CD 5%		0.84	

Planting patterns: Planting patterns had no significant influence on phosphorus uptake in both the years at all stages of crop growth except at 60 DAT when skip-row planting recorded significantly higher phosphorus uptake than conventional planting

Row spacings x Planting patterns Interaction: This was found significant during 1996 at 60 DAT and at harvest in rice straw (Table 4.46 and 4.47).

At 60 DAT, 15 cm row spacing with either of plantings recorded significantly higher phosphorus uptake than 20 cm row spacing with either of plantings. Furthermore, in skip-row planting, 15 cm row spacing recorded significantly higher phosphorus uptake than 20 cm row spacing.

Table 4.46 Effect of row spacings on phosphorus uptake (kg ha^{-1}) of rice as influenced by planting patterns at 60 days after transplanting (1996)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	16.3	19.8
15	21.8	22.0
SEm ±	0.58	
CD 5%	1.75	

In straw in conventional planting, significantly higher P uptake was obtained at 15 cm row spacing than at 20 cm row spacing. Whereas the trend was reverse in case of skip-row planting.

Table 4.47 Effect of row spacings on phosphorus uptake (kg ha^{-1}) of rice straw as influenced by planting patterns (1996)

	Planting patterns	
Row spacings (cm)	**Conventional**	**Skip-row**
20	5.8	7.2
15	7.3	6.3
SEm ±	0.21	
CD 5%	0.65	

Varieties x Plantings patterns Interaction: This was found significant in grain during 1996 (Table 4.48) and showed that in skip-row planting, rice hybrid NDHR 2 recorded significantly higher P uptake than Pusa 834. Furthermore Pusa 834 recorded significantly higher P uptake with conventional planting than with skip-row planting.

Table 4.48 Effect of varieties on phosphorus uptake (kg ha^{-1}) of rice grain as influenced by planting patterns (1996)

	Planting patterns	
Varieties	**Conventional**	**Skip-row**
Pusa 834	8.4	7.2
NDHR 2	8.0	8.6
SEm ±	0.28	
CD 5%	0.84	

Nitrogen: With each successive increase in the level of nitrogen phosphorus uptake was increased significantly at all stages of crop growth during both the years of study.

Several workers reported that increase in P uptake due to increase in nitrogen application (Biswas *et al.*, 1987; Sharma and Mittra, 1990; Sreedevi and Thangamuthu, 1991).

Row spacings x Nitrogen Interaction: It was found significant during 1995 at 60 DAT and in straw and data are presented in Tables 4.49 and 4.50

At 60 DAT, at both the levels nitrogen application there was a significant increase in the uptake of phosphorus with 15 cm row spacing than with 20 cm row spacing. Furthermore the utilization of phosphorus was more with 15 cm row spacing at 60 kg N ha^{-1} than with 20 cm row spacing at 120 kg nitrogen application.

Table 4.49 Effect of row spacings on phosphorus uptake (kg ha^{-1}) of rice as influenced by nitrogen levels at 60 days after transplanting (1995)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	12.9	17.4	19.7
15	14.0	20.6	27.0
SEm ±		0.95	
CD 5%		2.74	

In straw, at all levels of nitrogen application 15 cm row spacing recorded significantly higher phosphorus uptake than with 20 cm row spacing. Furthermore the phosphorus uptake obtained with 15 cm row spacing at 60 kg nitrogen application was same as that obtained with 20 cm row spacing with 120 kg nitrogen application

Table 4.50 Effect of row spacings on phosphorus uptake (kg ha^{-1}) of rice straw as influenced by nitrogen levels (1995)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	5.5	7.0	8.5
15	6.2	8.5	10.4
SEm ±		0.17	
CD 5%		0.49	

Table 4.51. Effect of varieties, row spacings, planting patterns and nitrogen levels on potassium uptake (kg ha^{-1}) of rice.

Treatments	1995				1996			
	30DAT	60DAT	Grain	Straw	30DAT	60DAT	Grain	Straw
Varieties								
Pusa 834	36.8	111.1	13.7	118.7	34.0	111.4	10.6	93.0
NDHR 2	42.4	111.4	12.9	127.7	34.4	109.7	10.3	104.7
SEm ±	2.19	5.36	0.25	3.12	2.68	4.76	0.27	3.17
CD 5%	NS	NS	0.74	NS	NS	NS	NS	9.63
Row Spacings (cm)								
20	34 9	100.3	13.0	113.7	26.9	100.3	10.2	98.8
15	44.3	122.2	13.6	132.7	41.5	120.8	10.7	98.9
SEm ±	2.19	5.36	0.25	3.12	2.68	4.76	0.27	3.17
CD 5%	6.64	16.26	NS	9.47	8.14	14.43	NS	NS
Planting Patterns								
Conventional	38.6	96.0	13.4	123.5	31.2	104.1	10.7	98.1
Skip-row	40.6	126.4	13.2	122.8	37.2	117.0	10.2	99 6
SEm ±	2.19	5.36	0.25	3.12	2.68	4.76	0.27	3 17
CD 5%	NS	16.26	NS	NS	NS	NS	NS	NS
N Levels (kg ha^{-1})								
0	26.4	70.1	11.5	89.6	20.7	85.6	7.9	66 9
60	40.2	110.5	13.4	123.3	34.0	109.1	10.6	97.9
120	52.3	153.1	15.0	156.6	47.9	136.9	12.9	131.8
SEm ±	1 69	4.87	0.13	2.38	1.75	2.15	0 19	2.30
CD 5%	5.11	14.78	0.39	7.21	5.30	6.52	0 59	6.99

DAT : Days After Transplanting

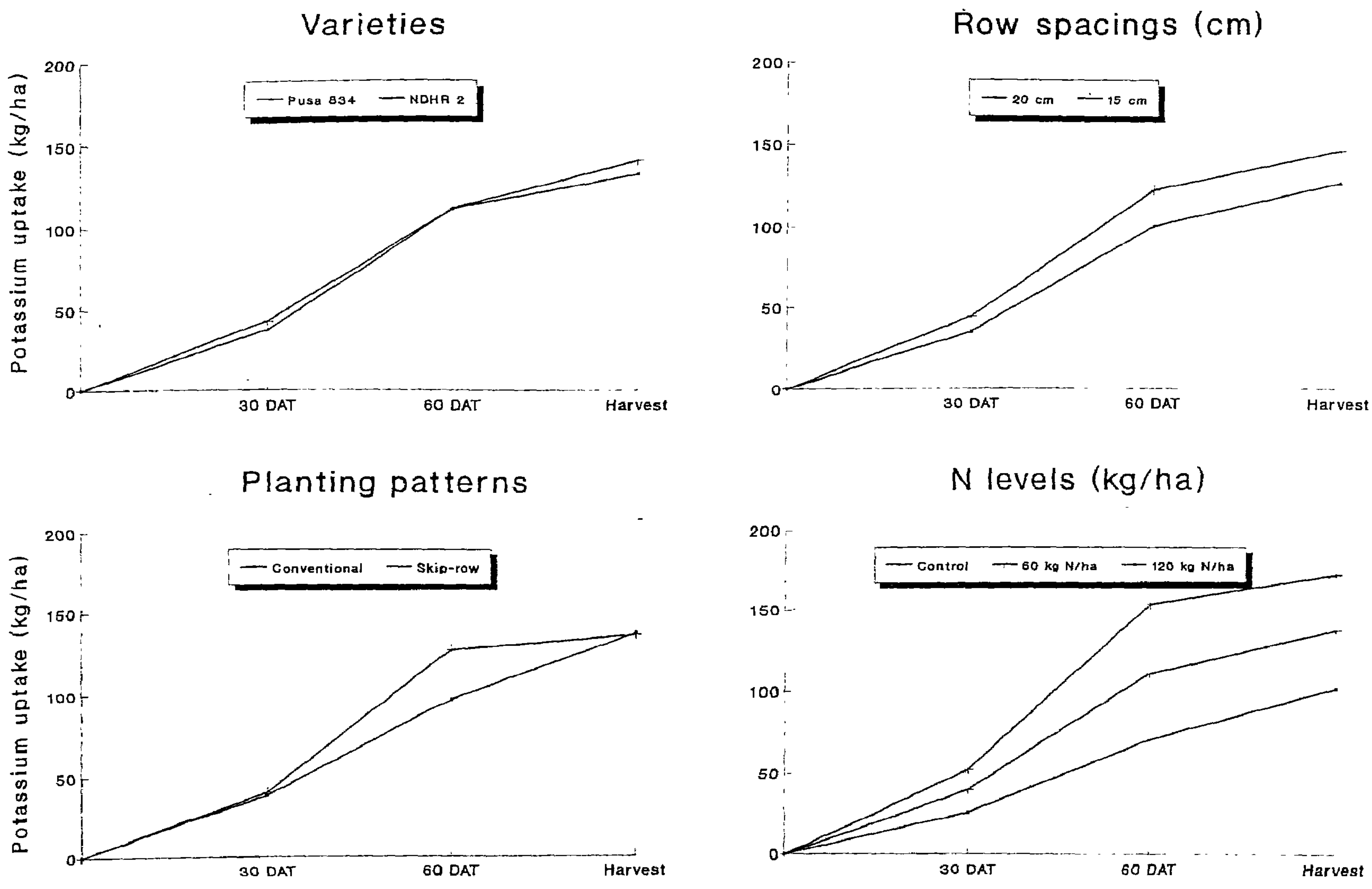

Fig. 8a. Potassium uptake (kg/ha) of rice as influenced by varieties, row spacings, planting patterns and nitrogen levels during 1995

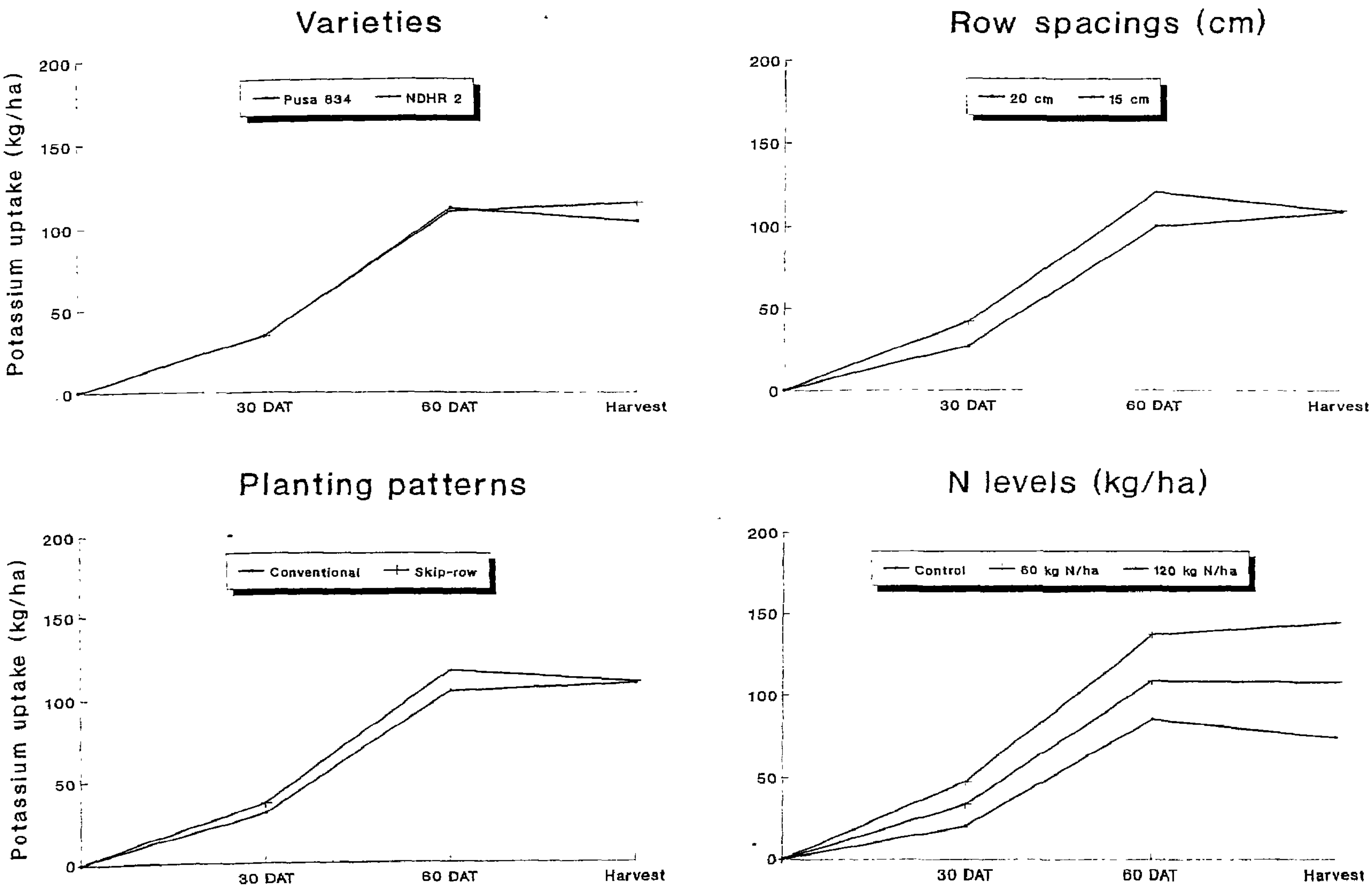

Fig. 8b. Potassium uptake (kg/ha) of rice as influenced by varieties, row spacings, planting patterns and nitrogen levels during 1996

4.5.3 Potassium uptake

The data on potassium uptake (kg ha^{-1}) as influenced by varieties, plant population, planting patterns and nitrogen levels are presented in Table 4.51 and Fig 8a & b.

