INFLUENCE OF LEVELS OF NITROGEN, METHODS OF APPLICATION AND PLANT POPULATION ON THE PERFORMANCE OF THE HIGH YIELDING RICE VARIETY 'SABARI'

BY
U. MOHAMED KUNJU

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DECLARATION

I hereby declare that this thesis entitled "Influence of levels of nitrogen, methods of application and plant population on the performance of the high yielding rice variety Sabari" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

(U. MOHAMED KUNJU)

Place: Vellayani,
Date : 10-2-1989.

CERTIFICATE

Certified that this thesis entitled "Influence of levels of nitrogen, methods of application and plant population on the performance of the high yielding rice variety Sabari" is a record of research work done independently by Sri. U. Mohamed Kunju, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

12.4.89

Dr. N. SADANANDAN
Chairman, Advisory Committee
Director (P.G. Studies)
Kerala Agricultural University

Vellayani,

Date: 10-2-1989

APPROVED BY

Chairman

Dr. N. SADANANDAN

Members

1. Dr. M.M. KOSHY

2. PROF. K.P. MADHAVAN NAIR

3. PROF. P.V. PRABHAKARAN

4. Dr. (Mrs.) ALICE ABRAHAM

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LIST OF ABBREVIATIONS

LAI - Leaf Area Index

DMP - Dry matter production

AICRIP - All India Co-ordinated Rice Improvement Project

DAT - Days after transplanting

INTRODUCTION

INTRODUCTION

With the evolution and introduction of high yielding, fertiliser responsive and non-lodging dwarf varieties of rice and wheat, the long standing concept of crop production has been revolutionised. These varieties have been successful in increasing the production in a short span of time. The tremendous yield potential created by the dwarf indicas has led to a crash hybridization programme in order to improve the local varieties in their yield potential. With this idea in mind, a number of varieties were evolved at the Regional Agricultural Research Station, Pattambi in Kerala State. But, any variety, however great its yielding potential be, may fall short of its promise in the absence of proper agro-technical factors.

Realisation of high yields rests in proper management of the rice crop, the most critical of which are nutrition and plant population. When grown under unfavourable environmental conditions or without the required cultural practices and fertilization techniques, the improved varieties may not manifest their maximum yield potential.

It is well known that nitrogen is the most limiting nutrient in rice soils of India and at the same time the most needed nutrient for successful rice production.

Further, it has been well established that high yielding varieties make heavy demand for major nutrients and judicious application of fertilizers is therefore essential to exploit fully the yield potential of these varieties.

Studies with high yielding varieties of rice have indicated high fertilizer response upto 200 kg N/ha (Kalyanikutty, 1970). Nitrogen is the most mobile nutrient and hence it suffers considerable loss primarily due to leaching and volatilization. To make better utilisation of applied nutrients and thereby to increase its efficiency, various techniques like placement, foliar spray etc. have been attempted. Information obtained from field trials and tracer studies have shown that nitrogen losses in varying forms and magnitudes ranging from 30 to 50 per cent of applied nitrogen are likely to occur in the case of soil application. Because of the diversities in soil and environmental conditions, the application of nitrogen at times is rendered ineffective under situations like prolonged flooding and dryspell during crop growth. Methods other than soil application should therefore be explored to ensure efficient nitrogen supply at the critical periods. Thus, a knowledge of the yield and profit maximising doses and of the resulting increase by its use in production and net profits would be necessary for making meaningful decisions regarding its appropriate application levels.

Foliar spray of nitrogenous fertilizers is frequently necessary for quick recovery of plants exhibiting deficiency symptoms and is particularly important for the high yielding varieties for satisfying the heavy demand for nitrogen within a short pace of time during the critical stages of growth. The beneficial effects of foliar application of nitrogen on increased uptake and efficiency have been reported in several crops. Supply of a part of the total requirement of nitrogen through foliage has been found to have increased nitrogen efficiency in addition to a reduction in the quantity required. Preliminary studies revealed that foliar application of nitrogen increased the grain yield of rice as compared to soil application (Bhaskaran, 1970). In the high yielding dwarf varieties which are capable of remaining physiologically active in the post-flowering stage, the nitrogen supply at the panicle development stage may be all the more critical and an evaluation of soil and foliar methods of nitrogen application in respect of nutrient uptake and grain yield would be of practical benefit.

Plant population is another important yield contributory character which can be manipulated to attain the maximum production from a unit land area. An optimum plant population per unit area of land would be essential for effective utilisation of the inputs and environment. Under various plant densities, the plants manifest a remarkable capacity to exploit the environment with varying competition stresses. Adjusting the plant population according to the availability of plant growth factors becomes thus a cardinal principle in exploiting the maximum potential of crops like rice. Experiments conducted at different places have revealed that there is an optimum spacing for each variety of rice especially for high yielding varieties.

It was therefore considered worthwhile to undertake a study on the effects of various levels of nitrogen, methods of application and plant population on the high yielding rice variety '<u>Sabari</u>'.

The main objectives of the present investigation are the following.

1. To study the effects of graded doses of nitrogen on the growth and yield of rice variety '<u>Sabari</u>' and to work out the optimum dose of the nutrient;

2. To determine the relative merits of foliar and soil application of nitrogen to rice under the agro-climatic conditions of the South Region of Kerala;

3. To assess the effects of varying plant populations on the performance of the variety and to suggest

the best suited plant population for higher yields under different nitrogen levels; and

4. To work out the economics of nitrogen application to rice at varying levels and methods and under different plant populations.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Among the major plant nutrients, nitrogen is the most limiting one for successful rice production. Method of application is an important factor in determining the response of the crop to fertilizers. Plant density is another important yield contributing character which can be manipulated to attain the maximum yield. Many experiments and investigations have been conducted on these aspects in India and abroad which are briefly reviewed hereunder.

2.1. Effect of nitrogen

Nitrogen is the key to the realization of the yield potential of modern rice varieties. The response of the rice crop to the application of nitrogen is almost universal, the extent of response depending on the form of the fertilizer, the method and time of application, the soil type and the response potential of the varieties. The favourable response to nitrogen is attained by its influence on the growth and yield of the plant and through its role on the metabolic functions in rice (Murata, 1969). The recovery of applied nitrogen by the rice crop seldom exceeds 40 to 50 per cent (Craswell and De Datta, 1980; and Mandal and Dutta, 1987).

2.1.1. Effect of N on growth characters

Patnaik (1961) described the typical N deficient rice plant as a small sized one with less number of tillers, orange coloured lower leaves and yellowish medium and upper leaves. The upper leaves are also small, straight and stiff.

a. Plant height

The effect of nitrogen in increasing the plant height is well known. Increases in plant height due to incremental doses of nitrogen application had been reported by many workers (Panda, 1969; Mani, 1979; Iruthayaraj and Morachan, 1980; De Datta, 1981; Yoshida, 1981; Balasubramanian and Dawood, 1987 and Singh and Sharma, 1987).

Progressive increase in plant height due to N upto 200 kg/ha was reported by Nair and George (1973), Kalyanikutty and Morachan (1974) and Sadayappan et al. (1974), and upto 120 kg N/ha by Kuriakose and George (1974), Singh and Singh (1976), Chang and Su (1977), IRRI (1986) and Thakur and Singh (1987).

Padmaja (1976) observed a sharp increase in plant height upto 20 ppm N in the culture solution. The increase was gradual between 20 and 60 ppm, beyond which there was decrease in plant height. Munegowda and Panikar (1977) observed highest plant height at 160 kg/ha. While Singh and Sharma (1987) observed increased plant height upto 180 kg N/ha, Thangamuthu et al. (1987) found increase in plant height only upto 116 kg N/ha.

b. Tiller number

The initiation of tiller primordia is not influenced by environmental factors, but its emergence and development are greatly influenced by them including N supply (Yamasaki, 1966). Tanaka (1964) reported the critical contents of nutrients required for the increase in tillers as 2.50 per cent N, 0.23 per cent P_2O_5 and 1.50 per cent K_2O. Increase in tiller production with incremental levels of nitrogen application has been reported by several workers. Kalyanikutty and Morachan (1974) showed that the tiller number was increased upto 200 kg N/ha. Sadayappan et al. (1974) also reported similar results, but the levels 150 kg and 200 kg N/ha were on par. Lenka et al. (1976) observed that increase in nitrogen levels from zero to 180 kg/ha increased the number of tillers per plant. Chang and Su (1977) and Thakur and Singh (1987) showed increase in number of tillers only upto 100 kg N/ha. Murty and Murthy (1978) found increased tillering with increase in N upto 120 kg/ha. The rice variety Jaya grown on a sandy clay loam soil gave significant increase in number of tillers per hill with increased nitrogen levels upto 180 kg/ha (Raju, 1979). Balasubramanian (1980), Yoshida (1981), Ramaswamy (1982) and Sadayappan (1982) also reported increase in tiller number with increase in N application. It was also reported that the stored N was less effective than the supply of N from the medium in promoting tillers. In the field trials at the International Rice Research Institute, Philippines, tiller number was increased upto 120 kg N/ha (IRRI, 1986) whereas Srinivasulu Reddy (1986) found maximum tiller number at 180 kg N/ha. Increase in number of tillers with increasing N was also reported by Santos et al. (1986). Balasubramanian and Dawood (1987) pointed out that tillering was associated with the nutritional condition of the mother culm which supplies carbohydrates and other nutrients to the developing tillers in the early stages. Ghosh et al. (1987) also obtained significant increase in the number of tillers due to incremental levels of nitrogen.

From the foregoing review it is observed that nitrogen fertilization favourably influences tiller number in rice.

c. Leaf area index

Increase in leaf area index due to nitrogen application has been reported by several workers. The LAI progressively increased with N upto 160 kg/ha (Panda, 1969). Palit *et al*. (1976) observed that LAI was progressively increased with N doses upto 136 kg N/ha. Similar increases in LAI due to incremental doses of N were reported by Panaev and Bekniyazov (1977), Murata and Matsushima (1978), Wells and Faw (1978), Balasubramanian (1980), Yoshida (1981), Ramaswamy (1982) and Sadayappan (1982). Sobhana (1983) revealed that progressive increases in LAI were brought about by increasing fertilizer levels. Abdul Salam (1984) reported that the LAI increased significantly with N application upto 120 kg/ha in all seasons except summer at which the effect of 120 kg N/ha was on par with 90 kg N/ha.

From the above review it was concluded that there was significant increase in LAI due to N application.

d. Dry matter production

Ishizuka and Tanaka (1960) found that the dry matter production was considerably increased when the deficient rice plants were grown in complete nutrient solution. Rapid early growth with high dry matter production of vegetative parts was recorded and correlated with low rate of growth in later period and poor nitrogen response in tall *indica* varieties whereas in dwarf *indica* at the early stages, the dry matter production was low, the nitrogen uptake was slow but it markedly increased at the later stages (AICRIP, 1968). Panda (1969) reported that the increasing levels of nitrogen upto 160 kg/ha increased the dry matter production in rice.

Chinnaswami and Chandrasekharan (1977) found that the 'DMP' was progressively increased with N application upto 160 kg/ha and suggested that plants suitable for heavy manuring could maintain high efficiency of DMP through high photosynthetic efficiency with added N.

The effect of nitrogen in increasing dry matter production has also been reported by Singh and Modgal (1978a), Balasubramanian (1980), Iruthayaraj and Morachan (1980), De Datta (1981), Yoshida (1981), Sadayappan (1982), Ramaswamy (1982), Ghosh et al. (1987) and Thakur and Singh (1987).

e. Days to 50 per cent flowering

Period taken for blooming of 50 per cent plant population was significantly affected by levels of N (Bhaskaran, 1970). He also noticed first flowering in plants receiving the lowest level of N (50 kg/ha). The levels 50 kg and 100 kg N/ha were on par. Kuriakose and George (1974) observed that at lower N level flowering was hastened.

Prasad (1981) found that N doses recorded significant differences in the flowering of plants. There was linear increase in days to 50 per cent flowering with an increasing dose of N. Highest number of days to 50 per cent flowering was noticed in 120 kg N/ha.