Varieties: Varieties Pusa 834 and NDHR 2 did not differ significantly in respect of their potassium uptake during both the years of study at all stages of growth except at harvest in rice grain during 1995, when Pusa 834 recorded significantly higher potassium uptake than NDHR 2 and in rice straw, during 1996 when NDHR 2 recorded significantly higher potassium uptake than Pusa 834.

Row spacings: 15 cm row spacing recorded significantly higher potassium uptake than 20 cm row spacing during both the years of study at all stages of crop growth except at harvest in grain during 1995 and 1996 and in straw during 1996 when the differences were not significant.

Varieties x Row spacings Interaction: It was found significant at 30 DAT and at harvest in rice straw during 1995 (Table 4.52 and 4.53).

At 30 DAT, traditional variety Pusa 834 recorded significantly higher potassium uptake at 15 cm row spacing than at 20 cm row spacing, whereas NDHR 2 did not.

Table 4.52 Effect of varieties on potassium uptake (kg ha^{-1}) of rice as influenced by row spacings at 30 days after transplanting (1995)

	Row spacings (cm)	
Varieties	**20**	**15**
Pusa 834	28.3	45.2
NDHR 2	41.4	43.4
SEm ±	3.10	
CD 5%	9.40	

At harvest in straw rice hybrid NDHR 2 recorded significantly higher potassium uptake with 15 cm row spacing than with 20 cm row spacing whereas, Pusa834 did not.

Table 4.53 Effect of varieties on potassium uptake (kg ha^{-1}) of rice straw as influenced by row spacings (1995)

Varieties	Row spacings (cm) 20		15
Pusa 834	115.1		122.2
NDHR 2	112.2		143.1
SEm ±		4.42	
CD 5%		13.39	

Planting patterns: Planting patterns did not differ significantly in respect of potassium uptake during both the years of study at all stages of crop growth, except at 60 DAT in 1995, when skip-row planting recorded significantly higher K uptake than conventional planting.

Varieties x Planting patterns: This interaction was found significant at harvest in rice grain during 1996 (Table 4.54) and showed that traditional variety Pusa 834 with conventional planting recorded significantly higher potassium uptake than with skip-row planting, whereas NDHR 2 did not.

Table 4.54 Effect of varieties on potassium uptake (kg ha^{-1}) of rice grain as influenced by planting patterns (1996)

Varieties	Planting patterns Conventional		Skip-row
Pusa 834	11.4		9.8
NDHR 2	10.0		10 7
SEm ±		0.38	
CD 5%		1.15	

Table 4.55 Effect of row spacings on potassium uptake (kg ha^{-1}) of rice straw as influenced by planting patterns (1996)

Row spacings (cm)	Planting patterns Conventional		Skip-row
20	90.7		107.0
15	105.6		92.2
SEm ±		4.49	
CD 5%		13.62	

Row spacings x Planting patterns Interaction: It was found significant during 1996, in rice straw (Table 4.55) and showed that in skip-row planting, 20 cm spacing recorded significantly higher K uptake than with 15 cm row spacing, however, the trend was reverse in conventional planting.

Nitrogen: At all stages of crop growth, during both the years of study, there was a significant increase in potassium uptake with an increase in the level of nitrogen upto 120 kg ha^{-1}.

Increase in K uptake due to N fertilization were also obtained by Sharma and Mittra (1984), Biswas *et al* (1987) and Sreedevi and Thanganuthu (1991). Similar increase in K uptake due to N application was also reported by Singh *et al.* (1994).

Row spacings x Nitrogen: Row spacing and nitrogen interaction was found significant during 1996 in rice grain (Table 4.56) and showed that 20 cm row spacing at 120 kg N ha^{-1} produced more potassium uptake than with 15 cm row spacing at 120 kg N ha^{-1}.

Table 4.56 Effect of row spacings on potassium uptake (kg ha^{-1}) of rice grain as influenced by nitrogen levels (1996)

	Nitrogen levels (kg N ha^{-1})		
Row spacings (cm)	**0**	**60**	**120**
20	7.6	11.0	13.4
15	8.1	10.1	12.5
SEm ±		0.27	
CD 5%		1.09	

4.6 Apparent N Recovery, Agronomic and Physiological Efficiency

The data on apparent recovery and agronomic and physiological efficiency of nitrogen by rice as affected by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.57.

Varieties: Traditional variety Pusa 834 and rice hybrid NDHR 2 had no significant influence on neither apparent recovery nor agronomic and physiological efficiency by

Table 4.57 Effect of varieties, row spacings, planting patterns and nitrogen levels on apparent N recovery, agronomic and physiological efficiency of rice.

Treatments	Apparent N recovery (%)			Agronomic efficiency (kg grain / kg N applied)			Physiological efficiency (kg grain / kg N uptake)		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Varieties									
Pusa 834	23.9	33.6	28.8	5.9	11.0	6.6	19.0	30.0	24.5
NDHR 2	22.0	30.6	26.3	7.2	8.1	7.7	24.1	26.0	25.1
SEm ±	0.95	1.87	-	0.72	1.51	-	2.16	3.60	-
CD 5%	NS	NS	-	NS	NS	-	NS	NS	-
Row Spacings (cm)									
20	22.3	34.8	28.6	6.7	12.3	9.5	19.6	32.2	25.9
15	23.5	29.4	26.5	6.4	6.9	6.7	23.5	23.7	23.6
SEm ±	0.95	1.87	-	0.72	1.51	-	2.16	3.60	-
CD 5%	NS	NS	-	NS	4.54	-	NS	NS	-
Planting Patterns									
Conventional	21.5	29.1	26.8	6.6	7.5	7.1	21.2	26.3	23.8
Skip-row	24.4	35.1	28.3	6.5	11.7	9.1	21.9	29.7	25.8
SEm ±	0.95	1.87	-	0.72	1.51	-	2.16	3.60	-
CD 5%	NS	5.66	-	NS	NS	-	NS	NS	-
N Levels (kg ha^{-1})									
60	35.7	50.8	43.3	10.9	15.0	13.0	29.1	29 1	29.1
120	33.1	45.4	39.3	8.7	13.7	11.2	35.5	54.9	45.2
SEm ±	1.03	1.47	-	0.55	1.19	-	1.99	2.51	-
CD 5%	NS	4.47	-	1.68	NS	-	6.04	7 61	-

rice on either of two years of study. However, Pusa 834 resulted in more N recovery than NDHR 2. The agronomic efficiency was also similar to apparent N recovery, with the exception that during 1995, NDHR 2 resulted in higher agronomic efficiency.

Plant population: Different plant populations studied had no significant influence on neither apparent recovery nor agronomic and physiological efficiency by rice, except in 1996 when the differences in agronomic efficiency being significant , and 20 cm row spacing resulted in significantly higher agronomic efficiency.

Planting patterns: Planting patterns also did not differ significant in respect of agronomic efficiency and physiological efficiency during both the years of study, but the apparent recovery was significantly more in skip-row planting during 1995 and 1996.

Nitrogen: With each successive increase in the level of nitrogen apparent N recovery, agronomic efficiency and physiological efficiency decreased significantly except in 1995 in case of apparent N recovery.

Several research workers reported that fertilizer N recovery in general was in the range of 20 to 60 per cent (Prasad and De Datta, 1979; Matsushima, 1980; Hamissa *et al.*, 1989; Pandey and Tripathi, 1994).

George and Prasad (1989) found a decrease in recovery with an increase in the rate of fertilizer nitrogen. Similar results were reported by Racho and De Datta (1968) and Rajale and Prasad (1975). It was also observed that fertilizer recovery was high at low levels of fertilizer N (Prasad and De Datta, 1979; Yoshida, 1981; Manickam and Ramaswami, 1985; Mongia, 1992).

4.7 Nutrient Harvest Index (%)

The data on nutrient harvest index by rice as influenced by varieties, plant population, planting patterns and nitrogen levels are given in Table 4.58.

Table 4.58 Effect of varieties, row spacings, planting patterns and nitrogen levels on nutrient harvest index of rice.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Varieties									
Pusa 834	60.0	37.5	48.8	58.6	57.7	58.2	10.8	10.7	10.8
NDHR 2	58.5	34.3	46.4	52.5	52.3	52.4	9.6	9.3	9.5
SEm ±	0.94	0.85	-	0.69	0.95	-	0.28	0.40	-
CD 5%	NS	2.58	-	2.11	2.90	-	0.85	1.20	-
Row Spacings (cm)									
20	59.6	35.8	47.7	56.1	55.0	55.6	10.7	10.1	10.4
15	59.0	36.0	47.5	54 9	55.0	55.0	9.8	9.9	9.9
SEm ±	0.94	0.85	-	0.69	0.95	-	0.28	0.40	-
CD 5%	NS	NS	-	NS	NS	-	0.85	NS	-
Planting Patterns									
Conventional	58.1	36.8	47.5	55.7	56.2	56.0	10.1	10.4	10.3
Skip-row	60.4	35.0	47.7	55.3	53.8	54.6	10.4	9.7	10.1
SEm ±	0.94	0.85	-	0.69	0.95	-	0.28	0.40	-
CD 5%	NS	5.66	-	NS	2.90	-	NS	1.20	-
N Levels ($kg\ ha^{-1}$)									
0	62.1	37 1	49.6	58.7	55.6	57.2	11.9	10.9	11.4
60	58.5	35.5	46.8	54.7	54.7	54.7	9.9	10.0	10.0
120	57.2	35.0	46.4	53.2	54 6	53.9	8.9	9.1	9.0
SEm ±	0.55	0.62	-	0.42	0.66	-	0.31	0.28	-
CD 5%	1.65	1.89	-	1.28	NS	-	0.95	0.86	-

Table 4.59. Gross income, cost of cultivation and net income (Rs ha^{-1}) from 1 ha of rice as influenced by varieties, row spacings, planting patterns and nitrogen levels

	Gross Income			Cost of cultivation			Net Income		
Treatments	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Varieties									
Pusa 834	24,440	20,145	22,293	11,388	11,147	11,268	13,052	8,998	11,025
NDHR 2	23,895	20,393	22,144	12,192	11,950	12,071	11,703	8,443	10,073
Row Spacings (cm)									
20	23,285	20,090	21,688	11,656	11,414	11,535	11,629	8,676	10,153
15	25,050	20,490	22,770	11,924	11,682	11,803	13,126	8,808	10,967
Planting Patterns									
Conventional	24,305	20,670	22,488	11,790	11,548	11,669	12,515	9,122	10,819
Skip-row	24,030	19,868	21,949	11,478	11,236	11,357	12,552	8,632	10,592
N Levels (kg ha^{-1})									
0	21,540	16,043	18,792	10,355	10,113	10,234	11,185	5,930	8,558
60	24,270	20,538	22,404	10,853	10,611	10,732	13,417	9,927	11,672
120	26,675	24,290	25,483	11,351	11,109	11,230	15,324	13,181	14,253

Varieties: Traditional variety Pusa 834 had significantly higher N, P and K harvest indices than NDHR 2 during both the years of study except in 1995, when differences in N harvest index were not significant.

Row spacings: Row spacings had no significant influence on N, P and K harvest index during both the years of study except in 1995 in the nutrient harvest of K, when 20 cm row spacing produced significantly more K harvest index than 15 cm row spacing.

Planting patterns: Planting patterns studied also had no significant influence on N, P and K harvest indices during both the years of study except in 1996 when conventional planting recorded significantly higher P and K harvest indices than skip-row planting.

Nitrogen: With increasing levels of nitrogen, there was a decrease in the N, P and K harvest indices. However, the differences were significant during bolth the years of study

4.8 Economics

The data on gross income, cost of cultivation and net income (Rs ha^{-1}) from one ha of rice as influneced by varieties, plant population, planting patterns and nitrogen levels was given in Table 4.59.

Varieties, Plant population and Planting patterns : The mean data on net income was higher with Pusa 834 than NDHR 2. Net income was more with 15 cm spacing than with 20 cm spacing. Conventional planting produced higher net income than skip-row planting.

Nitrogen : The mean data on net income showed that with each successive increase in the level of nitogen there was an increase in the net income.

SUMMARY

Field experiments were carried out on a sandy clay loam soil (Main Block-14C Research Farm) at the Indian Agricultural Research Institute, New Delhi during *kharif* 1995 and 1996 to study the effect of plant population, planting patterns and levels of nitrogen on growth, yield, nutrient uptake and economics of conventional and hybrid rice varieties. The experiment was laid out in split plot design with three replications. The treatments consisted of eight combinations of two varieties (a conventional high yielding variety Pusa 834 and a hybrid NDHR 2), two plant populations obtained with two row spacings of 20 and 15 cm with a uniform intra-row distance of 10 cm and two planting patterns (convetional and skip-row planting - skipping one row after each two rows) in main plots and three nitrogen levels (0, 60 and 120 kg N ha^{-1}) in sub-plots.

The important findings are:

1. Varieties

1.1 Traditional variety Pusa 834 and rice hybrid NDHR 2 were at par in respect of plant height and number of tillers per hill, however, NDHR 2 produced more dry matter than Pusa 834 at all stages of crop growth, during both the years of study.

1.2 Rice hybrid NDHR 2 produced longer and heavier panicles, more filled, sterile, total spikelets per panicle and 1000-grain weight than Pusa 834. On the other hand Pusa 834 produced more panicles m^{-2} and significantly lesser serile spikelets $panicle^{-1}$ than NDHR 2, which nullified the superiority of

NDHR 2 in having longer and heavier panicles, more grains $panicle^{-1}$ and higher 1000-grain weight of rice. This resulted in similar yields (4.3 and 4.5 t ha^{-1}) of hybrid NDHR 2 and Pusa 834.

1.3 Rice hybrid NDHR 2 produced more straw than the traditional variety Pusa 834 at all levels of nitrogen during both the years of study, which reduced its harvest index.

1.4 During the initial stages of crop growth (30 DAT), NDHR 2 recorded higher N and K content, however, Pusa 834 caught up later and at harvest there was no significant difference between the two varieties. Furthermore, the interaction 'varieties x nitrogen' was significant and showed that in control plots NDHR 2 had significantly higher N content than Pusa 834 at 60 kg N ha^{-1} and at 60 kg N ha^{-1} it had higher N content than Pusa 834 at 120 kg N ha^{-1}. N, P and K uptake by NDHR 2 was also higher than Pusa 834 during initial stages of crop growth.

1.5 Based on the mean data, apparent recovery was more with Pusa 834 (28.8%) than NDHR 2 (26.3%). However, agronomic efficiency was more with NDHR 2 (7.7%) than Pusa 834 (6.6%). Physiological efficiency was also higher with NDHR 2 (25.1%) than Pusa 834 (24.5%).

1.6 The mean data on nutrient harvest indices of N, P and K were more with Pusa 834 (48.8%, 58.2% and 10.8% respectively) than with rice hybrid NDHR 2 (46.4%, 52.4% and 9.5% respectively).

1.7 Based on the mean data the net income was more with Pusa 834 (11,025 Rs ha^{-1}) than with NDHR 2 (10,073 Rs ha^{-1}).

2. Plant population

2.1 In general, closer spacing tended to produce taller plants than wider spacing. The number of tillers prouced by both the row spacings were at par with each other, however, closer spacing (15 cm) produced more dry matter than wider spacing (20 cm).

2.2 Closer spacing of 15 cm resulted in more panicles m^{-2} than wider spacing of 20 cm during both the years of study. The two spacings were at par in respect of other yield attributing characters.

2.3 Grain yield was higher with 15 cm row spacing than with 20 cm row spacing mainly due to more panicles m^{-2}. Closer spaicng also produced more straw than wider spacing at all levels of nitrogen. Furthermore the straw yield produced at 60 kg N ha^{-1} with 15 cm spacing was at par with that produced at 120 kg N ha^{-1}.

2.4 In general, 15 cm row spacing recorded higher N, P and K content than 20 cm row spacing. N, P and K uptake was more with 15 cm spacing than with 20 cm spacing at early stages of crop growth, however, during later stages of growth, both the spacings were at par in their uptake.

2.5 Apparent N recovery, agronomic and physiological efficiency were more with 20 cm row spacing than with 15 cm row spacing.

2.6 Wider spacing of 20 cm resulted in higher nutrient harvest index of N, P and K than closer spacing of 15 cm.

2.7 The mean data showed that the net income was more with 15 cm row spacing (10,967 Rs ha^{-1}) than 20 cm row spacing (10,153 Rs ha^{-1}).

3. Planting patterns

3.1 Skip-row planting gave more tillers and higher dry matter than that obtained with conventional planting. Also at 15 cm spacing, conventional planting produced more dry matter than at 20 cm spacing.

3.2 Skip-row planting produced heavier panicles and more filled and total spikelets $panicle^{-1}$ than conventional planting in 1995. However, conventional planting produced significantly more panciles m^{-2} than skip-row planting in 1995.

3.3 Planting patterns were at par in respect of grain yield. This may be due to the fact that conventional planting produced more panciles m^{-2} in 1995, which nullified the effect of heavier panicles and more filled and total spikelets $panicle^{-1}$ produced in skip-row planting. Conventional planting produced more straw than skip-row planting.

3.4 Planting patterns did not differ in their N, P and K contents. However, at 30 DAT i.e. in the initial stages of crop growth, rice hybrid NDHR 2 recorded higher N and K content than Pusa 834. Skip-row planting resulted in more nutrient uptake than conventional planting.

3.5 The mean data on apparent N recovery, agronomic and physiological efficiency was more with skip-row planting (28.3%, 9.1% and 25.8% respectively) than conventional planting (26.8%, 7.1% and 23.8% respectively).

3.6 The mean data of nutrient harvest index was higher for N in skip-row planting but nutrient harvest index of P and K were more in conventional planting.

3.7 The mean data on net income was higher with conventional planting (10,819 Rs ha^{-1}) than with skip-row planting (10,592 Rs ha^{-1}).

4. Nitrogen levels

4.1 Each successive level of nitrogen increased plant height and number of tillers per hill which led to significantly more dry matter production.

4.2 With each successive increase in the level of N, all the yield attributing characters increased significantly except sterile spikelets and sterility percentage which led to higher grain yield. Based on the pooled data, the increase in grain yield due to 60 kg N ha^{-1} over no nitrogen content was 17.8% that with 120 kg N ha^{-1} over 60 kg N ha^{-1} was 13.1%.

4.3 There was a significant increase in straw yield due to each successive increment of 60 kg N ha^{-1} upto 120 kg N ha^{-1} in both the years of study.

4.4 There was a significant reduction in the harvest index with an increase in the level of nitrogen, due to increase in the straw yield without similar increase in grain yield with successive increase in N application.

4.5 With each successive increment in the level of nitrogen, there was a significant increase in the nutrient (N, P and K) content and uptake of both the varieties of rice at different stages of crop growth during both the years of study.

4.6 There was a decrease in the recovery of applied N, agronomic and physiological efficiency with the increase in the level of nitorgen.

4.7 With each successive increase in the level of nitrogen, there was a decrease in nutrient harvest indices of N, P and K.

4.8 An increase in the level of nitrogen resulted in an increase in net income during both the years of study.

CONCLUSIONS

Rice hybrids are being recommended because of their high yield potential over the varieties. However, NDHR 2 (New Delhi Hybrid Rice 2) developed at the Indian Agricultural Research Institute, which I took in my studies, does not seems to have yield potential over variety Pusa 834 used in the comparative studies in the present investigation. Nevertheless NDHR 2 had more tillers, produced more dry matter and heavier panicles than the variety Pusa 834. However, in our studies the highest level of nitrogen was 120 kg ha^{-1}. This could be one barrier to attainment of higher yield by the hybrid NDHR 2. The majority of farmers in India will not apply nitrogen doses higher than 120 kg ha^{-1}. In view of the findings of this study NDHR 2 does not appear to be a promising rice hybrid. However, there is a necessity to develop high yielding hybrids to fully exploit the hybrid vigour to make them suitable for diversified conditions.

Recommendations for future research:

1) Based on our studies NDHR 2 cannot be recommended to the farmers. More studies are needed with higher yield potential hybrids.

2) Further research is required with higher dose of nitrogen and also with timings of nitrogen application.

3) Age of seedling and time of transplanting, and inter and intra row spacings are also to be worked out.

4) Further research on the requirement of phosphorus , potassium and zinc is also needed to obtain higher yields.

BIBLIOGRAPHY

Agasimani, C.A., Hazra, S.K. and Ghosh, A.K. (1980). Influence of stand geometry and nitrogen and phosphorus uptake on growth parameters and yield of two rice varieties. *Indian Agricul.* 24(1): 35-41.

Agasimani, C.A., Hazra, S.K. and Ghosh, A.K. (1983). Influence of stand geometry and nitrogen on growth parameters and yield of two rice varieties. *Indian J. Agri. Res.* **17**: 198-202.

Alam, S.M. and Azmi, A.R. (1990). Influence of wild plant and crop residues on rice yield. IRRN **15**(3): 22.

Alam, S.M., Azmi, A.R. and Naqvi, S.S. (1989). Genotypic variations in mineral uptake of rice mutants and parents. *International Rice Research Newsletter* **14**: 8.

Anand Kumar, C.R. and Subramaniam, M. (1988). Performance of IRRI rice hybrids at Madurai, India. *International Rice Research Newsletter* 14: 4.

Anonymous (1954-55). Border effect. Annual report of C.R.R.I., Cuttack (Orissa), 1954-55: 12-13.

Anonymous (1983-84). Grain yield of rice crop as influenced by regular vs. border method of planting at optimum and lower levels of seed rates and fertilizer application. Annual report of All India Co-ordinated Agronomic Research Project, 1983-84: 88.

Anonymous (1986-87). Studies on border method of sowing of crops. Annual report of All India Co-ordinated Agronomic Research Project, 1986-87: 50-53.

Anonymous (1987-88). Studies on border method of sowing of crops. Annual report of All India Co-ordinated Agronomic Research Project, 1987-88.

Anonymous (1993). Rice Research in a time of change: IRRI's medium term plan for 1994-1998. Int. Rice Res. Inst., Manila, Philippines.

Anonymous (1995). Development and use of hybrid rice technology. Annual Report 1993-94, Work plan 1994-95, Directorate of Rice Research, Hyderabad, India.

Aragones, D.V and Wada, G. (1989). Effect of seedling age and planting density on growth and yield of rice varieties. *Crop Sci.* **14**: 847.

Arny, A.C., Hayes, H.K. (1918). Experiments in field technique in plot tests. *J. Agric. Res.* **15**(4): 251-252.

Austin, R.B., Ford, F.A., Efrich, J.A. and Blackwall, R.D. (1977). The nitrogen economy of winter wheat. J. A gric. Sci. Camb. **88**(1): 159-167.

Ayyangar, G.N., Rangaswamy, Ayyar, M.A., Shankara and Rajabhooshanam, D.S. (1939). Border effect on the crop in irrigated sorghum. *Madras Agric. J.* **27**(4): 112-118.