2.1.2. Effect of N on yield components

Nitrogen had marked effect both on yield and yield attributes. The grain yield in rice is determined by the yield components viz., the number of panicles per unit land area, the number of spikelets per panicle, the filled grain percentage and the mean grain weight.

a. Number of panicle

Ishizuka and Tanaka (1960) noted a very poor panicle production under complete N deficiency and the panicle per plant were 1.5 and 10.0 in the case of N deficient and complete fertilised plants respectively. Tanaka (1964) also observed that low N responsive varieties have a limited increase in panicle number whereas high responsive varieties exhibit a large increase with an increase in N application. In an experiment on the N requirement of IR 8 and Taichung (Native) 1, Gupta et al. (1970) observed an increase in the number of panicles with increase in nitrogen upto 135 kg/ha. Similar increases in the number of panicles per hill due to increases in the dose of N were reported by Ramanujam and Rao (1971), Muthuswamy et al. (1972), Sadayappan (1972), Subramanian and Kolandaiswamy (1973), Eunus and Sadeque (1974), Rajagopalan et al. (1974), Rethinam (1974) and Subbiah and Morachan (1974). Kuriakose and George (1974) found that the levels 90 and 120 kg N/ha did not show any significant difference in the number of panicles per hill, however, the maximum number was noticed at 90 kg N/ha. Increases in the number of panicles per hill and unit land area due to N doses were also reported by Pillai et al. (1975), Gowda and Panikar (1977), Subbiah et al. (1977), Dixit and Singh (1977), Mani (1979), Pillai et al. (1984), Heenan and Bacon (1985), Santos et al. (1986), Singh and Singh (1976), Balasubramonian and Dawood (1987), Dalai and Dixit (1987) and Mandal et al. (1987).

b. Panicle length and weight

Length of panicle is a character much dependent on the genetic character of the plant, but, it can also be manipulated by providing nutritional status and other environmental conditions. The total length of panicle is contributed mainly by the length of few basal internodes. The elongation of these internodes was found to be regulated by nitrogen supply. By providing good nutritional conditions, the length of the internodes can be encouraged. In dwarf *indica* varieties the panicle length was found to increase upto a level of 150 kg N/ha, while at 200 kg N/ha level, a slight decrease was noticed (AICRIP, 1968). The increase in length of panicle due to N application was also reported by Ramanujam and Rao (1971), Panda and Leeuwrik (1972), Alexander et al. (1973), Sadayappan et al. (1974), Raj et al. (1974), Chang and Su (1977), Subbiah et al. (1977), Raju (1979) and Mani (1979).

Increase in panicle weight due to incremental doses of nitrogen was reported by Padmaja (1976), Singh and Singh (1976), Chang and Su (1977), Balachandran Nair et al. (1979) and Ghosh et al. (1987).

However, no appreciable increase in panicle weight due to additions of N could be noticed by Subbiah and Morachan (1974).

c. Number of grains per panicle

Matsushima (1966) found that increasing nutrient supply resulted in a significant increase in spikelet number. However, very late application did not change the spikelet number but had a strong influence in preventing spikelet degeneration. Patnaik and Broadbent (1967) found top dressing of N at booting stage was useful to increase the number of filled grains per panicle and consequently the weight of grain per panicle. Gupta et al. (1970) reported that increasing the rate of applied N from zero to 135 kg/ha increased the number of grains per ear significantly. Panda and Leeuwrik (1972) observed an increase in the number of fertile and sterile spikelets per panicle upon increasing N levels upto 200 kg/ha. The number of filled grains increased with N application (Sadayappan, 1972). Number of grains per panicle exhibited an increasing trend with increase in N levels and the rate of increase was significant only upto 120 kg N/ha (Kalyanikutty and Morachan, 1974). In the case of short duration varieties, the number of grains per panicle was highest at 60 kg N/ha, it was on par with 90 kg N/ha and a reduction in the number of grains per panicle was observed at 120 kg N/ha (Kuriakose and George, 1974). This reduction might be due to the larger number of spikelets formed under that level and the insufficiency of assimilates available in the plants for filling these large number of yield containers. Increases in the number of grains due to increases in N application were also reported by Subbiah et al. (1975) and Singh et al. (1979) upto 120 kg N/ha, Chang and Su (1977) and, Dixit and Singh (1979) upto 80 kg N/ha. Similar increases in the number of grains per panicle due to incremental doses of N were recently reported by Pillai et al. (1984), Srinivasulu Reddy (1986), Dalai and Dixit (1987), Ghosh et al. (1987), Mandal et al. (1987) and Sudhakara et al. (1987).

As against the above findings, Srivastava *et al.* (1970), Purushothaman and Morachan (1974), Lenka *et al.* (1976) and Santos *et al.* (1986) did not get any significant effect on the number of grains due to incremental doses of N.

d. Test weight of grains

The weight of 1000 grains is determined by the size of the hull and quality of photosynthates stored in it. Kuichi and Ishizuka (1960) observed that the grain weight was favoured when the plant analysis showed a nitrogen content of 1.14 to 1.78 per cent at heading time and 0.85 to 0.90 per cent at maturity. Ishizuka and Tanaka (1960) recorded the 1000 grain weight as 23.0 g for plants grown in complete nutrient solution and 20.5 g for those grown in N deficient nutrient solution. Matsushima (1967) reported that the weight of 1000 grain was decisively determined by the effects of nutritional status of rice plant at the reduction division stage. He also reported that the top dressing of rapidly available nutrients just before the reduction division stage significantly increased the 1000 grain weight. Panda and Leeuwrik (1972) reported that nitrogen increased 1000 grain weight upto 200 kg N/ha. Though there was a positive influence of applied nitrogen to test weight, the treatment effects due to 50 to 200 kg

N/ha were on par (Sadayappan *et al*., 1974). Positive increase in thousand grain weight due to nitrogen application was also obtained by Padmaja (1976), Gowda and Panikar (1977), Balachandran Nair *et al.* (1979), Mani (1979), Raju (1979), Pillai *et al*. (1984), Ali Ahmad *et al*. (1985), Santos *et al*. (1986), Srinivasulu Reddy (1986), Dalai and Dixit (1987), Ghosh *et al*. (1987), Mandal *et al*.(1987) and Sudhakara *et al*. (1987).

As against the above reports, Muthuswamy *et al*. (1972), Eunus and Sadeque (1974), Natarajan *et al*. (1974), Pillai *et al*. (1975), Lenka *et al*. (1976) and Chandrasekharan and Salam (1985) revealed that the weight of 1000 grains remained unaffected by nitrogen application.

e. Sterility percentage

Sterility percentage was high due to high N application (Padmaja, 1976). The sterility percentage is increased especially under conditions of low light intensity (Togari and Kashiwakura, 1968). In high N responsive varieties it was less significant.

2.1.3. Effect of nitrogen on grain yield

Influence of nitrogen on grain yield of rice is well known. Increase in yield due to nitrogen application is universal with almost all the varieties though the degree of response varies among the varieties. At IRRI, highest yield of 6.10 t/ha was obtained in IR 20 rice at 150 kg N/ha whereas in IR 22, the highest yield was 6.07 t/ha at 120 kg N/ha (IRRI, 1969). In the sandy clay soils of Bhavanisagar, IR 20 recorded the maximum grain yield at 100 kg N/ha, but at Coimbatore, the response goes upto 132 kg N/ha (Anon., 1970). The grain yield increased with enhanced levels of nitrogen in several high yielding varieties (Ramanathan and Krishnamurthy, 1971). Kulandaivelu and Kaliappa (1971) observed positive response upto 135 kg N/ha with the variety ADT.27 and the yield was reduced on further increase in nitrogen. In the case of Karuna and Annapurna varieties of rice, the response to nitrogen was significant and the grain yield increased upto the level of 100 kg N/ha beyond which a decrease was noticed (Unnikrishna Kurup and Sreedharan, 1971). Sadayappan (1972) found no response in IR 20 beyond 100 kg N/ha. In the rice varieties IR 8 and Jaya, the optimum dose for maximum production was found to be 155 kg N/ha and the most economic level was 125.5 kg/ha. The response equation worked out was $Y = 4576 + 28.14\,x - 0.09075\,x^2$ (Sumbali and Gupta, 1972). Atar Singh and Pal (1973) found that the yield of rice increased with increase in N upto 150 kg/ha. The grain yield increased with increasing levels of nitrogen upto 120 kg/ha with 80 kg N and 120 kg N on par (Alexander et al., 1973). The physical and economic optimum doses of nitrogen for Tainan 3 were 102.0 and 92.0 kg N/ha and for Ptb. 9 they were 98.7 and 87.6 kg/ha respectively. In the case of IR 8 the response was linear upto 120 kg and application of higher doses of nitrogen appeared essential to exploit the full production potential of the variety (Nair and George, 1973). However, the optimum level of nitrogen for IR 8 was found to be 117 to 153.8 kg/ha under different situations (Singh, 1973). Eunus and Sadeque (1974) reported that in dwarf indicas linear response to applied nitrogen upto 135 kg was obtained. The optimum doses of nitrogen for ADT.27 and CO.33 were 106 kg and 157 kg/ha respectively (Kalyanikutty and Morachan, 1974). They also found that the response curves to N was quadratic in nature. The variety CO.33 recorded 29, 22, 18, 15 and 13 kg of increased yield per kg of nitrogen at 40, 80, 120, 160 and 200 kg N/ha. The highest net profit was obtained from 200 kg N/ha in CO.33. Kuriakose and George (1974) obtained an average grain yield of 5.6 t/ha at 90 kg N/ha and this was higher than the yield obtained in other levels. The yield was reduced on further nitrogen application. They also found that the optimum level of nitrogen for culture 24-20 was 82.35 kg/ha. Purushothaman and Morachan (1974) reported that IR 8 responded economically upto 225 kg N/ha at Coimbatore whereas the same variety at Kariyiruppu gave the highest yield at 120 kg N/ha (Anon., 1977). Quadratic form of response curve was found to be the best fit for dwarf _indicas_ and the additional yield due to fertilizer application was maximum at the level of 160 kg N/ha and the additional income was Rs.1694.50/ha (Rethinam, 1974). Sadayappan _et al_. (1974) found that the economic optimum dose for the variety 14-20 was 145 kg/ha. The added profit, though gradually increased with increased doses of nitrogen, was higher than the added cost upto 150 kg/ha. The response equation worked out from this trial was $Y = 3970.4 + 23.302\ x + 0.06948\ x^2$. Linear increase in grain yield even upto 160 kg N/ha was reported by Singh _et al_. (1974). Varma (1974) reported positive increase in yield of rice upto 120 kg N/ha while Pillai _et al_. (1975) observed that the yield increased progressively only upto 80 kg N/ha and the rate of increase beyond 80 kg was not significant. Rethinam _et al_. (1975) found that the increase in yield was sequential, to the graded levels of nitrogen and a maximum yield was obtained with 160 kg N/ha in both tall and dwarf _indica_ rice varieties. Similar results were also reported by Sahu and Murty (1975). The results of the work involving combinations of 3 varieties IR 8, T(N) 1 and Padma and three levels of nitrogen, 0, 60 and 120 kg/ha showed that the grain yield of dwarf rice significantly increased with increase in N application upto

120 kg/ha (Lal et al., 1976). Grain yield was increased significantly upto 136 kg N/ha level (Palit et al., 1976). Increasing the N level from 0 to 120 kg/ha increased the grain yield from 4.33 to 6.89 t/ha (Pandey, 1976). Satyanarayana and Sharma (1976) reported that increase in nitrogen rates from 0 to 120 kg/ha increased average paddy yield in six early maturing varieties. In field trials with the rice variety Padma, Sharma and De (1976) observed that increasing the nitrogen rates from zero to 150 kg/ha increased average grain yields, but that further increase in N rates gave no additional yield. Singh and Singh (1976) observed that average grain yield increased from 1.44 t/ha to 2.0 t/ha with increase in N application from 30 to 90 kg/ha. From the investigations by Venkatachari et al. (1976) it was evident that maximum yield of rice could be obtained at 150 kg N/ha whereas the response per kg of applied N was highest at 50 kg/ha.

In a study on the varietal response of rice to nitrogen, Chandragiri et al. (1977) reported that optimum dose of nitrogen for the different varieties ranged from 146.88 kg to 165.13 kg/ha. The grain yield was substantially increased with increase in N application (Chang and Su, 1977). Gowda and Panikar (1977) observed that the response to nitrogen was linear upto 160 kg N/ha in the case of Jaya, IR 8 and IR 5 whereas in the case of

IR 28 and IR 36, the grain yield was not influenced by fertilizer rates at moderate levels (Macalinga et al., 1977). Nitrogen application upto 150 kg/ha increased yields of rice by 52 per cent (Nozaki et al., 1977). Panaev and Bekniyazov (1977) found that the grain yield was substantially increased when the N rate increased from 90 kg to 120 kg/ha. The yields of eight cultivars, given zero to 200 kg N/ha, increased with increase in nitrogen rates, the economic optimum rate was 100 kg/ha (Rao, 1977). There was linear response upto 100 kg N/ha (Reddy and Prasad, 1977). Roy et al. (1977) found that in trials with long duration cultivar, Pankaj, grain yield was highest with 120 kg N/ha. The economic optimum doses of N for Jaya and IR 20 were 158 and 116 kg/ha respectively (Singh and Modgal, 1977). Singh et al. (1979) found that the net return per rupee invested ranged between Rs.2.69 to Rs.3.05 for different varieties. Increasing N levels from 0 to 180 kg/ha increased the average yield from 3.23 to 4.74 t/ha, the response was significant only upto 120 kg N/ha (Srivastava and Mahajan, 1977). Subbiah et al. (1977) from their studies on the influence of levels of nitrogen on yield of rice varieties worked out the response equation as $Y = 3336.92 + 25.15\ x - 0.0643\ x^2$ and the optimum dose was found to be 196 kg N/ha. Plants fertilised with 90 kg N significantly increased grain yield over 45 kg N/ha* (Clarete and Mabbayad, 1978). The investigation by Dargan and Chhillar (1978) showed that significant increase in grain yield was obtained with 100 kg N/ha over control. Murty and Murty (1978) observed that rice yields increased with N rates upto 120 kg/ha. Significant yield increase with N was also reported by Prasad and Rathi (1978). The yield of rice was increased with increase in N application and the increases were significant only upto 90 kg N/ha (Singh and Modgal, 1978b). Venkateswarlu (1978) observed that application of 250 kg N/ha increased the grain yield significantly over 50, 100, 150 and 200 kg/ha. The optimum N was found to be 120 kg/ha as higher rates increased the risks of lodging and diseases in rice varieties (Wells and Shockley, 1978). Dixit and Singh (1979) observed that grain yields increased from 2.18 t/ha with no N to 4.19 t/ha with 80 kg N/ha. Panda and Das (1979) observed that increasing the rates of applied N from zero to 200 kg/ha increased the average paddy yields from 6.13 to 8.96 t/ha in seven dwarf cultivars tried. Increase in grain yields with N doses upto 180 kg/ha was reported by Raju (1979). After reviewing a large number of experiments, Sekhon (1979) reported that the response of rice to fertilizer N as 10.8 and 9.8 kg grain per kg N under 60 and 120 kg levels. The yield of grain was increased from 3.76 t/ha to 5.56 t/ha when the N level was increased from 0 to 150 kg/ha. At 200 kg N/ha the yield was only 5.48 t/ha (Sharma and

Rajat De, 1979). Mengel and Wilson (1981) also reported that grain yield increased with increased nitrogen application. Field experiments conducted on Jaya rice showed that nitrogen required to produce one tonne of grain was 19.9 kg in dry season and 23.5 kg in wet season (Sambasiva Reddy et al., 1982). The response of dwarf indica varieties to N application varied under different situations (Singh and Kumar, 1983). Mittra et al. (1984) and Reddy and Mittra (1985) reported that considerable variations existed in the response of rice to applied nitrogen. Pillai et al. (1984) found that N application gave appreciable increase in grain yield. Sannigrahi and Mandal (1984) observed that the grain yield of rice increased significantly with successive increment of N from 30 to 90 kg/ha. Increasing N rates upto 150 kg/ha increased the average paddy yields from 3.02 to 6.56 t/ha in the variety Jaya (Harbir Singh et al., 1985). The grain yield increased with an increase in N level from 0 to 150 kg/ha. The response was quadratic in the first year of experiment and linear in the second year (Mohankumar and Singh, 1985). Patel et al. (1985) obtained positive increase in yield upto 120 kg N/ha. Rice cv Mahsuri gave average yields of 3.89, 4.33 and 4.98 t/ha under 50, 100 and 150 kg N/ha levels respectively (Kanade and Kalra, 1986). Khader et al. (1986) found that the grain yield and its attributes were significantly influenced by levels of N applied as urea upto 90 kg N/ha. N at 120 kg/ha gave significantly higher yield over zero. The response per kg of applied N worked out to be 18.9 at 80 kg N/ha and 16.8 at 120 kg N/ha (Raghuwanshi et al., 1986). Grain yield increased significantly with successive increment of nitrogen from 30 to 90 kg/ha. The rate of increase was maximum (30 per cent) from 30-60 kg/ha followed by 0-30 kg N/ha (25 per cent) and was only 17 per cent from 60-90 kg/ha level. The magnitude of increase in yield with 30, 60 and 90 kg N/ha over control was 25, 63 and 90 per cent respectively (Ramasubba Reddy et al., 1986). Increasing N rates from 40 to 80 and 120 kg/ha increased the yields of low land rice from 4.62 to 5.38 and 5.79 tonnes per hectare (Reddy and Reddy, 1986). Sawant et al. (1986) found that the yield of grain increased with N application upto 120 kg/ha. Increasing N levels from 0 to 150 kg increased rice yields progressively (Singh et al., 1986) while Singh and Singh (1986) obtained highest yield at 120 kg N/ha. The variety Jaya responded upto 180 kg N/ha at Tirupati (Srinivasulu Reddy, 1986). Dalai and Dixit (1987) and Ghosh et al. (1987) also reported increase in yield due to additional levels of nitrogen upto 180 kg/ha. The grain yield increased significantly with an increase in N application (Gill and Shahi, 1987). Application of 80, 100, 120 and

140 kg N/ha to rice cv. IR 22 gave average paddy yields of 3.74, 4.23, 4.51 and 4.74 t/ha respectively, 100 kg N being the optimum economic rate (Patel et al., 1987). Application of 180 kg N/ha increased the yield from 1.3 to 3.4 t/ha (Singh and Sharma, 1987). Increases in yield due to N application were also reported by Sudhakara et al. (1987). Thakur and Singh (1987) observed yield increase with N upto 100 kg/ha. The highest yield was obtained at 116 kg N/ha with no significant difference between 87 and 116 kg N/ha levels (Thangamuthu et al., 1987). Om et al. (1988) reported that the grain yield increased significantly upto 150 kg N/ha and the average yield obtained was 5.5 t/ha.

2.1.4. Effect of N on straw yield

Significant increase in straw yield due to N application was recorded in many cases. Sastry and Freeman (1971) stated that the straw production due to N application was closely parallel to grain production. Straw yield was increased upto 100 kg N/ha (Unnikrishna Kurup and Sreedharan, 1971), upto 180 kg/ha (Ramanujam and Rao, 1971), upto 120 kg/ha (Muthuswamy et al., 1972) and upto 200 kg/ha (Sumbali and Gupta, 1972). Alexander et al. (1973) obtained straw increase upto 120 kg N/ha, Eunus and Sadeque (1974) upto 135 kg/ha and Kalyanikutty and Morachan (1974) upto 200 kg/ha. Maximum straw yield of 5010 kg/ha was obtained at 120 kg N/ha, but it was not significantly different from the straw yield at 90 kg/ha (Kuriakose and George, 1974).

Sadayappan et al. (1974) revealed that nitrogen influenced the straw yield significantly and found that the levels of 150 kg and 200 kg/ha were on par. Singh et al. (1974) and Rethinam et al. (1975) also obtained significantly increased straw yield due to increased levels of N. Venkateswarlu (1978) reported that straw yield increased upto 200 kg N/ha, beyond this dose the straw yield decreased. Somasundaram (1981) recorded significant increase in straw yield with N application. Significant increases in straw yield were also reported by Mohankumar and Singh (1985) and Singh and Singh (1986) upto 150 kg N/ha, Srinivasulu Reddy (1986) upto 180 kg N/ha, Dalai and Dixit (1987), Singh and Sharma (1987) and Sudhakara et al. (1987) upto 120 kg/ha. Straw yield was increased upto 150 kg N/ha and the average straw yield was 6.2 t/ha at this level (Om et al., 1988).

2.1.5. Effect of N on grain : straw ratio

Yoshida (1972) stated that grain : straw ratio was clearly correlated to varietal characteristics. However, management practices including nutrition influenced this character to some extent. Highest grain : straw ratio of

1.17 was reported at 60 kg N/ha and this was on par with 90 kg N/ha. The ratio was found to be smaller at 120 kg N/ha (Kuriakose and George, 1974). Nitrogen influenced the grain : straw ratio (0.77) at all levels and the ratio was high in 40 kg N/ha and the ratio was lowered at higher levels of N (Kalyanikutty and Morachan, 1974). On the other hand the harvest index in rice was not changed due to incremental doses of N (Palit et al., 1976). Murty and Sahu (1977) revealed that the harvest index was reduced when the level of nitrogen increased. Similar results were also reported by Prasad (1981). Avijitsen and Gulati (1986) recorded lower harvest index at higher N level and this was mainly due to higher vegetative growth.

2.1.6. Effect of nitrogen on grain and straw quality

Grain quality in rice is found to be influenced by varieties, rates of N application and the time and method of application of N.

Kido and Yamatori (1968) demonstrated that all the manurial and cultural conditions such as heavy fertiliser application resulted in protein enrichment of the kernel.

There was significant increase in protein content of grain and N content of straw with increasing levels of N (Ahammed, 1970; Ramanujam and Rao, 1971; Ghosh et al., 1971; Unnikrishnakurup and Sreedharan, 1971 and Kulkarni, 1973). Abraham *et al*. (1974) found that the protein content of grain was increased with nitrogen and the maximum of 7.37 per cent was obtained at 120 kg N/ha. Increased application of nitrogen increased the crude protein content of rice grain (Kalyanikutty and Morachan, 1974). Srivastava and Verma (1974) obtained increased grain protein content with successive increases in nitrogen upto the maximum of 200 kg/ha. Significant increases in protein content of grain and nitrogen content of straw were noticed with nitrogen application upto 120 kg/ha (Bhargava *et al*., 1975). Kothandaraman *et al*. (1975) observed that increased application of nitrogen increased the crude protein content of the rice grain. Considerable increase in grain protein content with nitrogen application was reported by Nagarajan *et al*. (1975). Pisharody *et al*. (1976) found that the grain protein content was increased by application of incremental doses of N. Rabindra *et al*. (1977) found that increasing the nitrogen rates from zero to 160 kg/ha increased the grain protein content from 5.42 to 6.92 per cent. Dutta and Barua (1978) observed that nitrogen rates from zero to 80 kg/ha increased grain protein. There was significant increase in the percentage protein with increasing nitrogen application (Gangadharan *et al*., 1978). Raju (1979) reported increased protein content of grain with applied nitrogen. Increased nitrogen rates and foliar application increased the crude protein content of the grain (Sharma and Rajat De, 1979). Ghosh *et al.* (1987) observed increased protein content in grain due to incremental levels of nitrogen. The nitrogen content of straw was also increased with N. Sudhakara *et al.* (1987) and Thakur and Singh (1987) also reported increase in protein content of grain due to increased doses of nitrogen application.