Bains, K.S. and Singh, S.P. (1967). Effect of fertilizer, spacing and number of seedlings per hill on paddy yields under low hill conditions. *Indian J. Agron.* **12**: 132-137.

Bajaj, J.C. and Singh, D. (1976). Relationship between organic carbon and mineralizable nitrogen in different soil series of Delhi. *Fert. News* **21**(11): 29-31.

Balasubramanian, P.and Palaniappan, S.P. (1991a). Effect of high density population and fertilizer rate on growth and yield of lowland rice (Ortza sativa). *Indian J. Agron.* **36**(suppl.): 10-13.

Balasubramanian, P. and Palaniappan, S.P. (1991b). Effect of population density, fertilizer level and time of application of rice (*Oryza sativa*)-groundnut (*Arachis hypogea*). *Indian J. Agron.* **36**(Suppl.): 218-221.

Balasubramaniyan, P. (1985). Management of aged seedlings of medium duration rices. IRRN **10**: 1-28.

Barber, E.W. (1914). Note on the influence on shape and size of plots and tests of varieties of grain. MC. *Agric. Exp. Sta. Bull.* **226**: 76-84.

Bathkal, B.G. and Patil, D.H. (1970). Effect of inter-row spacing and nitrogen levels on yield of drilled paddy. *Indian J. Agron.* **15**(3): 288-292.

Bhalli, M.A., Day, A.D., Rucher, J., Thompson, R.K. and Moslay, G.D. (1964) End border effect in irrigated barley yield trials. *Agron. J.* **48**(3): 116-118.

Bhaskar, M.B. (1980). Studies on border method of dwarf paddy under varying row and hill spacings M.Sc. (Ag.) thesis, submitted to C.S Azad Univ. of Agri. and Tech., Kanpur.

Bhattacharya, H.C. and Singh, K.N. (1992). Response of direct seeded rice to level and time of nitrogen application. *Indian J. Agron.* 37: 681-685

Biswas, C.R. and Bhattacharya, B. (1987). Optimisation of nitrogen supply and plant density for a high yielding rice in coastal saline soil. *Oryza* 24: 231-235.

Biswas, C.R., Bhattacharya, B., Bandyopadhyay, B K and Bandyopadhyay, A K (1987). N, P and K uptake of rice on coastal saline soils. *International Rice Research Newsletter* **12:** 42.

Blanco, L.C., Akita, S. and Virmani, S.S. (1986). Growth and yield of F1 rice hybrids in different levels of nitrogen. *Japanese J. Crop Sci.* 55: 12-13.

Blanco, L.C., Cascal A., Akita, S. and Virmani, S.S. (1990). Biomass grain yield and harvest index of F1 rice hybrids and inbreds. *International Rice Research Newsletter* **15:** 9.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analysis of sloils. *Agron. J.* **54:** 464-465.

Bower, C.A., Reifemeier and Fireman, M. (1952). Exchangeable cation analysis saline and alkali soils. *Soil Sci.* **73**: 251-261.

Brown, C.M. and Weibel, R.O. (1957). Border effects in winter wheat and spring oat tests. *Agron. J.* **49**(7): 382-384.

Cassman, K.G. (1994). Part I. Raising the rice yield ceiling *In:* Breaking the yield Barrier, IRRI, Los Banos, Philippines.

Cassman, K.G., Kropff, M.J. and Zhende, Y. (1994). A conceptual framework for nitrogen management of irrigated rice in high yield environments. *In.* Hybrid Rice Technology New Developments and Future prospects (ed. Virmani, S.S.), IARI, Philippines. pp. 81-96.

Chandra, D. and Manna, G.B. (1988). Effect of planting date, seedling age and planting·density on late planted wet season rice in India. *International Rice Research Newsletter* **13**(6): 30-31.

Chandra, D., Mittra, B.N. and Mukherjee, R.K. (1990) Effect of N levels under various plant population on wet summer rice. *J. Andaman Sci. Assoc.* **6** 115-121.

Chandragiri, K.K. and Iruthayaraj, M.R. (1991). Effect of planting geometry and time of sapplication of nitrogen on growth analysis of short duration rice varieties. *Oryza* **28**: 145-150.

Chandrakar, B.L. and Khan, R.A. (1981). Optimum spacing for early, medium and late duràtion tall indica rice cultivars. *Oryza* **18**(2): 108-109.

Chang, W.L., Lin, E.H. and Yang, C.N. (1973). Manifestation of hybrid vigour in rice. *J. Taiwan Agric. Res.* **20(A)**: 8-23.

Chatterjee, B.N. and Maiti, S. (1985). Principles and practices of rice growing. Oxford and IBH Publishing Co., New Delhi. pp. 233.

Chau, N.M. and Deshmukh, P.S. (1991). Nitrogen induced physiological changes in lowland rice. *Oryza* **28**: 205-209.

Cheng, W. and Cheng, R.Y. (1989). Effect of N rates and application dates on different rice cultivars. Zhejiang Agricultural Sciences. 1989, No. 3, 124-128.

Chengxiu, L. and Shangxian, Z. (1988). Nutrient requirement and fertilizer management in hybrid rice. **In.** Proceedings of the International Symposium on Hybrid Rice. pp. 275-276.

Chowdhary, S.L. and Raheja, P.C. (1962). Effect of nitrogen level, placement and nitrogen riding and spacing on yield of paddy. *Indian J. Agron.* **6**: 216-225.

Cochran, W.G. and Cox, G.M. (1957). Experimental Designs. Asia Publishing House, New Delhi.

Craigmiles, J.P., Stansel, J.W. and Glinchum, W.T. (1968). Feasibility of hybrid rice. *Crop Sci.* **8**: 720-722.

Dahatonde, B.N. (1992). Response of promising pre-released rice (*Oryza sativa*) varieties to graded levels of nitrogen. *Indian J. Agron.* **37**(4): 802-803.

Dalai, P.K. and Dixit, L. (1987). Response of medium duration rice varieties to levels of nitrogen. *Indian J. Agron.* **32**(3): 286-287

Das, K., Biswas, D. and Pradhan, J. (1988). Effect of plant density and age of seedlings on the growth and yield of rice variety parajit. *Oryza* **25**: 191-194.

De, G., Dasmahapatra and Chatterjee, B.N. (1984). Transplanting with skip rows. *Indian J. agric. Sci.* **54**(4): 280-283.

Deshmukh, D.D. and Borulkar, O.N. (1993). Studies on border method of sowing in paddy. *J. Maharashtra Agril. Univ.* **18**(3): 457.

Deshmukh, P.S. and Chau, N.M. (1992). Effect of nitrogen level on the relation between sink - source parameters and grain yield. *International Rice Research Newsletter* **17**: 7-8.

Devaraju, K.M., Gowda, H. and Mohan Raju, B. (1996). Nitrogen response of Karnataka rice hybrid-2. Abstracts, Proc. 3rd Int. Symp. on Hybrid rice.

Dhal, P. and Misra, G. (1993). Effect of nitrogen on grain filling and yield of rice. *Oryza* **30**: 162-164.

Drapala, W,Z. and Johnson, C.M. (1961). Border and competition effect in millet and Sudan grass plot characterised by different levels of nitrogen fertilization. *Agron. J.* **53**(1): 17-19.

DRR (1992-93). Development and use of Hybric Rice Technology. Annual report 1992-93. Directorate of Rice Research, Hyderabad. pp. 51.

Dubey, S.K. and Bisen, C.R. (1989). Nitrogen uptake by rice as influenced by different levels, sources and methods of nitrogen application. *Oryza* **26**: 37-42.

Durga Rani, Ch.V. and Murthy, P.S.N. (1994). Performance of experimental hybrids in Andhra Pradesh, India, *International Rice Research Notes* **19**: 20.

Fagi, A.M. and De Datta, S.K. (1981). Environmental factors affecting nitrogen efficiency in flooded tropical rice. *Fert. Res.* **2**: 53-67.

FAI (1995-96). Fertilizer statistics 1995-96. The fertilizer association of India, New Delhi

Fisher, R.A. and Yates, F. (1963). Statistical tables for biological, agricultural and medical research. 6th Ed. Oliver and Boyd, London.

George, M. and Prasad, R. (1989). Studies on the effect of legumes on fertilizer N utilization by rice using ^{15}N technique in rice based crolpping system. *Res. Dev. Agric.*, **6**: 115-118.

Geroge, Mercy (1987). Studies on the effect of cereal-cereal and cereal-legume cropping systems on the productivity and fertility of soil. Ph.D. Thesis submitted to Div. of Agronomy, IARI, New Delhi.

Ghobrial, G.I. (1983). Response of irrigated dry seeded rice to N levels, inter row spacing and seedling rate in semi arid environment. *International Rice Research Newsletter* **8**: 27-28.

Ghosh, A.B., Bajaj, J.C., Hasan, R. and Singh, D. (1983). Soil and water testing methods. A laboratory manual, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi.

Gomez, K.A. (1972). Border effects in rice experimental plots. II. Varietal competition. *Expl. Agric.* **8**(4): 295-298.

Gomez, K.A. and De Datta, S.K. (1971). Border effects on rice experimental plots. I. Unplanted borders. *Expt. Agric.* 7: 87-92.

Gowda, N.A.J., Badrinath, P.S. and Rao, K.B. (1987). Impact of level and source of slow release N fertilizers on rice yield and yield components. *International Rice Research Newsletter* **12**: 37.

Green, J.A. (1956). Border effect in cotton variety tests. *Agron. J.* **48**: 116-118.

Guindo, D., Wells, B.R. and Norman, R.J. (1994). Cultivar and nitrogen rate influence on nitrogen uptake and partitioning in rice. *Soil Sci. Soc. Am. J.* **58**: 840-845.

Gui-Ting, H.E., Xigang, Z. and Flinn, J.C. (1987). A comparative study of economic efficiency of hybrid and conventional rice production in Jiangsu Province of China, *Oryza* **23**: 285-296.

Gulati, J.M.L., Panda, S.C., Misra, B., Tara, M., Acharya, N., Singh, N and Dash, A.N. (1987). Effect of levels of nitrogen, spacing and plant duration on rice yield. *Oryza* **24**: 358-362.

Guled, M.B., Setty, R.A., Veewraraj Urs, Y.S., Mohan, S.L. and Lingaraju, S. (1988). Comparative performance of intan mutant lines and recommended rice varieties at graded levels of nitrogen. *Oryza* **25**: 195-197.

Gupta, M.P. (1985). Studies on the effect of pot size and fertility levels on transplanted paddy by border method. M.Sc. (Ag.) thesis submitted to C.S. Azad Univ. of Agri. & Tech., Kanpur.

Hamissa, M.R. and Mahrous, F.N. (1989). Fertilizer use efficiency in rice. **In.** Proceedings of an International Symposium on Rice Farming Systems, IRRI, Philippines. pp. 130-139.

Hamissa, M.R., Mahrous, F.N., Nour M. and Wahab, E.A. (1989). Using tracer technique to measure effect of rate, timing and method of application on fertilizer nitrogen use by rice. **In.** Proceedings of an International Symposium on Rice Farming Systems. IRRI, Philippines. pp. 353.

Hartwig, E.E., Herbert, W.J. and Robert, B.C. (1951). Border effects in soybean test plots. *Agron. J.* **43**: 443-445.

Hayes, H.K. and Arny, A.C. (1917). Experiment in field technique in rod tests *J. Agric. Res.* **11**(9): 399-419.

He, G.T., Zhu, X., Flinn, J.C. (1987). Hybrid seed production in Jiangsu, China. *Oryza* **24**: 297-312.

Hedayetullah, S., Ray, K.P. and Sen, S. (1947). A study on effect of cultural factor in transplanting paddy on the behaviour of some plant characters influencing the yield. *Indian J. agric. Sci.* **17**(2): 60-80.

Hussain, T., Jilani, G. and Ghaffar, A. (1989). Influence of rate and time of N application on growth and yield of rice in Pakistan. IRRN. **14**(6): 18.

Ichii, M. and Tsumura, H. (1989). Comparison of nutrient uptake in ecospecies and ecotypes of rice seedlings. *Japanese J. Crop Sci.* **58**(1): 7-12.

International Rice Research Institute (IRRI) (1980) *In:* Proc Symp Agrometeorology of rice crop. World Meteorological Organisation and International Rice Research Institute, Manila, Philippines 254 p.

International Rice Research Institute (IRRI) (1980a) Yield potential of hybrid rice Annual Report. pp. 14.

International Rice Research Institute (IRRI) (1984). Physiological basis of heterosis. Annual Report. pp. 14.

International Rice Research Institute (IRRI) (1987). Effect of plant density and nitrogen level on yield of F_1 hybrids and elite lines. Annual Report. pp. 13.

International Rice Research Institute (IRRI) (1988). Yield of experimental rice hybrids in Korea. Annual Report **12:** pp 608.

IRRI (1993). Program report for 1992. Int. Rice Research Instt., Manila, Philippines.

Jain, N.K., Singh, V., Singh, R.V. and Nathu, U. (1969). Response of rice (*Oryza sativa* L.) varieties to different levels of fertility and spacing. *Indian J. Agric. Sci.* **39**(9): 893-897.

Jennings, P.R. (1967). Rice heterosis at different growth stages in the tropical environment. *International Rice Communication Newsletter* **16**: 24-26

Jindal, V.K. and Kalia, H.P. (1971). Response of Nortin-18 paddy to different fertility levels and plant spacing. *Fertil. News* **16**(5): 37-38.

John, S.C. and Hallsted, A.L. (1926). The effect of out side rows on the yields of plots of Kafir and Milo at Hays. *Kans J. Agric. Res.* **32**(10): 991-1002.

Johnson, C.M. and Ulrich, A. (1959). Analytical methods for use of plant analysis. California Agric. Expt. Sta. Bull. No. **766**: 26-27.

Jones, D.B. and Snyder, G.H. (1987). Seeding rate and row spacing effects on yield and yield components of drill seeded rice. *Agron. J.* **79**(4): 626.

Kalyanikutty, T. and Morachan, Y.V. (1974). Influence of NPK on growth, yield and composition of rice varieties in inherent yield potential *Madras Agricultural Journal* **61**: 239-244.

Kalyankutty, T., Narayanan, T.R. and Srinivasa, V (1969). High yielding varieties of rice in Tamilnadu and their response to nitrogen and spacing. *Madras Agric. J.* **56**: 209-215.

Kanade, M. and Kalra, G.S. (1986) Performance of Mashuri rice variety under different ages of seedlings and plant densities in lateritic soils of coastal Maharashtra. *J. Indian Soc. Coastal Agric. Res.* **4**(1): 63-67.

Kanungo, A.P. and Roul, P.K. (1994). Response of transplanted summer rice (*Oryza sativa*) genotypes to varying levels of fertility and plant density. *Indian J. Agron.* **39**(2): 216-219.

Karel Marx M. (1986). Relative efficiency of urea and placement of urea supergranules at different depths and rates on rice. M.Sc. Thesis.

Katyal, J.C., Singh, B., Vlek, P.L.G. and Craswell, E.T. (1985). Fate and efficiency of nitrogen fertilizer applied to wetland rice. II. Punjab, India. *Fert. Res.* **6**: 279-280.

Krishnakumar, V. and Subramonian, S. (1992). Nitrogen uptake, per cent recovery and response to nitrogen of rice varieties with different water management practices. *Madras Agric. J.* **79**(12): 694-699.

Krishnan, R., Natarajan, S. and Palaniswamy, C. (1994). Effect of spacing, Azolla and levels of niktrogen on rice. *Madras Agric. J.* **81**(9): 514-515.

Kumar, V. (1981). Studies on the comparison of border method with regular transplanting of dwarf paddy under varying row and hill spacings. M.Sc. (Ag.) thesis submitted to C.S. Azad Univ. of Agri. & Tech., Kanpur.

Kumar, V., Chauhan, P.M. and Singh, A.C. (1975). Effect of three levels of nitrogen and three spacing on grain yield of two varieties of rice. *Indian J. Agron.* **21**(1): 57-58.

Kumara, A. (1956). Studies on the effect of internal nitrogen concentration of rice plant on the constitutional factor of yield. *Proc. Crop Sci. Soc., Japan.* **24**: 177-180.

Kupkanchankeel, T. and Vergara, B.S. (1980). Nitrogen response of rice grown in medium deep water. *Thai. J. Agric. Sci.* **13**: 213-225.

Lal, P., Gautam, R.C. and Bisht, P.S. (1986) A new way of transplanting rice. *Indian Fmg.* **36**(2): 24-27.

Lin, J.L. and Lin, T.L. (1985). Tiller number and leaf area index in the rice community as influenced by planting geometry and nitrogen fertilizer. *J. Agric. Assoc. China* **129**: 14-34.

Lin, S.C. and Yuan, L.P. (1980). Hybrid rice breeding in China. **In**. Innovative Approach to Rice Breeding. IRRI, Los Banos, Philippines. pp. 35-51.

Liou, T.M. (1987). Effect of spacing and fertilizer levels on changes of ear types of rice. *J. Agric. Assoc. China* **140**: 1-10.

Lokaprakash, R., Shivasankar, G., Mahadevappa, M., Shankar Gowda, B.T. and Kulakarni, R.S. (1992). Heterosis in rice. *Oryza* **29**: 293-297

Longping, Y. (1993). China's experiences in the development of hybrid rice research programme. **In.** Hybrid Rice - Food Security in India (ed. Barwale, B.R.), Macmillan India Press, Madras, pp. 22-27.

Luo, A., Xu, J. and Yang, X. (1993). Edffect of nitrogen (NH_4NO_3) supply an absorption of ammonium and nitrate by conventional and hybrid rice during reproductive growth. Pl. Nutri. from Genetic Engg. to field practice. Barrow (ed.) 537-540.

Majumdar, S., Basu, T.K., Mandal, B.K. and Jana, P.K. (1989). Effect of planting geometry on the growth and yield of rice. *Indian Agriculturist* **33**(4): 227-231.

Malik, S., Robles, R., Aguilar, A. and Varma, B.S. (1988). Rice heterosis for panicle branching, spikelet number and vascular bundle number. *International Rice Research Newsletter* **13**: 8.

Mandal, B.B. and Mahapatra, I.C. (1968). Effect of date of planting, spacing and level of nitrogen on the yield of rice. *The Andhra Agric. J* **15**: 93-100.

Manickam, T.S. and Ramaswami (1985). Influence of N level and source on rice yield. *International Rice Research Newsletter* **10**: 28-29.

Manna, G.B., Moorthy, B.T.S. and Rao, K.S. (1981). Studies on strip-row planting and related economisation of inputs (*kharif*, 1981). Annual report of C.R.R.I., Cuttack (Orissa), 1981: 36-37.

Manna, G.B., Moorthy, B.T.S., Rao, K.S. and Padalia, C R (1980). Studies on strip-row planting and related economisation of inputs. Annual report of C.R.R.I., Cuttack (Orissa), 1980: 68-69.

Manna, G.B., Moorthy, B.T.S., Rao, N.S., Patel, C.S. and Nigam, R.K. (1982). Studies on strip-row planting and related economisation of inputs. Annual Report of C.R.R.I., Cuttack (Orissa), 1982: 17-18.

Matsushima, S. (1980). Rice cultivation for the million. Japan Scientific Societies Press, Tokyo p. 4-97.

Mc. Clelland, C.K. (1934). Border rows of oat plants as affecting yields and variability. *J. Amer. Soc. Agron.* **26**(6): 491-496

Mc.Clelland, C.K. (1929). The effect of narrow alleys on small grain yields. *J. Amer. Soc. Agron.* **21**(5): 524-532.

Mc.Rostie, G.M. and Hamilton, R.I. (1927). The accurate determination of dry matter in forage crops. *J. Amer. Soc. Agron.* **19**: 243-251.

Mikkleson D.S and De Datta, S.S. (1979). Rice culture, *In:* rice, production and utilization, chapter 4 Ed. by Bor. S. Luh, Ph.D., AVI Publishing Company INC Westport, Connecticut.

Mohapatra, A.K. and R.C. Jee, (1993). Response of lowland rice (*Oryza sativa*) to green manuring, levels and sources of phosphatic fertilizers in coastal Orrisa. *Indian J. Agron.*, **38**(3): 374-377.

Mongia, A.D. (1992). Efficiency of nitrogen as affected by level and time of its application in wet-land rice. *Indian J. Agron.* **37**: 558-560.

Moorthy, B.T.S and Saha, S. (1996). Personal commnication through letter of Oct. 24, 1996.

Murali, V., Kulandaivelu, R. and Reddy, T.Y. (1985). Effect of levels and modified forms of urea and ammonium chloride on lowland rice. JRRN **10**: 6-29.

Murthy, K.S., Dey, S.K. and Jachuck, P.J. (1991). Heterosis in physiological attributes of rice hybrids. *International Rice Research Newsletter* **16**: 7.

Murthy, P.S.S. and Murthy, S.M. (1980). Effect of spacing on the physiological attributes of two high yielding long duration rice cultivars. *Oryza* **17**: 148-150.

Murthy, P.S.S., Ramesh, K.S., Rao, G.V.H. and Narayanan, A. (1992). Influence of nitrogen on grain-filling potential and yield of rice (*(Oryza sativa)* varieties. *Indian J. Agron.* **37**(1): 17-158

Nair, M.A. and George, C.M. (1973). Studies on performance of rice viz. culture 12035 under varying levels of nitrogen and spacing. *Agric. Res. J. Kerala* **10**: 1-4.

Nair, R.V. (1975). Note on the influence of spacing and time of nitrogen application on the grain protein in rice. *Indian J. agric. Sci.* **45**. 175-176.

Narang, R.S., Cheema, S.S., Grewal, D.S., Sharma, B.D. and Dev. G. (1990). Yield, nutrient removals and changes in soil fertility under intensive rice-wheat cropping system *Indian J. Agron.* **35**(1 and 2). 113-119.

Nayar, P.K., Mishra, A.K., Surya Rao, A.V. and Patnaik, S (1980). Effect of N rates with and without foliar application of Mo on the yield, micronutrient content and uptake by rice plant. *Il Riso* **28**(1): 19-23.

Nguu, N.V. and De Datta, S.K. (1979). Increasing efficiency of fertilizer nitrogen on wetland rice by manipulation of plant density and plant geometry. *Field Crop Res.* **2**: 19-34.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus by extraction with sodium carbonate. USDA Circ. No 939, p. 19.

Padmaja Rao, S. (1995). Yield and high density grain as influenced by crop density and N level in scented rice. *Madras Agric. J.* **82**(2): 108-112.

Palaniappan, S.P., Ramaswami, C., Balasubramaniyam P. and Honora J., Francis (1992). Time of application of potash andits effect on N and K uptake and yield of low land rice (IR-64).*Madras Agric. J.*, **79**(9): 540-541.

Panda, M. and Rao, C.H.N. (1991). Influence of coated nitrogen on photosynthesis and productivity of rice in dry and wet seasons *Oryza* **28**: 37-40.

Pande, N.C., Samanta ray, R.N., Mahapatra, P. and Mohanty, S.K. (1993). Effect of optimal and sub optimal nutrient management on nutrient changes, yield and nutrient uptake. *Soil Sci.* **41**(1): 90-95.

Pandey, J. and Singh, R.P. (1985). Response of newly developed medium duration and high yielding rice genotypes to nitrogen. *Indian J. Agron.* **30**: 114-116.

Pandey, N. and Tripathi, R.S. (1994). Effect of coated nitrogen fertilizers, their levels and time of application on yield of rice (*Oryza sativa*) in vertisols. *Indian J. Agron.* **39**: 290-292.

Papadakis, J. (1970). Mechanism of plant population stress and soil intoxication by roots. Fundamentals of Agronomy. Buenous Aires, Argentia, pp. 28-29.

Papadakis, J. (1979). Personal Communication through letter of Oct. 24, 1979.

Paramasivan, K.S. and Sreerangaswamy, S.R. (1988). Heterosis in hybrids of rice varieties. *Oryza* **25**: 396-401.

Paramasivan, K.S. and Sreerangaswamy, S.R. (1990). Heterotic studies on spikelet sterility in rice. *Oryza* **27**: 322-324.

Patil, R.B., Patil, P.G., Naik, A.G. and Patil, G. (1979). Effect of row spacing on yield of rice in summer season. *Indian J. Agron.* **24**(4): 440-441.

Patnaik, S., Rao, M.V. and Nanda, B.B. (1982). Some considerations of N uptake by high yielding rice varieties. *Int. Rice Comm. Newsl.* **17**(2): 26-27.