The above review clearly shows that the protein content of grain and nitrogen content of straw were significantly increased by nitrogen application. However, Muthuswamy *et al.* (1973) and Subramanian *et al.* (1974) observed no significant difference in these characters due to increased application of N.

2.1.7. Effect of N on nutrient uptake

Uptake of N increases with increasing levels of nitrogen application. Koyama and Niam Srichand (1973) found a linear relationship between total nitrogen uptake and the level of applied N. Prasad and Jha (1973) also obtained similar results. Nagarajan *et al.* (1975) showed that N application at the flag leaf and heading stages resulted in high fertilizer N uptake. Uptake of N at harvest increased progressively with incremental doses of nitrogen upto 120 kg/ha (Abraham *et al.*, 1976). Chattopadhyay *et al.* (1976) found that N uptake was more under N application.

N content in grain and straw and the total uptake of N increased with increasing N rates upto 75 ppm but decreased with 150 ppm N (Khan and Pathak, 1976). Similar observations were made by Pandey (1976). Gopalaswamy and Raj (1977) reported that increasing rates of applied nitrogen from zero to 200 kg/ha produced linear increase in the uptake of nitrogen. Application of N upto 120 kg/ha increased the uptake (Agarwal, 1978). Similar increases were also noticed by Raju (1979) and Singh and Modgal (1978b). Increase in N uptake due to incremental doses of N application was reported by Mani (1979). Rai and Murty (1979) noticed increased uptake of N only upto 80 kg N/ha level. Uptake of N was enhanced due to additional doses of N and the highest N uptake value was noticed in 100 kg N/ha level (Sadayappan, 1982). Srinivasulu Reddy (1986) found that the uptake of N was more with 180 kg N. Similar increases in the uptake of N due to higher rates of N application were reported by Ghosh et al. (1987). Sudhakara et al. (1987) and Thakur and Singh (1987). Salam (1988) reported that the uptake of N increased upto 120 kg N/ha level.

Increases in the uptake of phosphorus by application of incremental doses of nitrogen were reported by Singh and Modgal (1978a), Sadayappan (1982) and Srinivasulu Reddy (1986).

The uptake of potassium by the application of N was also studied and it was found that the total uptake of K increased with higher rates of N application (Subramanian, 1976; Singh and Modgal, 1978a; Sadayappan, 1982 and Srinivasulu Reddy, 1986).

2.2. Effect of foliar application of N on growth, yield and quality of rice

The efficiency of applied N is influenced by the method of application. The ability of plants to absorb mineral nutrients through roots and foliage was recognised much earlier. Crop feeding through soil is the most widely practiced and universally accepted conventional method of application of fertilizers while foliar feeding is restricted to the nutrition of trace elements, correction of deficiencies and to certain crops and specific situations.

Foliar application of N and other nutrients have been found to increase the nutrient uptake and rate of absorption. Extensive absorption and distribution throughout the plant within 24 hours have been shown by the use of N^{15} labelled urea applied to the foliage in different crops (Burr _et al_., 1957).

The spraying of nutrients on the foliage of crop plants has been recommended under different situations and soil conditions such as flooding, water logging, soil moisture stress etc. (Bhaumik, 1966). There are a number of reports both supporting as well as contridicting the response of crops to such practices (Gasser, 1964 and Sadayappan and Rethinam, 1969).

The loss in N utilisation efficiency for urea application in standing water of rice by broadcasting, concentrated urea spray and diluted urea spray, was estimated as 13 per cent, 10 per cent and 8 per cent respectively (AICRIP, 1969).

Narayanan and Vasudevan (1957) recorded 6 per cent increase in yield of paddy when urea was sprayed on foliage. Subramanian (1959) found 9.4 per cent increase in yield of paddy with spray application of 30 kg N/ha over the corresponding application to soil. Foliar application of dilute urea solution might be preferred over soil application where rice roots might have been damaged by reduced conditions or excessive salinity (Nagai, 1958). Mahapatra and Sharma (1963) recorded an yield increase of 29 per cent and 23 per cent by foliar application of urea to supply 15 and 30 kg N/ha respectively at the active vegetative growth stage over the same level of N applied all through soil. At Jabalpur, 20 kg N as urea supplied half as basal and half as foliar spray gave an additional yield of 50 kg grain per hectare over the same dose given through soil

(Bhaumik, 1966). Sahu and Lenka (1967) found 33.8 per cent yield increase by half soil plus half foliar application over control as against 19.3 per cent and 25.7 per cent increase recorded for full foliar and full soil applications. De et al. (1967) found significant increase in grain yield of paddy by half soil plus half foliar spray upto 160 kg N/ha over the corresponding dose given through soil. Beyond 160 kg N/ha, the yield differences were not significant. Dhua and Ray (1968) could find beneficial effect of foliar application in respect of straw yield only. Sadayappan and Rethinam (1969) observed that soil application of 120 kg N/ha gave the highest yield in ADT-27 while the same dose given half through soil and half through foliage depressed the grain yield by 7.7 per cent. Mahapatra (1969) found that 100 kg N/ha applied as half basal plus half foliar spray gave a significantly better performance in rice than 150 kg N/ha all applied through soil. Veerarajan Urs and Havanagi (1969) recorded that application of 50 kg N/ha as basal and 50 kg N as four foliar sprays gave the highest yield of IR 8 and Taichung 65 than the corresponding dose given through soil.

In a study on the urea spray in submerged and alternate drying and wetting conditions in rice, it was found that 75 per cent soil plus 25 per cent foliar was better than 50 per cent soil plus 50 per cent foliar and full soil application in both situations. Studies at Hyderabad centre of AICRIP showed that 75 per cent soil plus 25 per cent foliar spray and 66 per cent soil plus 34 per cent foliar spray of diluted urea solution yielded higher than that of concentrated urea spray or broadcast application of the same dose of urea. It was also observed that as the basal soil application fraction decreased below certain level, the yield also decreased with the foliar spray treatment (AICRIP, 1969).

When the second top dressing of nitrogen was given through foliage, the dry matter production, number of panicles per m^2, number of spikelets per panicle, number of filled grains, panicle weight and yield of grain were increased significantly when compared to soil application (Bhaskaran, 1970). The effects were conspicuous at the 100 kg N/ha level. He also found that the uptake was more in foliar spray treatment. The protein content of grain was increased due to foliar spray of nitrogen. Gupta (1971) reviewed the work on the foliar application of nutrients to rice and the beneficial influence of the practice reported.

Experiment conducted at CRRI, Cuttack revealed that the yield of grain was high when 75 kg N/ha was applied as foliar as compared to the soil application of the same quantity of N (Mudholkar _et al._, 1973).

In all the experiments where foliar spray of nitrogen was made, the N concentration in grain and straw were high. Foliar spray also encouraged total uptake of N. Apparently foliar spray of urea increased the N supply in foliage and the nitrogen was subsequently translocated into different plant parts including grain and straw (Jha et al., 1974). Foliar spray increased paddy yields (Gowda et al., 1976).

Plant height, yield of grain and straw and protein content of grain increased with foliar application of nitrogen and number of empty spikelets reduced (Bhuiya et al., 1975).

Ramiah and Morachan (1976) observed that the grain and straw yields were significantly increased in the plots which received aerial application of urea at the panicle initiation stage. The number of effective tillers, number of grains per panicle and 1000 grain weight were also increased. With full N through soil and 75 per cent through soil plus 25 per cent through foliage gave yields of 5.13 and 5.51 t/ha respectively (Sharma and De, 1976). Foliar application of N increased paddy yield by 800 kg/ha and the grain protein content was increased appreciably (Fanyaw and Yakovlev, 1977; and Gomes and Vahl, 1979). Spraying 2 per cent urea solution on the leaves of rice gave increased protein content of grain (Nishizawa et al., 1977). Subramanian and Kangasabai (1977) reported that the foliar application was more effective for increasing crop yields. Foliar application in general helped to save 25 per cent nitrogen requirement. The response of rice varieties to foliar vs. soil application of nitrogen was studied and found that foliar application was significantly superior to soil application. Increase in grain yield of rice was observed by foliar application (Puttaswamy et al. 1975; and Venkatesan et al., 1977). On the other hand Ramakrishnan (1974) and Alice Abraham and Koshy (1978) did not get any significant difference in the yield of grain or straw due to foliar application of complex fertilizers partially or fully. Two per cent urea spray gave better results at the CRRI by increased grain yield (Mahapatra and Gupta, 1978). Raju et al. (1978) observed that there was no significant difference in plant height due to soil or foliar application, but the 1000 grain weight was significantly increased due to foliar application. Foliar application increased grain yield at the corresponding level of nitrogen applied through soil while straw weight was not increased. The yield was higher with part of the total nitrogen given through foliar application (Singh and Modgal, 1978a). Sharma and Rajat De (1979) found that when 50 per cent nitrogen was applied through soil plus 50 per cent through foliage the yield was 5.19 t/ha whereas complete N through soil resulted in 5.13 t/ha.

When 75 per cent N was applied through soil and 25 per cent through foliage, the yield increased to 5.50 t/ha.

In low nitrogen plots, spraying of urea increased the 1000 grain weight whereas in high nitrogen plot it was not significant (Chen, 1986).

From the foregoing review, it appears that in many cases application of 25 per cent nitrogen through foliage at the second top dressing stage is beneficial for increasing the yield components and quality of rice. However, there are few reports contridicting the response of crops to foliar nutrition.

2.3. Effect of spacing and plant population

2.3.1. Effect of spacing and plant population on growth characters

Proper plant spacing is one of the important factors to obtain good performance in rice particularly in transplanted conditions. In general, under poor fertility conditions, spacing between hills should be narrower so as to obtain enough number of tillers per unit area regardless of the plant type.

Fagade and Datta (1971) reported that increasing plant density through closer spacing increased the LAI at flowering. Different spacings (10 x 10 cm and 15 x 10 cm) influenced plant height, wider spacing resulted in taller plants (Unnikrishnakurup and Sreedharan, 1971). Baccam et al. (1975) observed that spacing had no effect on plant height and that wider spacing increased the number of tillers per hill. The narrow spacings increased LAI and DMP but decreased plant height and days to flowering (Mishra, 1976). Plant height and LAI were found to increase with decrease in spacing, but narrow spacing hastened flowering (Chang and Su, 1977). Panda and Mahapatra (1977) revealed that the number of leaves/m^2 and the LAI decreased with increasing spacing beyond 20 x 10 cm. The effect of plant spacing on LAI was studied by Pothiraj et al. (1977) in two rice varieties Kanchi and Kannagi and found that planting 100 hills (10 x 10 cm) with single seedling per hill recorded the maximum LAI of 7.31 at flowering. In wider spacing the LAI was reduced due to over crowding of tillers and mutual shading and consequent senescence of leaves. Shieh Yuh-Jang (1977) found that the total dry weight, tiller number and LAI based on unit ground area increased with increasing plant density although values of these characters per hill decreased with increasing plant density. Fagundo et al. (1978) reported that low density planting led to increased height whereas high density planting reduced tillering. Wells and Faw (1978) observed higher LAI with increasing population. Ghosh et al.

(1979) reported that LAI at ear emergence and dough stage was related to yield and was higher with closer planting than wider spacing. The cv. Pankaj gave higher values at a closer spacing of 15 x 15 cm than at a wider spacing of 20 x 20 cm. Ibrahim et al. (1980) revealed that plant height and tillering increased with increased spacing. The values for LAI were highest at a spacing of 10 x 10 cm and progressively decreased with increased spacing (Murty and Murty, 1980). Pedroso (1987) found that the plant height was not significantly affected by spacing. Rao and Raju (1987) observed that closer spacing of 15 x 10 cm reduced the number of days to 50 per cent flowering.

2.3.2. Effect of spacing and plant population on yield components, yield and quality of rice

Bathkal and Patil (1970) were of opinion that spacing did not influence grain yield. They also noted that straw yield was not influenced by spacing. Spacing between hills did not affect the test weight of grain (Singh and Modgal, 1977). Unnikrishnakurup and Sreedharan (1971) observed that different spacings (10 x 10 cm and 10 x 15 cm) did not have any significant effect on grain and straw yield eventhough the number of tillers and plants per unit area were more in closer spacing. They also found that closer spacing recorded significantly low protein content than wider spacing probably because of more competition and less photosynthetic activity at the reproductive stages. Varma (1972) reported that larger spacing brought about significant improvement in all yield components except the test weight. Greater availability of feeding zone per clump due to wider spacing might have positively affected the uptake and effective translocation of nutrient elements which in turn was responsible for improvement in all yield attributes. Chakraborthy (1973) found that grain yield at a closer spacing of 25 x 10 cm was relatively better than that obtained at wider spacing. Closer spacing of 10 x 10 cm was significantly superior to 20 x 10 cm or 20 x 20 cm. The closer spacing resulted in more tillers per unit area, higher number of panicles and higher yield of grain. The 1000 grain weight was not affected by spacing (Pothiraj, 1973). Sewa Ram _et al_. (1973) observed that the nitrogen fertilization and plant population per unit area considerably influenced the grain yield. Yield was maximum in 15 x 10 cm spacing when compared to 15 x 20 cm or 15 x 30 cm. Number of tillers, plant height, panicle length and test weight showed a reverse trend and the results were in favour of wider spacing. Increases in these characters under wider spacing were mainly due to minimum competition for growth among the plants as compared to closer spacings. But increased growth of plants under wider spacing failed to supercede over closer spacing with respect to yield. This was because increased growth of plants under wider spacing could not compensate the plant population per unit area as under closer spacing. Singh and Singh (1973) observed that higher plant population obtained with 15 x 10 cm spacing recorded 11.1 per cent higher grain yield than 20 x 10 cm spacing. Highly significant effect of spacing on grain yield was noted by Barthakur and Gogoi (1974). Spacing of 15 x 15 cm proved to be superior to the other two spacings of 10 x 22.5 cm and 15 x 22.5 cm. The highest grain yield was obtained under 15 x 15 cm spacing and the lowest in 15 x 22.5 cm. Panicle density was also more under 15 x 15 cm spacing. Investigations by Eunus and Sadeque (1974) revealed that the number of panicles per plant increased when the between plant distances were increased from 15.5 cm to 25.5 cm. The straw yield per plant was also increased due to increase in spacing. Rumiati and Oldeman (1974) reported that with increasing plant densities tiller number and number of panicles per hill decreased. The number of filled grains per panicle increased due to closer spacing and the 1000 grain weight was decreased in closer planting. Baccam *et al*. (1975) found that grain yield was unaffected by plant spacing. Chakraborthy (1975) suggested that factors like spacing and number of seedlings per hill play only a secondary role in determining the yield/ha. The results of an experiment conducted during two successive seasons showed that a spacing of 15 x 15 cm was superior to 25 x 25 cm with regards to yield (Kumar et al., 1975). Majid et al. (1976) observed that closer spacing gave higher yield in Basmati rice and the yield decreased with increased spacing and the differences diminished with increased fertility levels. Paddy yields were higher at the spacing of 20 x 5 cm and 10 x 5 cm than that at wider spacings. Narrow spacings increased the number of panicles per unit area but decreased the number of filled grains per panicle, 1000 grain weight and nitrogen content of grain and straw (Mishra, 1976). According to the reports by Parashar (1976) IR 8 paddy gave the highest grain yield of 6.46 t/ha at 7.5 x 7.5 cm and the lowest yield of 3.80 t/ha at 30 x 15 cm. Bhattacharya (1977) reported increased grain yield with closer spacing. The number of tillers per hill decreased with decrease in spacing while increased spacing increased length of panicle, weight of panicle, grains per panicle and yield of grain (Chang and Su, 1977). Fagade and Ojo (1977) observed that spacing at 10 x 10 cm gave highest paddy yields of 4.15 t/ha whereas 25 x 25 cm gave the lowest yield of 2.93 t/ha. Grain yield was increased with increasing plant density (Shieh Yuh-Jang, 1977). No increase in the yield of grain or straw could be obtained due to changes in plant spacing in IR 8 (Panicker et al., 1978). Schiller and Dogkeaw (1978) found that the total yield of grain and the mean grain size were not significantly affected by sowing rate, plant spacing or applied nitrogen. The effective number of tillers/m^2 increased with closer spacing, but the increased number of productive tillers was not reflected in the grain yield since the length of earhead and number of spikelets per ear were less though not significant (Gurnal Singh et al., 1979). Patel et al. (1979) reported that transplanting seedings of three rice cv at a spacing of 15 cm in rows 15, 20, 25 and 30 cm apart gave average paddy yields of 6.18, 5.90, 5.60 and 5.43 t/ha respectively. Murty and Murty (1980) obtained highest yields at a spacing of 10 x 10 cm and progressively decreased with increasing spacings. A reduction in the number of effective tillers at wider spacing was noticed by Venkateswarlu and Singh (1980). They also found that there was no significant difference in yield of crops grown at different spacings. Ahmed and Haque (1981) observed that the number of panicles per unit area and grain yield were not significantly different at different spacings. Chatterjee and Maiti (1981) reported that under high fertility level, plant type characteristics become more important in deciding the optimum spacing. Panicles of earlier tillers are heavier than the panicles derived from late tillers. In wider spacing formation of more tillers per plant is encouraged, but with narrower spacing, formation of more ear bearing tillers per unit area is encouraged which may be heavy as well. Closer planting helps in better utilization of the available nutrient from the soil at the beginning. Closely spaced plants stopped tillering earlier than widely spaced plants. Pyarelal et al. (1982) from their experiments to assess the advantage of increased plant population in Jaya rice under limited supply of N, found that in an unfertilised crop, the grain yield was almost constant regardless of plant density, but in partially fertilised one it increased from 6.1 to 7.5 t/ha by increasing the hills from 125 to 200 hills/m^2. When the full amount of fertilizer was applied, the yield difference between low and high plant populations narrowed down indicating that N fertilization compensated for low plant population. The study contridicted the common notion that plant population compensate for inherent low soil fertility. Ghosh (1982) and Rathi et al. (1984) found that closer spacing increased the number of panicles/m^2. Reddy and Ghosh (1982) suggested that increasing plant population/m^2 or high plant density was not effective in increasing grain yield. High plant density increased panicle number/m^2, but decreased grain number, grain weight/panicle and 1000 grain weight. Moody et al. (1983) found that grain yields generally increased with decreased plant spacing even though differences were not always significant. The yield at a closer spacing of 5 cm was higher than that at 20 cm (Hakansson, 1984). Akobundu and Ahissan (1985) stated that number of tillers and panicle per hill decreased as the inter row distance decreased from 45 to 15 cm apart. No significant difference was noticed in yield of crops grown in rows 15, 18 and 21 cm apart (Pathak and Hazarika, 1985). Kanade and Kalra (1986) found that the rice cv Mahsuri grown in rows 20 cm apart with between plant spacings of 15, 20 and 25 cm gave yields of 4.76, 4.34 and 4.12 t/ha respectively. Raghuwanshi et al. (1986) observed that the crop transplanted at a spacing of 20 x 15 cm gave higher paddy yields than when planted at 20 x 20 cm. The yield of grain was increased with decrease in spacing from 20 cm (Thorat and Patil, 1986). Highest yield of grain was obtained at the closest spacing of 10 x 15 cm when compared to other spacings of 15 x 15 cm and 15 x 20 cm (Sawant et al., 1986). Srinivasulu Reddy (1986) found that the straw yield was significantly more in lower plant populations or wider spacing. This might be due to the more number of total tillers per hill. Lower plant population resulted in more number of productive tillers per plant and filled grains per panicle. Uptake of N, P and K increased with decrease in plant population. A population of 6.67 lakh hills/ha with a spacing of 15 x 10 cm gave significantly higher yield compared to a population of 10 lakhs (10 x 10 cm). The increase in grain yield with increase in spacing might be attributed to more number of grains per panicle. Though the plant population per unit area is less in 15 x 10 cm spacing than with 10 x 10 cm, the plants with 15 x 10 cm more than compensated the yield by producing more number of productive tillers per hill and filled grains per panicle. Varshney (1986) found that under wider (20 cm) or narrower (10 cm) spacing, the nitrogen utilization efficiency was relatively lower than 15 cm spacing. Gautam and Sharma (1987) revealed that short duration varieties had higher production efficiency at high plant density than mid-duration varieties. In mid-duration varieties production efficiency was maximum at medium density of population. They also found that the N uptake increased with increasing plant density. Jones and Snyder (1987) showed that narrow row spacing increased grain yield. Increased sowing rates increased number of panicles/m^2 and this increase was compensated for by decreased filled grain number/panicle resulting in no significant yield differences among sowing rates. Rice cv Tainung 67, Tainung 68, Tainan 6 and Taipei 309 were grown at spacings of 12.5 x 12.5 cm, 25 x 25 cm or 50 x 50 cm at different fertility levels. The close spacing markedly decreased panicle length and number of grains per ear (Liou, 1987). Pedroso (1987) revealed that the widest row spacing gave the best yield due to more panicles and heavier grains. Rao and Raju (1987) observed that the grain per panicle decreased in closer spacing, but closer spacing gave higher straw yield. Grain yield remained unaffected by spacings of 15 x 15 cm or 15 x 10 cm. They also found that the spikelet sterility also significantly increased under 15 x 10 cm spacing when compared to 15 x 15 cm spacing. Among the planting spacings of 20 x 10 cm, 20 x 15 cm and 27 x 10 cm highest increase in grain yield was under 20 x 10 cm spacing. Panicle/m^2 was also high at this population. The weight of panicle was more in wider spacing but 1000 grain weight was not significantly influenced by spacing (Sharma and Warsi, 1987). Tsai (1987) raised different cultivars at two different spacings of 30 x 15 cm and 30 x 7.5 cm. With wider spacing, the 'high grain weight variety' flowered earlier and had lower tiller and panicle numbers than the 'less grain weight variety' while closer spacing tended to decrease panicle number per hill, but significantly increased panicle number per unit area.

From the foregoing review it appears that the growth, yield and yield components have been influenced differently by spacing and plant population. It is also noticed that rice varieties responded differently to spacing.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field investigations were carried out during 1975-77 to study the effect of graded doses of nitrogen, method of application and plant population on the growth and yield of the high yielding rice variety Sabari in the sandy loam soils of Vellayani for two years. The details of the materials used and the methods adopted for the investigation are described here.

3.1. Location

The experiment was conducted in the Kaithakkakom Block of the Instructional Farm of the College of Agriculture, Vellayani. The farm is located at 8°-18' N latitude and 76°-48' E longitude with an average elevation of 29 metres above mean sea level.

3.2. Soil

Composite soil samples from 0-20 cm layer were taken from the experimental area for studying the physical and chemical characteristics. The soil type was sandy loam which was low in available nitrogen, medium in available phosphorus and low in available potassium. The pH of the soil in the experimental site was 5.3. The results of the analysis of the soil are given in Table 1.

Table 1. Physical and chemical characteristics of soil in the experimental area

A. Physical characteristics	
Mechanical composition:	
Coarse sand	61.5 per cent
Fine sand	18.2 "
Silt	9.4 "
Clay	10.2 "
B. Chemical characteristics	
Total nitrogen (Modified microkjeldahl method)	0.025 "
Available nitrogen (Alkaline permanganate method)	58.0 kg/ha
Available P_2O_5 (Bray's colorimeter method)	25.6 "
Available K_2O (Ammonium acetate method)	36.0 "
Cation exchange capacity (me./100 g soil)	3.94
pH (1:2.5 soil-water ratio)	5.3

3.3. Cropping history of the experimental plot

The plot was under bulk paddy during the previous two years. High yielding varieties of rice were grown under uniform package of practices. The experiment was conducted in the same plots during both years.