Pendelton, J.W. and Seif, R.D. (1962). Role of height in corn competition. *Crop Sci.* **2**(2): 154-156.

Perumal, R., Jayaraman, C. and P. Duraiswamy, (1986). P and K fertilization on rice yield and nitrogen efficiency as influened by added nitrogen. *Madras Agric. J.*, **74**(4): 221-225.

Pillai, G.R., Nair, R.R., Pisharody, P.N. and Gopala Krishnan, R. (1972). Effect of spacing, number of seedlings per hill and nitrogen on growth and yield of Annapurna Rice. *Agric. Res. J. Kerala* **10**: 86-92.

Pillai, K.G. (1996). Chief scenario in rice and prospects for sustainable rice production. *Fert. News* **41**(2): 15-23.

Pillai, K.G., Rao, N.S., Reddy, N.V. and Wilson, M.J. (1973). Nitrogen variety trials. Central Rice Research Institute, Annual Report, Cuttack pp. 137.

Piper, C.S. (1950). Soil and Plant Analysis. The University of Adelaide, Australia. p. 286.

Pradeep, P., Ashok Kumar and Prasad, U.K. (1994). Effect of irrigation and nitrogen on yield of medium-duration direct seeded rice (*Oryza sativa*). Indian J. Agron. **39**(2): 294-296.

Prakash, B.G. and Mahadevappa, M. (1987). Evaluation of some experimental rice hybrids for field performance and standard heterosis. *Oryza* **24**: 75-78.

Prasad, M. and Prasad, R. (1980). Nitrogen management and its economics in rice-wheat rotation. *Indian J. Agron.* **25**(4): 608-613.

Prasad, R. (1982). A Practical manual for soil fertility. Division of Agronomy, IARI, New Delhi-110012.

Prasad (1982a). The use of nitrification inhibitors and slow release N fertilizers for manipulation of growth and development. J.S. Mclaren (Ed.) Butterworth Scientific London pp. 451-464.

Prasad, R. and De Datta, S.K. (1979). Increasing fertilizer-N efficiency in wetland rice. **In**. Nitrogen and Rice, IRRI, Los Banos, Philippines pp. 165-484.

Prasad, U.K., Sharma, N.N. and Ojha, S.N. (1982). Yield of medium maturing rice varieties at different levels of nitrogen. *Indian J. Agron.* **27**: 85-87.

Racho, V.V. and De Datta, S.K. (1968). Nitrogen economy in cropped and uncropped flooded rice soils under field conditions. *Soil Sci.* **105**: 419-427.

Raghuwansi, R.K.S., Paradkar, V.K., Gupta, R.K. and Jain, S.C. (1986). Effect of plant spacing and nitrogen on yield of rice on sodic black clay soils. *Indian J. Agron.* **31**: 428-429.

Rai, O.P., Singh, N.B. and Singh, R.A. (1991). Effect of varying doses of nitrogen applied in different forms on the yield and nitrogen efficiency of rice.

Raj, K.G. and Siddiq, E.A. (1986). Hybrid vigour in rice with reference to morphological components of yield and root density. *SABRAO.J.* **18**: 1-7.

Rajale, G.B. and Prasad, R. (1975). Nitrogen and water management for irrigated rice. *Il Riso* **24**(2): 117-125.

Raju, M.S. and Rao, Ch.P. (1984). Effect of nitrogen, spacing and age of seedlings on rice yield. *The Andhra Agric. J.* **31**(4): 349-350.

Raju, R.A., Reddy, G.V. and Nageswara Reddy, M. (1989). Response of long duration rice to spacing and age of seedlings. *Indian J. Agron.* **34**: 506-507.

Raju, V.R., Jagannathan, A. and Sudhakar Rao, A. (1990). Performance of scented rice (*Oryza sativa*) varieties under different levels of nitrogen in Andhra Pradesh. *Indian J. agric. Sci.* **60**(10): 694-696.

Ramasamy, S., Sivasubrmanian, V. and Sankaran, S. (1985). Effect of split-applied N on rice yields. *International Rice Research Newsletter* **10**: 25.

Ramesh, K.S. (1989). Influence of graded levels of nitrogen on grain filling potential of rice varieties. M.Sc. (Ag.) Thesis, Andhra Pradesh Agricultural University, Hydrabad.

Ramesh, P. (1986). Fertilizers and plant population for improving the productivity of late planted rice. M.Sc. Thesis. Dept. of Agronomy, Agricultural College, Bapatla.

Rangaswamy, M. and Murthy, K.N. (1988). Hybrid rice heterosis in Tamilnadu. *International Rice Research Newsletter* **13**: 5.

Rao, C.P. and Raju, M.S. (1987). Effect of age of sedlings, nitrogen and spacing on rice. *Indian J. Agron.* **32**: 100-102.

Rao, I.N., Rao, G.M., Murthy, P.S.S. and Seetharamaiah, K.V. (1985). Performance of International Rice Research Institute hybrids in Andhra Pradesh. *International Rice Research Newsletter* **10**: 8.

Rao, K.S., Moorthy, B.T.S. and Manna, G.B. (1990). Plant populations for higher productivity in Basmati type scented rice. *International Rice Research Newsletter* **15**(1): 26.

Rao, K.S., Murthy, B.T.S., Lodh, S.B. and Sahoo, K. (1993). Effect of graded levels of nitrogen on yield and quality of different varieties of scented rice (*Oryza sativa*) in coastal Orissa. *Indian J. agric. Sci.* **63**(8): 467-472.

Rathi, G.S., Patel, J.P. and Sharma, R.S. (1984). Relative performance of some dwarf varieties of rice and their response to spacing and planting pattern. *Indian J. Agron.* **29**: 218-221.

Rathi, K.S. and Verma, V.S. (1975). Research programme of Agronomy for *kharif*, 1975-76, C.S. Azad Univ. of Agric. & Tech., Kanpur.

Reddy, B.B. and Ghosh, B.C. (1984). Effect of seedling and hill density on the performance of rice under deep water conditions. *Oryza* **21**: 233-237.

Reddy, D.S. (1978). Effect of planting and planting densities on rice genotypes. M.Sc. (Ag.). Thesis Andhra Pradesh Agricultural University, Hyderabad.

Reddy, G.R. and Reddy, K.A. (1989). Effect of levels and sources of nitrogen on rice. *Indian J. Agron.* **34**(3): 364-366.

Reddy, G.S., Rao, G.M. and Mazhaboob, A.S. (1984). Festibility of hybrid rice production utilizing male sterility and fertility restoration system. *Oryza* **21**: 143-147.

Reddy, K.R., Angelo, E.D., Lindau, C. and Patrick, W.H. Jr. (1990). Urea losses in flooded soils with established oxidised and reduced soil layers. *Biol. Fert. Soils.* **9**: 283-287.

Reddy, K.S. and Reddy, B.B. (1992). Effect of transplanting time, plant density and seedlings age on growth and yield of rice (*Oryza sativa*). *Indian J. Agron.* **37**(1): 18-21.

Reddy, V.V. and Sreeramamurthy, V.M.M. (1985). Uptake of nitrogen and grain yield response of four high yielding rice varieties under different fertilizer levels. *The Andhra Agric. J.* **32**: 158-162.

Relwani, L.L. (1962). Studies on the effect of spacing, no. of seeds per hill and levels of N on paddy yields. *Indian J. Agron.* **6**(4): 279-288.

Relwani, L.L. (1963). Effect of dates of transplanting, spacing between hills and levels of nitrogen on paddy yields. *Indian J. Agron.* 7(3): 189-196.

Richmond, T.R. (1943). Competition in cotton variety tests. *J. Amer. Soc. Agron.* 35(7): 606-612.

Robinson, J.G. (1992). Dose and time of application of nitrogen for rice CR 1009. *Madras Agricultural J.* **79**: 47-48.

Roy, O.K., Thakur, R.B., Singh, S.B. and Singh, A.K. (1990). Effect of pre-released medium duration rice varieties to levels of nitrogen. *Annals of Agric. Res.* **11**(3-4): 311-313.

Sagwal, O.P. and Vijaya Kumar (1994). Effect of balanced use of fertilizers on productivity and profitability of basmati rice. *Fert. News.* **39**(10): pp. 55-57

Sahai, V.N. and Choudary, R.C. (1986). Root system in hybrid rice. *International Rice Research Newsletter* **11**: 13.

Sahai, V.N., Saran, S. and Choudhary, R.C. (1987). Hybrid rice research in Bihar, India. *International Rice Research Newsletter* **12**: 23.

Sahu, B.N. and Lenka, D. (1966). Cultural cum manurial trials on paddy. *Indian J. Agron.* **11**: 127-138.

Sahu, B.N. and Lenka, D. (1986). Effect of low light at different growth stages of crop on sink size. *Oryza* **23**: 123-125.

Saikia, L., Mahanta, T.C., Patgiri, D.K. and Bora, D.C. (1988). Response of rice varieties to nitrogen under late transplanting. *Indian J. Agron.* **33**: 423-425.

Sato, K. and Takahashi, K. (1983). An analysis of the border effect in rice paddy fields. *Japanese J. Crop Sci.* **52**(2): 168-176.

Satyavarma, N. (1988). Studies on the effect of spacing and number of seedlings per hill on rice. M.Sc. Thesis. Dept. of Agronomy, Agricultural College, Bapatla.

Schnier, H.F. Dingkuhu, M., De Datta, S.K., Mengel, K. and Faronilo, J.E. (1990). Nitrogen fertilization of direct-seeded flooded vs. transplanted rice: I. Nitrogen uptake, photosynthesis, growth and yield. *Crop Sci.* **30**: 1276-1284.

Sewaram, Kaushik, S.K. and Gupta, R.S. (1973). Effect of varying plant density and nitrogen levels on the yield of rice varieties. *Indian J. Agron.* **18**(1): 38-41.

Shah, M.H., Khushu, M.K., Khanday, B.A. and Bali, A.S. (1991). Effect of spacing and seedlings per hill on transplanted rice under late sown conditions. *Indian J. Agron.* **36**(2): 274-275.

Shahi, H.N., Gill, P.S. and Khind, C.S. (1976). Effect of number of seedlikngs per hill and spacing on growth and yield of rice. *Indian J. Agron.* **21**(4): 392-395.

Shahi, I.B. (1982). Effect of two plant geometries on growth, yield and quality of dwarf paddy (*Oryza sativa* L.) under varying levels of fertility. Ph.D. thesis submitted to C.S. Azad Univ. of Agric. & Tech., Kanpur.

Shanmugasundaram, P., Mohanasundaram, K., Thangaswamy, A, Veluswamy, M. and Rangaswamy, M. (1990). Performance of IR Rice hybrids in Ambasamudram, Tamilnadu, India. *International Rice Research Newsletter* **15**: 4.

Sharma, A.R. (1994). Effect of seed rate and row spacing on the performance of early and late maturing rice cultivars in mixed crop systems under intermediate deep water conditions (15-50 cm). *Agric. Sci. Camb.* **122**: 201-205.

Sharma, A.R. and Mittra, B.N. (1984). Effect of green manuring and mineral fertilizer on growth and yield of crops in rice based cropping on acid laterite soil. *J. Agric. Sci. Camb.* **110**: 605-608.

Sharma, A.R. and Mittra, B.N. (1988). Effect of combinations of organic materials and nitrogen fertilizer on growth, yield and nitrogen uptake of rice. *J. Agric. Sci. Camb.* **111**: 495-501.

Sharma, A.R. and B.N. Mittra (1990). Effect of organic materials and NPK levels on growth and yield of rice. *Indian Agriculturist*, **34**(3): 169-175.

Sharma, H.L. and Singh, C.M. (1989). Assessment of border method in relation to regular sowing in wheat (*Triticum aestivum*) and rice (*Oryza sativa*). *Indian J. agric. Sci.* **29**(1): 63-65.

Sharma, J.P. and Prasad, R. (1982). Studies on the response of high yielding varieties of rice to different levels of N and P. *Indian J. Agric. Res.* **16**: 15-18.

Sharma, J.P. and Prasad, R. (1984). Response of high yielding varieties of paddy to N and P levels. *Agric. Sci. Digest* **4**(1): 45-47.

Sharma, K.C. and Singh, M. (1971). Response of dwarf wheat to row direction and row spacing. *Indian J. Agron.* **16**(4): 396-399.

Sharma, R.B. and Singh, V.P. (1992). Effect of planting geometry on light interception and grain yield of transplanted rice. *Oryza* **29**: 270-272.

Sharma, S.K. and Warsi, A.S. (1987). Effect of planting pattern and nitrogen on rice. *Indian J. Agron.* **32**(2): 185-186.

Sharma, S.K., Yadava, M.P. and Tripathi, H.P. (1990). Effect of planting methods under various levels of nitrogen on yield and N-use efficiency of rice. *Narendra Deva J. agric. Res.* 5(1): 42-45.

Sharma, S.N. and Prasad, R. (1980). Carry over effects of rates and sources of nitrogen applied to rice on the succeeding spring wheat crop. Z. Ackerfund Pflanzenbau *J. Agron. Crop Sci.* **149**: 345-354.

Sharma, S.N., Singh, S. and Prasad, R. (1990). Relative response of short and medium duration rice to rate and time of nitrogen application. *Indian J. Agron.* **35**(4): 442-446.

Shear, G.M. and Miller, L. (1960). Influence of plant spacing of the Jumbo Runner peanut on fruit development, yield and border effect. *Agron. J.* **52**: 125-127.

Shoji, S., Ando, H. and Wada, G. (1986). Fate of nitrogen in paddy fields and nitrogen absorption by rice plants. *JARQ* **20**(2): 127-134.

Shukla, R.C., Sharma, R.S. and Chipde, S.J. (1993). Improvement of N-use efficiency in transplanted rice. *Oryza* **30**: 250-261.

Siddiq, E.A. (1993). Opportunities for hybrid rice in India. In Hybrid-Rice-Food security in India (ed. Barwale, B.R.), Macmillon India Limited, Madras.

Siddiq, E.A., Ahmed, M.I., Rangaswamy, M., Kumar, R.V., Vidyachandra, B., Viraktamath, B.C. and Chaterjee, S.D. (1996). Current status and future outlook for hybrid rice technology in India. In Hybrid Rice Proc. 3rd Int. Symp. Hyderabad, India.

Singh, B.K., Singh, R.P. and Thakur, R.B. (1989). Nitrogen and phosphorus requirements and suitable spacing for double transplanted rice in flood-affected areas. *Oryza* **26**: 193-195.

Singh, B.K., Thakur, R.B. and Singh, R.P. (1982). Effect of nitrogen levels and spacing on the performance of Kharuhan rice. *Indian J. Agron.* **27**: 310-312.

Singh, B.K., Thakur, R.B. and Singh, R.P. (1985). Nitrogen requirement and spacing for late transplanted, phto period sensitive tall indica rice. *International Rice Research Newsletter* **10**: 24-25.

Singh, D.V. (1980). Comparison of border and uniform methods with regular transplanting of dwarf paddy under varying row spacings. M.Sc. (Ag.) thesis submitted to C.S. Azad Univ. of Agric. & Tech., Kanpur.

Singh, I. (1983a). Studies on border method of paddy under increasing levels of fertility. M.Sc. (Ag.) Thesis submitted to C.S. Azad Univ. of Agric. & Tech., Kanpur.

Singh, I.D. and Stoskofif (1971). Harvest index kin cereals. *Agron. J.* **63**: 224-226.

Singh, Janardhan, Sharma, H.L. and Singh, C.M. (1994). Direct, residual and cumulative effects of potassium fertilization in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping systems. *Indian J. Agron.* **39**(3): 345-356.

Singh, K.K. (1983b). Studies on fertilizer economy in transplanted paddy (*Oryza sativa* L.) submitted to C.S. Azad Univ. of Agric, & Tech., Kanpur.

Singh, Mahatim, Singh, K., Srivastava, J.P. and Singh, R.P. (1979). Influence of nitrogen, phosphorus and potassium nutrition on uptake and yield of drilled rice. *Oryza* **16**(2): 91-98.

Singh, N.P., Rathi, S.S. and Siwach, M.S. (1972). Optimum spacing and fertilizer requirement of dwarf varieties of rice (*Oryza sativa* L.). *Indian J. Agric. Res.* **42**(11): 1036-1041.

Singh, O.P., Dharampal and Hari, O.M. (1987). Effect of seed rate in nursery and seedlings per hill on yield of transplanted rice. *Indian J. Agron.* **32**: 96-97.

Singh, R. (1990). Studies on border and regular methods of transplanted dwarf paddy (*Oryza sativa* L.) under varying levels of fertility. Ph.D. thesis submitted to C.S. Azad Univ. of Agric. & Tech , Kanpur.

Singh, R.K. (1981a). Studies on comparative performance of border method of dwarf paddy with regular and uniform methods at varying row spacings. M.Sc. (Ag.) thesis submitted to C.S. Azad Univ. of Agric. & Tech., Kanpur.

Singh, R.K. (1985). Studies on border effect from row and hill side in dwarf rice. M.Sc. (Ag.) thesis submitted to C.S. Azad Univ. of Agric. & Tech., Kanpur.

Singh, R.P. (1981b). Effect of direction and methods of planting on growth and yield of dwarf paddy. M.Sc. (Ag.) thesis submitted to C.S. Azad Univ. of Agric. & Tech., Kanpur.

Singh, R.P. and Modgal, S.C. (1977). Response of indica rices to nitrogen and plant spacings. *Indian J. Agron.* **22**(2): 82-86.

Singh, R.S. and Riccharia, A.K. (1980). Diallel analysis of grain yield and its components in rice. *Indian J. Agric. Sci.* **50**: 1-5.

Singh, R.S.. (1971). Response of three types of rice to various levels of nitrogen and spacing. *Indian J. Agric. Res.* 5: 185-189.

Singh, S.K., Pande, H.C. and Shukla, S.N. (1991). Response of rice varieties to nitrogen lvels under intermediate deep water condition. *Oryza* **28**: 115-116.

Singh, S.P. and Singh, V. (1973). Effect of different levels of nitrogen, plant population and different water regimes on grain yield of rice variety, Jamuna. *Indian J. Agro.* **18**(4): 445-449.

Singh, S.P., Rao, K.V., Subbaiah and Pillai, K.G. (1996a). Effect of planting geometry and N levels on grain yield of hybrid cultures. Abstracts, Proc. 3rd Int. Symp. on hybrid rice.

Singh, S.P., Sreedevi, B. and Subbaiah, S.V. (1996b). Effect of N levels and their time of application on grain yield of hybrid rice. Abstracts Proc. 3rd Int. Symp. on hybrid rice.

Smith, L.H. (1910). Plant agreement for variety experiments with corn. *Proc. Amer. Soc. Agron.* 5(1): 1907/09, 84-89.

Song, X.P., Agata, W. and Kawamitsu, T. (1990). A studies on dry matter and grain production of Chinese F_1 hybrid rice cultivars. I. characteristics of dry matter production. *Japanese J. Crop Sci.* **59**: 19-28.

Sreedevi, B. and Thangamuthu, G.S. (1991). Studies on N P K uptake by rice under integrated nitrogen management. *Oryza* **28**: 255-256.

Sreedevi, P. and Sreedharan, C. (1991). Performance of medium duration rice rice as influenced by plant population and fertilizer levels. *Agricultural Res. J. Kerala* **27**: 9-14.

Srinivasan, V., Kalyankutty, T. and Narayanan, T.R. (1968). Optimum spacing and nitrogen doses for high yielding rice varieites in Madras state. *Indian Fmg.* **18**(6): 12-15.

Srinivasulu Reddy, D. (1986). Effect of N and plant population on yield and yield components of Jaya rice under recommended irrigation practice. *Madras Agric. J.* **73**(6): 321-324.

Srinivasulu, K. (1994). Planting studies on hybrid rice. M.Sc. (Ag.) Thesis. Andhra Pradesh Agricultural University, Hyderabad.

Srivastava, K.N. and Singh, K.S.P. (1971). Performance of tall and dwarf rice varieties (*Oryza sativa* var. Indica) under varying levels of nitrogen. *Indian J. Agron.* **16**: 394-395.

Sta, P.C., Cruz and Wada, G. (1994). Genetic variation in nitrogen uptake by rice and the effects of management and soil fertility. *In*. Rice roots: Nutrients and Water Use. IRRI. Los Banos, Philippins.

Stringfield, G.H. (1927). Inter varietal competition among small grains. *J. Amer. Soc. Agron.* **19**(11): 971-983.

Subbaiah, S.V., Kumar, R.M. and Singh, S.P. (1996). Agronomic package for hybrid rice cultivation. Abstracts. proc. 3rd Int. Symp. on hybrid rice.

Subramanian, M. and Sivasubramanian, V. (1986). Comparison of rice hybrids and local varieties of TNRRI. *International Rice Research Newsletter* **1**: 21-22.

Sunohara, Y., Yajima, M., Seki, H. and Ishikara, Y. (1986). Dry matter production of F_1 rice hybrids, and yield response under different levels of fertilizer application. *Japanese J. Crop Sci.* **55**: 18-19.

Surekha, K., Reddy, M.N. and Vijaya Kumar, C.H.M. (1996). Response of rice hybrids to N sources and time of application of nitrogen and potash. Abstracts. Proc. 3rd Int. Symp. on hybrid rice.

Tanaka, A., Yamaguchi, J., Miura, S. and Tamaru, H. (1984). Comparison of fertilizer nitrogen efficiency among field crops. *Soil Sci. Plant Nutr.* **30**(2): 1990-2008.

Taylor, S.R., Banjongsuk, P. and Klampratum, D. (1987). Border method and fish culture synergistic effects on the yield of rice grain. Proceedings of the second International Symposium on Tilapia in Agriculture (I.S.T.A.I.I.) March 16-20, 1987, Bangkok, Thailand.

Thakur, R.B. (1989). Response of medium duration rice varieties to nitrogen. *Indian J. Agron.* **34**(4): 491-492

Thakur, R.B. (1993a). Effect of split application of nitrogen on growth, yield and N uptake in wetland rice (*Oryza sativa*). *Indian J. Agron.* **38**: 191-194.

Thakur, R.B. (1993b). Performance of summer rice (*Oryza sativa*) to varying levels of nitrogen. *Indian J. Agron.***38**: 187-190.

Thorat, S.T. and Patil, B.P. (1987). Nitrogen uptake by early rice cultivars as influenced by nitrogen fertilization and plant density. *Oryza* **24**: 262-264.

Thorat, S.T., Bhosale, R.J. and Patil, B.P. (1983). Performance of early varieties of rice under different levels of nitrogen and plant densities. *Indian J. Agron.* **28**: 189-190.

Tsai, J.C. (1987). Effect of cultural methods on the yield of some physiological characters of rice cultivars differing in grain weight. *Journal of Agricultural Association of China* **36**: 63-74.

Udaya Bhaskar, B. (1990). Relative efficiency of different complex fertilizers at varying levels for rice. M.Sc.' (Ag.) Thesis, Andhra Pradesh Agricultural University, Hydrabad.

Upadhyaya, R.M. and Pathak, A.N. (1981). Influence of N, P and Mn on dry matter and harvest of economic products in ratoon rice. *Indian J. Agric. Res.* **5**: 11-16.

Vachhani, K.S., Chauhan, P.M. and Singh, A.C. (1961). Effect of three spacings on yield of transplanted rice. *Indian J. Agric. Sci.* **44**(9): 618-620.

Varshney, J.G. (1986). Response of upland rice to nitrogen fertilization and different plant densities in hilly terrains of Meghalaya. *Oryza* **23**: 173-177.

Venkateswarulu, M.S. and Singh, M. (1980). Response of rice varieties to different spacings and fertility levels on yield attributes and yield. *Indian J. Agron.* **25**: 263-272.

Venugopal, K. and Singh, R.D. (1985). Effect of plant density and age of seedling on the yield of DR-92 rice variety in Sikkim. *Oryza* **22**: 162-165.

Verma, S.C. (1972). Effect of fertility status and plant population on the yield and yield components of high yielding indica rice varieties. *Indian J. Agron.* **17**: 158-161.

Virmani, S.S. (1996). Hybrid rice. *In.* Advances in Agronomy. Vol. **57**: pp. 378-449.