3.4. Climate and weather conditions

Vellayani enjoys a hot humid climate with a mean annual rainfall of 2053 mm. The area gets the benefit of both the South West and North East Monsoons. The mean annual maximum temperature is 30.4°C and the mean annual minimum is 24.3°C.

The field experiments were conducted during the period from October to February. The weather conditions for the crop period recorded at the meteorological observatory of the College of Agriculture are presented in Table 2. The total rainfall received during the crop period was 167.50 mm. during the first year and 697.20 mm. during the second year as against the normal rainfall of 683.59 mm. for the period. The mean maximum temperature ranged between 30.6°C and 30.0°C during the first year and between 31.1°C and 28.8°C during the second year of experimentation respectively. The mean minimum temperature for the period ranged between 20.5°C and 23.2°C and 22.5°C and 23.5°C respectively for the two successive seasons.

Table 2. Mean monthly maximum and minimum temperature, rainfall and relative humidity for the crop period and their normal values

Year	Month	Temperature °C				Rainfall (mm)		Relative Humidity %	
		Maximum		Minimum		During the month	Normal	During the month	Normal
		For the month	Normal	For the month	Normal				
First year	October	30.00	29.57	23.18	24.69	-	306.27	82.50	83.31
	November	30.03	29.53	22.82	24.20	64.50	187.30	83.13	84.95
	December	30.49	30.07	22.49	24.20	-	89.39	77.73	84.38
	January	30.60	30.32	22.34	23.40	40.00	64.23	72.60	79.31
	February	30.62	30.98	20.49	23.57	63.00	36.40	75.16	81.12
Second year	October	28.90	29.57	22.80	24.69	295.90	306.27	87.00	85.31
	November	28.80	29.53	22.90	24.20	308.30	187.30	85.00	84.31
	December	30.15	30.07	22.95	24.20	93.00	89.39	78.30	84.38
	January	30.80	30.32	22.45	23.40	-	64.23	73.50	79.31
	February	31.10	30.98	23.50	23.57	-	36.40	72.60	81.12

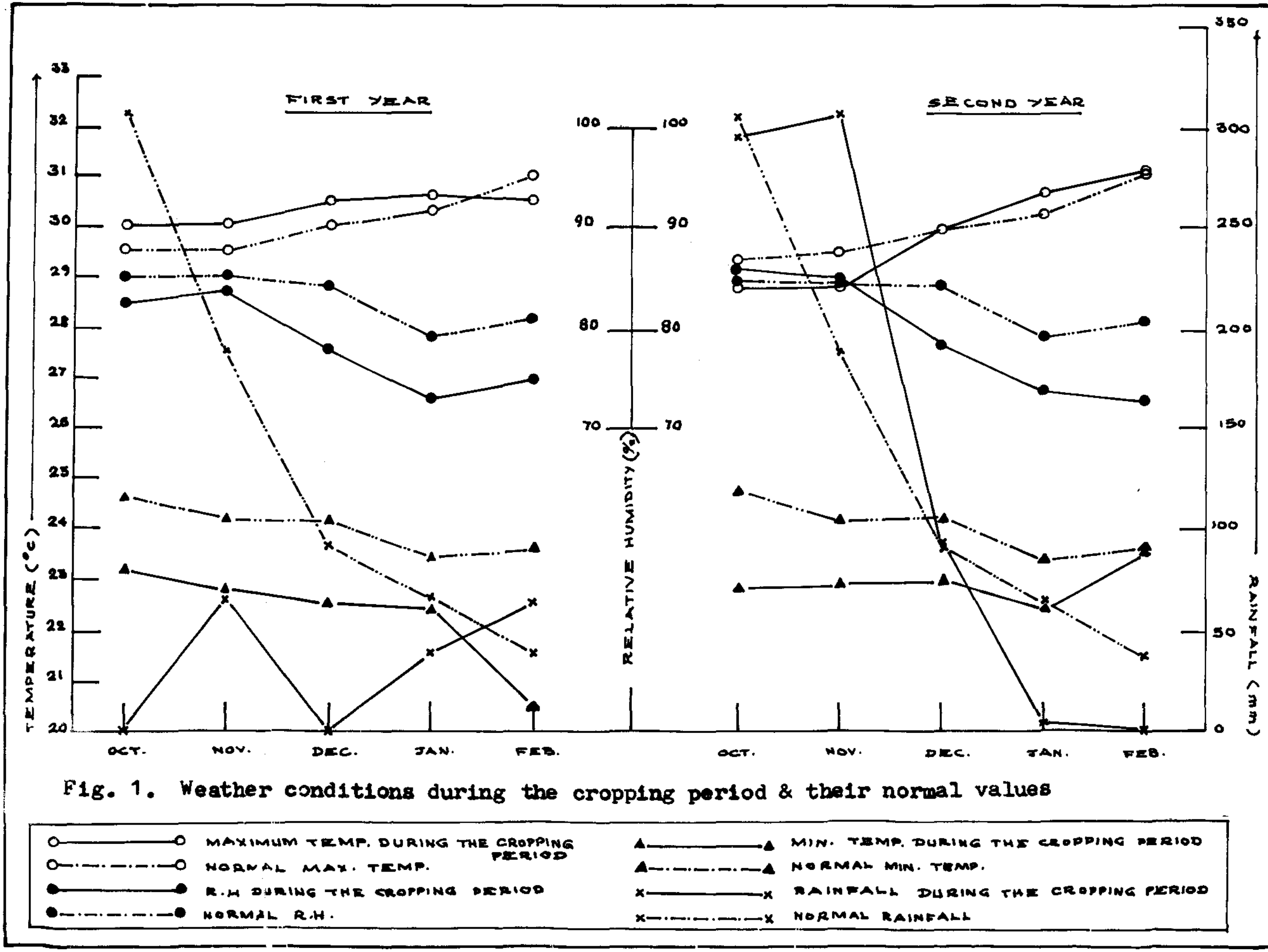

Fig. 1. Weather conditions during the cropping period & their normal values

The mean relative humidity ranged between 72.6 per cent and 83.1 per cent during the first year and between 72.6 and 87.0 per cent during the second year.

On an average, both the seasons were favourable for normal growth of the rice crop.

3.5. Variety

The variety used in the experiment was '*Sabari*'. It is a high yielding variety released by the Regional Agricultural Research Station, Pattambi. It is a cross between IR 8 and *Annapurna*. *Sabari* has a duration of 125 to 130 days. The kernel is red and bold. The variety responds well to fertiliser application.

The seed material required for the experiment was obtained from the Instructional Farm, Vellayani.

3.6. Experimental technique

i. Design: The experiment was conducted in split-plot design with three replications. The layout plan is given in Fig. 2.

ii. Treatments:

There were 8 main plot treatments and 3 sub plot treatments. The combinations of level of nitrogen and method of application were allotted to the main plots and

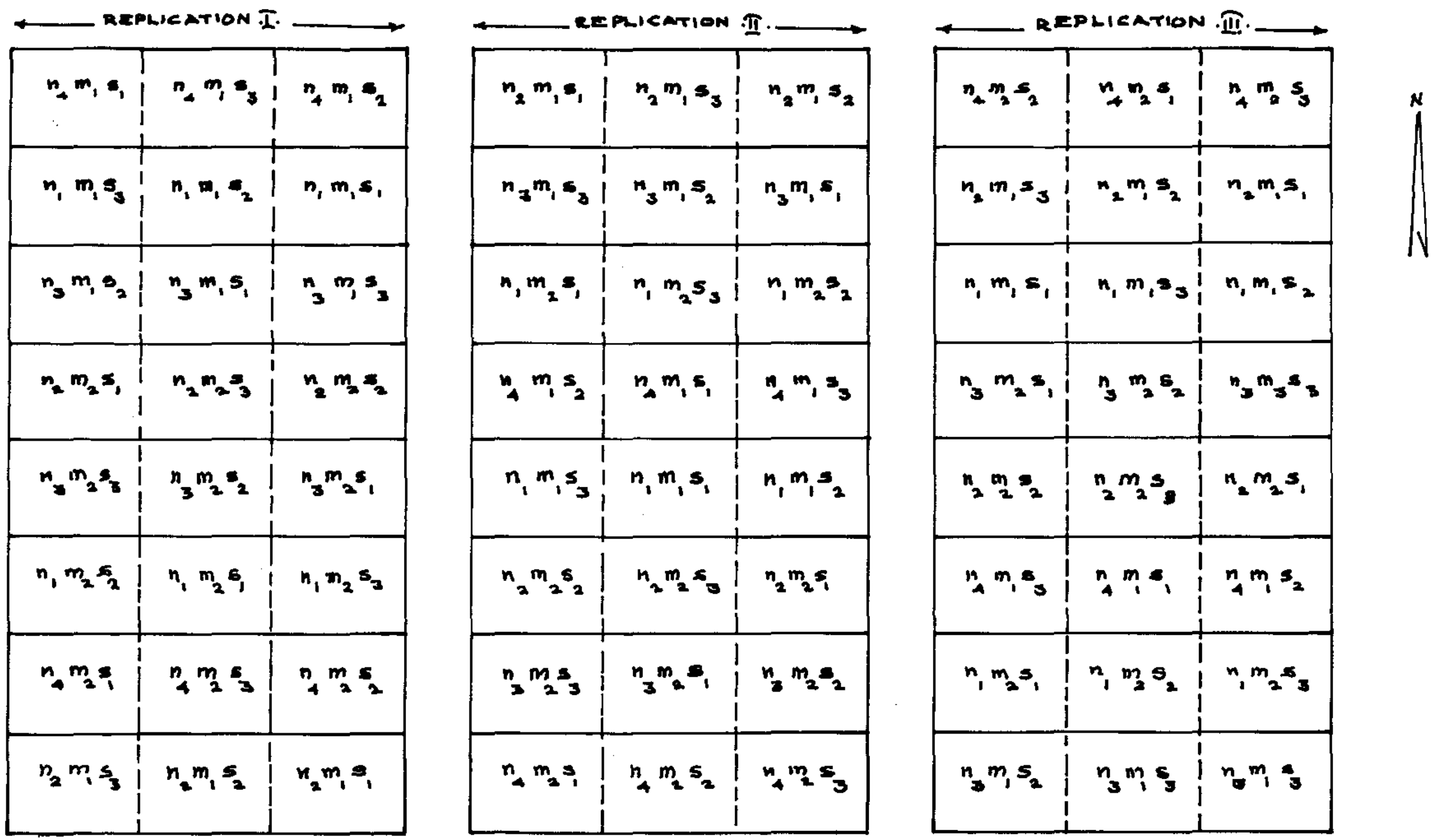

Fig. 2. Lay out plan - split-plot design

LEVELS OF NITROGEN	METHODS OF APPLICATION	POPULATION
n_1 - 40 kg N / ha.	m_1 - FULL N THROUGH SOIL	S_1 - 10 x 10 cm (100 HILLS/m^2)
n_2 - 80 kg N / ha.	m_2 - 75 % SOIL + 25 % FOLIAR	S_2 - 10 x 15 cm (67 HILLS/m^2)
n_3 - 120 kg N / ha.		S_3 - 10 x 20 cm (50 HILLS/m^2)
n_4 - 160 kg N / ha.		

the plant population (spacing) to the sub plots. Allotment of main treatments was made at random in each replication and that of minor treatments within each main treatment plot. The same set of treatments were repeated in the same plots during the second year also. Details of the treatments are given below.

a) Levels of nitrogen - 4

n_1 - 40 kg N/ha

n_2 - 80 "

n_3 - 120 "

n_4 - 160 "

b) Methods of application

m_1 - full quantity of nitrogen through soil application.

m_2 - 75 per cent of total nitrogen through soil plus 25 per cent through foliar application.

c) Plant population (spacing)

S_1 - 10 x 10 cm - 1.00 million hills/ha.

S_2 - 10 x 15 cm - 0.67 "

S_3 - 10 x 20 cm - 0.50 "

The main plot treatment combinations were as follows.

1. n_1m_1	5. n_3m_1
2. n_1m_2	6. n_3m_2
3. n_2m_1	7. n_4m_1
4. n_2m_2	8. n_4m_2

The plant population (spacing) treatments were allotted to the sub plots.

There were 24 treatment combinations in total.

1. $n_1m_1s_1$	7. $n_2m_1s_1$	13. $n_3m_1s_1$	19. $n_4m_1s_1$
2. $n_1m_1s_2$	8. $n_2m_1s_2$	14. $n_3m_1s_2$	20. $n_4m_1s_2$
3. $n_1m_1s_3$	9. $n_2m_1s_3$	15. $n_3m_1s_3$	21. $n_4m_1s_3$
4. $n_1m_2s_1$	10. $n_2m_2s_1$	16. $n_3m_2s_1$	22. $n_4m_2s_1$
5. $n_1m_2s_2$	11. $n_2m_2s_2$	17. $n_3m_2s_2$	23. $n_4m_2s_2$
6. $n_1m_2s_3$	12. $n_2m_2s_3$	18. $n_3m_2s_3$	24. $n_4m_2s_3$

iii. Replication: Three

iv. Total number of plots

Main plots : 24

Sub plots : 72

v. Size of plots:

Gross: 5 x 4.2 m (21.0 m^2)

Net plot size with S_1 spacing: 17.48 m^2

" S_2 " 16.56 m^2

" S_3 " 15.64 m^2

Number of guard rows: 2

vi. Number of hills per gross plot under

S_1 spacing	:	2100
S_2 "	:	1400
S_3 "	:	1050

Number of hills per net plot under

S_1 spacing	:	1748
S_2 "	:	1104
S_3 "	:	782

vii. Number of seedlings per hill: 2

3.7. Fertilizer and fertilizer application

a. Nitrogen

Source: Nitrogen was applied as Urea. Urea used for the experiment analysed 46 per cent nitrogen. Fresh urea was used for the experiment.

Time and stage of nitrogen application:

Nitrogen was given in three splits. Fifty per cent of the total quantity was applied as basal. The remaining 50 per cent was given in two equal splits as top dressing. The first top dressing was made at tillering and the last at the panicle initiation stage. The basal and the first top dressing of nitrogen were given through soil. The second top dressing with nitrogen at the panicle initiation stage was given through soil in treatment m_1 and through foliar in treatment m_2.

Method of application

Soil

For basal application, urea was broadcast and incorporated by puddling. For top dressing through soil, the required quantity of urea was mixed with moist soil and kept as such for 48 hours and then applied broadcast uniformly in the individual plots which were drained previously.

Foliar

In the case of foliar application, three per cent urea solution was made and applied as fine spray on the foliage of the crop with the help of a high volume sprayer. The quantity of spray solution required for one spray was 1.50 litres/plot. The number of sprays given to supply the required amount of nitrogen in different treatments is as follows.

Treatment	Number of sprays required
n_1m_2	1
n_2m_2	2
n_3m_2	3
n_4m_2	4

Quantities of nitrogen given at different stages were as follows.

Table 3. Quantities of urea at different stages (g/plot)

Treatment	Basal (g)	I top (g)	Second top		Total N as urea (g)	Total N in kg/ha
			Soil (g)	Foliar (g)		
1. n_1m_1	91.50	45.75	45.75	-	183	40
2. n_1m_2	91.50	45.75	-	45.75	183	40
3. n_2m_1	183.00	91.50	91.50	-	366	80
4. n_2m_2	183.00	91.50	-	91.50	366	80
5. n_3m_1	274.00	137.00	137.00	-	548	120
6. n_3m_2	274.00	137.00	-	137.00	548	120
7. n_4m_1	365.00	182.50	182.50	-	730	160
8. n_4m_2	365.00	182.50	-	182.50	730	160

b. Other Fertilizers (P and K)

A uniform basal dose of 60 kg P_2O_5/ha as superphosphate was given. The fertilizer used in the experiment analysed 16 per cent water soluble P_2O_5. This was also applied along with nitrogen at puddling. Potassium at the rate of 60 kg K_2O per ha was applied as muriate of potash in two equal splits as basal and at the panicle initiation stage.

3.8. Planting materials and planting

Drybed nursery was prepared. The nursery area was dug deep, clods were broken and made into raised beds of width one metre and length eight metres. Soaked seeds were sown on these beds. Proper irrigation was given as and when required. The seeds used gave a uniform germination percentage of 97 and 98 during the two seasons respectively. The stand of the seedlings was satisfactory and the seedlings possessed the required seedling vigour. A uniform spraying with Ekalux was given to the seedlings in the nursery 10 days prior to pulling out the seedlings. Twenty four day old seedlings were pulled out carefully and used for planting the main field.

3.9. Schedule of cultural operations done in the field

The crop was raised following the usual package of practices except the treatment. The plots were maintained at submergence, keeping 5 ± 2 cm of water. This level was retained upto 10 days prior to harvesting. The crop was harvested at full maturity, threshed, dried, cleaned and bagged. The straw was dried in the sun and heaped.

3.10. Observations recorded

A. Growth characters

i. Height of plant

Five 'two x two hill' sampling units per plot giving a total of 20 hills as described by Gomez (1972) were selected and marked for recording observations on height of plant and tiller count. Plant height was measured as the distance from ground level to the tip of the tallest leaf. For mature plants, it was measured from ground level to the tip of the tallest panicle. Plant height was observed at the 30, 60 and 90 DAT and at harvest and recorded in cm.

ii. Number of tillers

The hills selected for measurement of plant height were also used for tiller counts. Tiller counts were taken on 30, 60 and 90 DAT and at harvest. At harvest the tillers were separated into productive tillers and total tillers. From the values of tillers per hill, the number of tillers per unit area (1.2 m^2) was also calculated.

iii. Days to 50 per cent flowering

Observations were made in the sampling units on panicle emergence on alternate days. When 50 per cent of the hills flowered it was taken as the date of flowering and the number of days for flowering was worked out from the date of seeding to flowering in days.

iv. Leaf Area Index

This was measured at the flowering stage only. The procedure described by Yoshida et al. (1972) was followed. Six random hills were selected in each plot. The number of tillers in each selected hill was counted. The length and maximum width of all the leaves in the middle tiller were measured and computed the leaf area by length-width method using the value 0.75 as the adjustment factor. The leaf area per hill was computed by multiplying the total leaf area of the middle tiller with the total number of tillers in the respective hills.

Leaf Area Index was calculated by dividing the sum of the leaf area per hill of the six hills in cm^2 with the area of land occupied by the six hills in cm^2.

v. Dry matter production

Dry matter production was recorded twice, first at flowering stage and again at harvest. Five hills from each plot were marked out at random which were uprooted carefully and dried in shade and later in hot air oven to constant weight at temperature not exceeding 75°C and weighed. The dry matter production was expressed in quintals per hectare.

B. Yield components

i. Number of panicles per unit area

All the panicles in the sampling unit were counted when the crop was in the ripening stage. From this the number of panicles per unit area (1.2 m^2) was calculated and expressed as panicle density/unit area (Gomez, 1972).

ii. Panicle characters

Two hills were selected at random from each net plot and the panicles collected from these hills were used for the studies of panicle characters.

a. Panicle length

The length of each panicle was measured in cm from the neck-node to the tip of the apical grain and the average calculated and expressed in cm.

b. Number of spikelets per panicle

All the spikelets on each panicle were counted and the average number of spikelets per panicle worked out.

c. Number of filled grains per panicle

All the fertilised and developed spikelets were counted and average number per panicle was worked out. From this the number of grains per unit area was also calculated.

d. Number of unfilled grains per panicle

The unfilled grains in each panicle was counted and the average worked out.

e. Spikelet sterility

Completely sterile spikelets were identified by pressing between the fingers and by visual judgement. The percentage of sterile spikelet to the total spikelet was then calculated.

f. Panicle weight

All the panicles detached at neck-node, obtained from the sampling hills were weighed and the mean value for single panicle was calculated and expressed in g.

g. Thousand grain weight

Thousand grains were counted from the random samples drawn from the winnowed and cleaned produce. These were weighed and the weight was adjusted to 14 per cent moisture level and recorded in g/1000 grains.

C. Yield of grain and straw

The crop was harvested at full maturity. Border strips comprising two rows on all sides were harvested and removed first. The net plot was then harvested and threshed.

i. Grain yield

The grain harvested from the net plot was sun dried, cleaned, and the weight recorded. Moisture percentage was estimated in samples of 100 g from each lot and the grain yield was adjusted to weight at 14 per cent moisture using the formula,

Adjusted grain weight = A x W

where A is the adjustment coefficient and W the weight of the harvested grains (Gomez, 1972). The yield per plot so obtained was worked out to kg/ha.

ii. Straw yield

The straw obtained from each plot was sun dried and the weight recorded. The plot yield of straw was converted into quintals per hectare.

iii. Grain : Straw ratio

Grain : Straw ratio was worked out from the plot yields of the grain and straw.

D. Chemical Analysis

i. Plant

Plant samples were analysed for the following constituents in the laboratory. The nutrient contents were determined at flowering and after harvest. The plant samples used for recording dry matter production at flowering and harvest were powdered to 20 mesh using a Wiley Mill and used for the determination of nutrients.

a. Nitrogen

Nitrogen in the powdered sample was determined by modified micro-kjeldahl method (Jackson, 1973) and expressed as per cent of oven dry material. The whole plant at flowering stage and the grain and straw after harvest were used for the nitrogen estimation.

b. Phosphorus

The phosphorus was determined colorimetrically by Vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and expressed as per cent P_2O_5.

c. Potassium

The potassium content in the ground samples of grain and straw was estimated by using a Flame Photometer (Elico Model) in the tri acid extract. The potassium content was expressed as K_2O percentage of the oven dry material.

From the data on chemical analysis and the plant character observations, the following were computed.

Nitrogen uptake per hectare

Nitrogen content of the sample was multiplied by the respective dry matter production in each treatment and expressed in kg/ha.

Phosphorus uptake per hectare

P_2O_5 content in the sample was multiplied by the respective dry matter production and expressed in kg/ha.

Potassium uptake per hectare

K_2O content in the sample was multiplied by the corresponding dry matter production and expressed in kg/ha.

ii. Grain quality

Random samples of hulled rice was powdered in a Wiley Mill and used for the following estimations.

Protein content

The total nitrogen content in the hulled rice was determined by modified kjeldahl method (Jackson, 1973) and the values expressed as percentage. This was multiplied by the factor 6.25 and expressed as crude protein in hulled rice (A O A C, 1969).

iii. Soil Analysis

a. Pre-planting fertility status

Soil samples were collected from soil layers to a depth of 0-20 cm and analysed for physical and chemical characteristics immediately before laying out the experiment and the results are furnished in Table 1.

b. Residual fertility status

Soil samples in 0-20 cm layer were taken from each sub plot immediately after the harvest of the crop. The samples were oven dried at 105°C and powdered and seived through a 20 mm seive. The samples were analysed for the following:

i. Available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956).

ii. Available phosphorus by Bray's method (Jackson, 1973).

iii. Available potassium by ammonium acetate method (Jackson, 1973).

3.11. Economics of cultivation

The economics of cultivation under different levels and methods of nitrogen application and plant population was worked out based on the following:

Cost of labour:	Man/day	Rs.20.00
	Woman/day	Rs.18.00
Cost of nitrogen as urea per kg		Rs. 5.15
Price of paddy per kg		Rs. 2.00
Price of straw per kg		Rs. 0.50

The net income (gross income - total expenditure) and the benefit : cost ratio (gross income/total expenditure) were calculated and presented.

3.12. Statistical analysis

Data relating to the various observations were analysed statistically by applying the technique of analysis of variance for split plot experiments and the significance was tested by 'F' test (Cochran and Cox, 1962). Values of CD at 5 per cent probability level were furnished wherever the treatment differences were significant. Otherwise it was mentioned as non-significant (NS). Important correlations, response curves, physical optimum and economic optimum levels were also worked out.