Virmani, S.S., Choudary, R.C. and Khush, G.S. (1981). Current outlook on hybrid rice. *Oryza* **18**: 67-84.

Vlek, P.L.G., Hong, C.W. and Youngdahl, L.J. (1979). An analysis of nitrogen nutrition on yield and yield components for the improvement of rice fertilization in Korea. *Agron. J.* **71:** 829-833.

Voc, P.C. and Luat, N.V. (1987). Yield evaluation of F_1 hybrids in the mekong Delta. *Oryza* **18**: 67-84.

Wada, G., Aragones, D.V. and Aragones, R.C. (1989). Organic debris as macro site for nitrogen fixation. *Jpn. J. Crop Sci.* **58**(2): 231-235.

Wada, G., Shoji, S. and Mai, T. (1986). Relationship between nitrogen absorption, growth and yield of rice plants *JARQ.* **20**: 135-144.

Wagh, R.G. and Thorat, S.T. (1987). Effect of split application of nitrogen and plant densities on yield and yield attributes of rice. *Oryza* **24**: 169-171.

Wei, M.L. and Lin, D.J. (1986). The influence of partial leaf removal and plant densities on the yield of rice plants of differing in grain weight. *Journal of Agricultural Association of China* **25**: 413-423.

Wheeler, H.J. (1910). Some desirable precautions in plot experimentation. Proc. *Amer. Soc. Agron.* **5**(1): 1907/1909; 39-44.

Yadav, D., Bajpal, D.D. and Pathak, S.P. (1976). Effect of fertility levels and spacing on grain yield of rice. *Indian J. Agron.* **21**(1): 57-58.

Yamauchi, M. (1994). Hybrid Rice Technology: New developments and future prospects. Virmani, S.S. (ed.), IRRI, Los Banos, Philippines. pp. 71-80.

Yamauchi, M., Virmani, S.S. and Vergara, B.S. (1985). Harvest index and straw weight of some experimental F_1 rice hybrids. *International Rice Research Newsletter* **10**: 19-21.

Yan, Z. (1988). Agronomic management of rice hybrids compared with conventional varieties. **In**. Proceedings of the International Symposium on Hybrid-rice. 6-10 October, 1986. Changsha, Hunan, China. pp 217-223.

Yang, X.E. and Sun, X. (1991). The physiological effect of nitrate or ammonium top dressing on hybrid and conventional rice cultivars at the late growth stage. Acta-Agronomica-Sinicia. **17**(4): 283-291.

Yang, Y.Y., Zhang, S.J., Zhan, B.S. and Qiu, Q.J. (1987). Characteristics of N-uptake by hybrid rice and the effects of nitrogen fertilizers on the yield Soils Turang **19**(4): 196-200.

Yen, Z.D. and Hu, C.T. (1986). Establishment and adjustment of high yielding population of the rice hybrid. *Ganhua Acta Agronomic Sinica Jiansu*, China **12**: 145-153.

Yogeswara Rao, Y. Subbi Reddy, C., Faizuddin Khan, Wajid Ali and Gopal Naidu (1980). Performance of promising rice cultures under different N levels in *kharif* season. *Indian J. Agron.* **25**: 256-258.

Yoshida, S. (1981). Fundamentals of rice crop science. IRRI, Los Banos, Philippines. pp. 132-146.

Zimmermann, F.J.P. (1980). Border effect in experimental plots of dryland rice. *Pesquisa Agropecuaria* Brasileria (Brazil) **15**(3): 297-300.

Appendix I. Weekly meteorological data for crop season 1995.

Month	Standard week	Mean temp (°C) Max.	Mean temp (°C) Min.	Mean R.H. (%)	Total rainfall (mm)	Mean evaporation (mm/day)
June	28-03	44.4	25.6	34	0.0	14.8
	04-10	45.6	28.6	24	0.0	11.4
	11-17	45.1	31.1	29	0.0	15.7
	18-24	35.9	25.4	63	36.6	8.2
	25-01	38.3	28.2	58	0.0	8.1
July	02-08	40.5	30.3	48	0.0	9.6
	09-15	35.2	27.6	73	19.4	5.5
	16-22	33.8	26.9	77	29.4	4.4
	23-29	32.5	26.3	76	21.8	3.9
Aug.	30-05	32.2	26.7	83	66.2	2.6
	06-12	30.7	26.0	87	124.2	2.7
	13-19	33.1	26.7	76	14.6	3.9
	20-26	32.2	26.0	86	51.8	2.7
	27-02	30.7	25.1	87	173.4	2.4
Sept.	03-09	31.8	23.5	83	184.4	2.6
	10-16	32.4	24.1	74	0.0	3.2
	17-23	35.0	23.6	63	0.0	4.9
	24-30	36.0	24.0	61	0.0	5.5
Oct.	01-07	36.5	21.8	53	0.0	5.8
	08-14	34.3	20.9	63	0.0	4.4
	15-21	32.4	19.3	63	0.0	3.7
	22-28	31.2	14.4	50	0.0	4.1

Appendix I. Weekly meteorological data for crop season 1996.

Month	Standard week	Mean temp (°C) Max.	Min.	Mean R.H. (%)	Total rainfall (mm)	Mean evaporation (mm/day)
June	28-03	42.5	25.6	35	0.0	12.3
	04-10	40.9	26.6	48	0.0	11.6
	11-17	36.9	27.8	63	18.0	6.7
	18-24	35.7	26.6	70	42.1	5.2
	25-01	32.3	26.5	72	88.1	4.9
July	02-08	35.2	25.5	70	60.9	6.9
	09-15	35.4	27.7	68	12.0	6.1
	16-22	35.5	27.0	70	58.0	4.4
	23-29	33.5	26.7	78	62.0	4.8
Aug.	30-05	31.8	26.3	80	112.4	4.1
	06-12	33.6	26.9	76	33.9	4.4
	13-19	31.3	26.2	80	40.7	3.3
	20-26	30.0	24.7	89	128.6	3.2
	27-02	33.9	26.3	77	0.0	3.9
Sept.	03-09	30.7	25.1	88	90.0	3.3
	10-16	32.0	25.0	85	142.6	2.5
	17-23	33.0	24.5	69	0.0	4.0
	24-30	35.1	22.5	65	0.0	4.5
Oct.	01-07	33.1	22.5	69	33.0	3.5
	08-14	33.0	19.0	61	0.0	4.0
	15-21	32.4	17.0	57	0.0	2.7
	22-28	30.0	18.0	61	0.0	1.4

Appendix II General cost of cultivation (Rs ha^{-1}) of rice

Operation	Input	Rate	Cost ha^{-1} 1995	Cost ha^{-1} 1996
Raising nursery (1000 sq. m)				
1 Ploughing the field	1bullick pair for 1 day	Rs 55/70/day	55.00	70.00
	1 manday	Rs 53.15/	53.15	53.15
2 Puddling, making beds and sowing	6 mandays	Rs 53.15/	318.90	318.90
3 Weeding	2 mandays	Rs 53.15/	106.30	106.30
4 Nitrogen dressing	25 kg urea	Rs 166/50 kg	83.00	83.00
	1 manday	Rs 53.15/	53.15	53.15
5 Cost of irrigation (4 in number)	Water charges	Rs 50/ irrigation/ ha	20.00	20.00
	(1/2 manday)	Rs 53.15/	26.58	26.58
6 Rental value of land	for 1 month	Rs 2000/ha/year	16.67	16.67
Main field (1 ha)				
1 Discing	1 tractor for 4 hrs.	Rs 50/hr	200.00	200.00
2 Ploughing with a country plough puddling and planking	3 bullock pairs	Rs 55/70/day	165.00	210.00
	3 mandays	Rs 53.15/	159.45	159.45
3 Bunding	6 mandays	Rs 53.15/	318.90	318.90
4 Uprooting the seedlings and Transplantig	30 mandays	Rs 53.15/	1594.50	1594.50
5 Weeding	20 mandays	Rs 53.15/	1063.00	1063.00
6 Thinning and gap filling	1 manday	Rs 53.15/	53.15	53.15
7 Fertilizers- P_2O_5	60 kg P_2O_5	Rs 160/50kg	1200.00	1200.00
K_2O	40 kg K_2O	Rs 280/50 kg	380.00	380.00
ZnSo$_4$	10 kg ZnSo$_4$	Rs 120/20kg	167.50	167.50
	5 mandays	Rs 53.15/	265.75	265.75
8 Irrigations (10 in number)	Water charges	Rs 50/irrigation/ha	500.00	500.00
	5 mandays	Rs 53.15/	265.75	265.75
9 Insect control	Endosulfan 30 Ec (1 litre)	Rs 244/litre	244.00	-
	1 manday	Rs 53.15/	53.15	-
10 Harvesting and Threshing	30 mandays	Rs 53.15/	1594.50	1594.50
11 Rental value of land	for 2 months	Rs 2000/ha/yr	333.33	333.33
12 Interest on capital excluding land rent of Rs 350/-	for 2 months	@12%/annum	179.15	174.41
13 **Total**			**9469.88**	**9227.99**

For each irrigation of nursery 1 labour hour is required and for main field 4 labour hours/ha.
Cost of N/kg : Rs 7.25; Cost of kg P_2O_5: Rs 12; Cost of kg K_2O: Rs 9.50; Cost of kg ZnSo$_4$: 16.75

Appendix II Variable cost (Rs ha^{-1}) of rice cultivation

Treatments	Cost of seeds					Cost of urea					Total (Rs)
	Quantity (kg)	cost of seed (Rs/kg)	Total (Rs)	Interest on capital @ 12% /annum (Rs)	Subtotal a (Rs)	Cost of urea (Rs)	Cost of application (Rs)	Total (Rs)	Interest on capital @ 12% /annum (Rs)	Subtotal b (Rs)	
Varieties											
Pusa 834	26.25	20.00	525.00	10.50	535.50	435.00	53.15	488.15	9.76	1382.97	1918.47
NDHR 2	26.25	50.00	1312.50	26.25	1338.75	435.00	53.15	488.15	9.76	1382.97	2721.72
Row Spacings (cm)											
20	22.50	35.00	787.50	15.75	803.25	435.00	53.15	488.15	9.76	1382.97	2186.22
15	30.00	35.00	1050.00	21.00	1071.00	435.00	53.15	488.15	9.76	1382.97	2453..97
Planting Patterns											
Conventional	26.25	35.00	918.75	18.38	937.13	435.00	53.15	488.15	9.76	1382.97	2320.10
Skip-row	17 50	35.00	612.50	12.25	624.75	435.00	53.15	488.15	9.76	1382.97	2007.72
Mean	24.79	35.00	867.70	17.36	885.06	435.00	53.15	488.15	9.76	1382.97	2268.03
N Levels (kg ha^{-1})											
0	24.79	35.00	867.70	17.36	885.06	-	-	-	-	-	885.06
60	24.79	35.00	867.70	17.36	885.06	435.00	53.15	488.15	9.76	497.91	1382.97
120	24.79	35.00	867.70	17.36	885.06	435.00	53.15	488.15	9.76	995.83	1880.89
Mean	24.79	35.00	867.70	17.36	885.06	435.00	53.15	488.15	9.76	497.91	1382.97

Cost of N/kg : Rs 7.25

Variable cost is same during 1995 and 1996 for rice.

Appendix III Gross income (Rs ha^{-1}) from 1 ha of rice.

	Grain		Straw		Total	
Treatments	1995	1996	1995	1996	1995	1996
Varieties						
Pusa 834	19,960	16,830	4,480	3,315	24,440	20,145
NDHR 2	19,040	16,618	4,855	3,775	23,895	20,393
Row Spacings (cm)						
20	18,920	16,575	4,365	3,515	23,285	29,090
15	20,080	16,915	4,970	3,575	25,050	20,490
Planting Patterns						
Conventional	19,600	17,170	4,705	3,500	24,305	20,670
Skip-row	19,400	16,278	4,630	3,590	24,030	19,868
N Levels (kg ha^{-1})						
0	17,680	13,218	3,860	2,825	21,540	16,043
60	19,520	16,958	4,750	3,580	24,270	20,538
120	21,280	20,060	5,395	4,230	26,675	24,290

Minimum Support Price (Rs q^{-1})

	1995		1996	
	Grain	Straw	Grain	Straw
Pusa 834	400.00	50.00	425.00	50.00
NDHR 2	400.00	50.00	425.00	50.00

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