The data were analysed with the help of the 'micro-2200 Hindustan Computer' and the 'Keltron Versa IWS Computer' of the College of Agriculture, Vellayani.

RESULTS

4. RESULTS

The results of the field experiments conducted to study the effect of different levels of nitrogen, methods of nitrogen application and plant population on the growth characters, yield and nutrient uptake of the rice variety Sabari in the sandy loam soil of the College of Agriculture, Vellayani are presented in this chapter.

4.1. Height of plant

The mean height of plants as influenced by various treatments at 30 DAT, 60 DAT, 90 DAT and at harvest and the summary of the means for the two years are given in Tables 4a to 4e and 5a to 5e respectively.

During the first year, the effect due to levels of nitrogen was highly significant. There was progressive increase in plant height upto the highest level of nitrogen tried at all the stages of growth. The same trend continued during the second year also, but the increase was not of a significant magnitude at the harvest stage. However, there was appreciable increase in plant height due to incremental levels of nitrogen application.

The effects due to the method of application of nitrogen did not show any significant difference in plant height at any of the stages or years except at the 90 DAT

Table 4a. Mean height of plant (cm) at 30 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	51.30	53.68	50.89	51.95
n_2	55.33	54.65	54.84	54.94
n_3	55.30	58.32	56.72	56.78
n_4	58.72	58.40	58.57	58.57
Methods of N application				
m_1	56.11	57.43	56.07	56.54
m_2	54.21	55.10	54.44	54.58
Mean	55.16	56.26	55.25	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	53.56	50.34	51.95
n_2	56.47	53.40	54.94
n_3	56.25	57.31	56.78
n_4	59.86	57.27	58.57
Mean	56.54	54.58	

	SEm ±	CD (0.05)
For levels of nitrogen	0.671	2.032
For methods of N application	0.470	NS
For plant population	0.500	NS

Table 4b. Mean height of plant (cm) at 60 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	60.68	65.03	64.07	63.26
n_2	66.69	67.92	68.06	67.56
n_3	68.35	67.70	69.37	68.48
n_4	68.13	68.39	70.56	69.02
Methods of N application				
m_1	66.20	67.89	68.01	67.37
m_2	65.73	66.62	68.02	66.79
Mean	65.97	67.26	68.01	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	63.54	62.98	63.26
n_2	67.58	67.53	67.56
n_3	68.67	68.28	68.48
n_4	69.67	68.37	69.02
Mean	67.37	66.79	

	SEm ±	CD (0.05)
For levels of nitrogen	0.710	2.151
For methods of N application	0.500	NS
For plant population	0.541	1.552

Table 4c. Mean height of plant (cm) at 90 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	63.98	67.38	66.37	65.91
n_2	67.53	68.23	69.06	68.27
n_3	69.96	69.27	71.42	70.22
n_4	69.98	70.38	72.38	70.91
Methods of N application				
m_1	67.98	69.45	69.53	68.99
m_2	67.74	68.18	70.09	68.67
Mean	67.86	68.82	69.81	

Levels of nitrogen	Methods of N application		
	M_1	m_2	Mean
n_1	65.86	65.96	65.91
n_2	68.54	68.01	68.27
n_3	70.21	70.22	70.22
n_4	71.33	70.49	70.91
Mean	68.99	68.67	

	SEm ±	CD (0.05)
For levels of nitrogen	0.601	1.823
For methods of N application	0.430	NS
For plant population	0.432	1.244

Table 4d. Mean height of plant (cm) at harvest (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	63.41	66.14	65.06	64.87
n_2	66.26	65.87	67.28	66.47
n_3	67.60	66.85	69.26	67.90
n_4	67.68	68.43	69.82	68.65
Methods of N application				
m_1	66.56	67.37	67.67	67.13
m_2	65.92	66.28	68.24	66.81
Mean	66.24	66.82	67.85	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	65.21	64.53	64.87
n_2	66.52	66.42	66.47
n_3	67.72	68.08	67.90
n_4	69.07	68.22	68.65
Mean	67.13	66.81	

	SEm ±	CD (0.05)
For levels of nitrogen	0.542	1.643
For methods of N application	0.380	NS
For plant population	0.402	1.144

Table 4e. Mean height of plant (cm) at different stages of growth (summary for first year)

Treatments	30 DAT	60 DAT	90 DAT	At harvest
n_1	51.95	63.26	65.91	64.87
n_2	54.94	67.56	68.27	66.47
n_3	56.78	68.48	70.22	67.90
n_4	58.57	69.02	70.91	68.65
F	Sig	Sig	Sig	Sig
SEm ±	0.671	0.710	0.601	0.542
CD (0.05)	2.032	2.151	1.823	1.643
m_1	56.54	67.37	68.99	67.13
m_2	54.58	66.79	68.67	66.81
F	NS	NS	NS	NS
SEm ±	0.470	0.500	0.430	0.380
CD (0.05)	..	..	..	..
S_1	55.16	65.97	67.86	66.24
S_2	56.26	67.26	68.82	66.82
S_3	55.25	68.01	69.81	67.85
F	NS	Sig	Sig	Sig
SEm ±	0.500	0.541	0.432	0.402
CD (0.05)	..	1.552	1.244	1.144

Table 5a. Mean height of plant (cm) at 30 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	46.60	49.37	50.03	48.67
n_2	49.53	51.30	52.21	51.01
n_3	51.13	52.41	54.50	52.68
n_4	52.58	52.75	55.17	53.50
Methods of nitrogen application				
m_1	49.65	51.53	53.61	51.59
m_2	50.28	51.39	52.34	51.34
Mean	49.96	51.46	52.98	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	42.92	48.42	48.67
n_2	50.63	51.39	51.01
n_3	52.40	52.96	52.68
n_4	54.42	52.57	53.50
Mean	51.59	51.34	

	SEm ±	CD (0.05)
For levels of nitrogen	1.044	3.167
For methods of N application	0.738	NS
For plant population	0.480	1.382

Table 5b. Mean height of plant (cm) at 60 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	59.40	62.38	64.45	62.08
n_2	60.94	64.62	66.65	64.07
n_3	62.72	65.82	67.38	65.33
n_4	66.60	67.11	69.52	67.38
Methods of N application				
m_1	62.63	65.43	67.26	65.11
m_2	61.68	64.53	66.73	64.32
Mean	62.16	64.98	67.00	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	62.98	61.17	62.08
n_2	64.11	64.03	64.07
n_3	65.51	65.14	65.33
n_4	67.83	66.92	67.38
Mean	65.11	64.32	

	SEm ±	CD (0.05)
For levels of nitrogen	1.458	NS
For methods of N application	1.031	NS
For plant population	0.599	1.724

Table 5c. Mean height of plant (cm) at 90 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	62.84	68.33	69.68	66.95
n_2	66.28	67.47	71.02	68.59
n_3	66.03	69.92	71.83	69.26
n_4	67.73	70.98	72.54	70.42
Methods of N application				
m_1	66.78	70.63	72.50	69.97
m_2	64.66	68.21	70.04	67.64
Mean	65.72	69.42	71.27	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	68.26	65.65	66.95
n_2	69.64	67.54	68.59
n_3	70.54	67.97	69.26
n_4	71.44	69.39	70.42
Mean	69.97	67.64	

	SEm ±	CD (0.05)
For levels of nitrogen	0.968	NS
For methods of N application	0.684	2.075
For plant population	0.601	1.730

Table 5d. Mean height of plant (cm) at harvest (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	63.88	67.14	66.51	65.84
n_2	65.27	67.53	69.40	67.40
n_3	66.04	68.42	71.52	68.66
n_4	65.23	68.98	72.81	69.00
Methods of N application				
m_1	66.15	68.98	69.97	68.37
m_2	64.05	67.05	70.15	67.09
Mean	65.10	68.01	70.06	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	65.71	65.97	65.84
n_2	68.41	66.39	67.40
n_3	69.39	67.96	68.66
n_4	69.98	68.02	69.00
Mean	68.37	67.09	

	SEm ±	CD (0.05)
For levels of nitrogen	1.092	NS
For methods of N application	0.772	"
For plant population	0.669	1.927

Table 5e. Mean height of plant (cm) at different stages of growth (summary for second year)

Treatments	Mean height (cm)			
	30 DAT	60 DAT	90 DAT	At harvest
n_1	48.67	62.08	66.95	65.84
n_2	51.01	64.07	68.59	67.40
n_3	52.68	65.33	69.26	68.66
n_4	53.50	67.38	70.42	69.00
F	Sig	NS	NS	NS
SEm ±	1.044	1.458	0.968	1.092
CD (0.05)	3.167	..	..	..
m_1	51.59	65.11	69.97	68.37
m_2	51.34	64.32	67.64	67.09
F	NS	NS	Sig	NS
SEm ±	0.738	1.031	0.684	0.772
CD (0.05)	..	..	2.075	..
S_1	49.96	62.16	65.72	65.10
S_2	51.46	64.98	69.42	68.01
S_3	52.98	67.00	71.27	70.06
F	Sig	Sig	Sig	Sig
SEm ±	0.480	0.599	0.601	0.669
CD (0.05)	1.382	1.724	1.730	1.972

of the second year when a reduction in plant height due to foliar application of nitrogen was noticed.

Spacing had significantly influenced the height of plant at all the stages during both the years except at the 30 DAT in the first year. Closer spacing recorded the lower plant height while wider spacing produced taller plants.

None of the interactions was found to be significant. However the treatment combination of the lowest level of nitrogen and the closer spacing recorded the minimum plant height at all the stages and the highest dose of nitrogen with wider spacing showed the maximum height. The trends were similar during both the years.

4.2. Number of tillers per hill

The mean number of tillers per hill as influenced by various treatments at different stages of growth and the summary of means for the two years are given in Tables 6a to 6e and 7a to 7e respectively.

The effect due to nitrogen levels was significant at all the stages of growth during the first year only. There was progressive increase in the number of tillers per hill due to incremental doses of nitrogen. During the second year also the number of tillers per hill was increased

Table 6a. Mean number of tillers per hill at 30 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	7.24	8.94	9.41	8.53
n_2	7.35	9.24	10.45	9.01
n_3	8.11	9.60	10.90	9.54
n_4	8.17	10.33	11.85	10.12
Methods of N application				
m_1	7.77	9.58	10.74	9.36
m_2	7.67	9.48	10.56	9.24
Mean	7.72	9.53	10.65	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	8.60	8.46	8.53
n_2	9.17	8.84	9.01
n_3	9.53	9.54	9.54
n_4	10.14	10.09	10.12
Mean	9.36	9.24	

	SEm ±	CD (0.05)
For levels of nitrogen	0.293	0.726
For methods of N application	0.169	NS
For plant population	0.209	0.603

Table 6b. Mean number of tillers per hill at 60 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	6.18	7.68	9.32	7.73
n_2	6.02	8.43	10.34	8.26
n_3	6.58	8.74	10.23	8.52
n_4	6.85	9.09	10.04	8.66
Methods of N application				
m_1	6.38	8.48	9.87	8.24
m_2	6.43	8.49	10.10	8.34
Mean	6.41	8.49	9.98	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	7.48	7.97	7.73
n_2	8.13	8.39	8.26
n_3	8.67	8.37	8.52
n_4	8.69	8.63	8.66
Mean	8.24	8.34	

	SEm ±	CD (0.05)
For levels of nitrogen	0.193	0.583
For methods of N application	0.136	NS
For plant population	0.221	0.636

Table 6c. Mean number of tillers per hill at 90 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	6.03	7.93	8.72	7.56
n_2	6.46	8.47	9.51	8.14
n_3	6.63	8.58	10.05	8.42
n_4	6.87	8.74	10.19	8.60
Methods of N application				
m_1	6.48	8.37	9.73	8.19
m_2	6.51	8.49	9.50	8.17
Mean	6.50	8.43	9.63	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	7.54	7.57	7.56
n_2	8.21	8.08	8.14
n_3	8.50	8.34	8.42
n_4	8.52	8.68	8.60
Mean	8.19	8.17	

	SEm ±	CD (0.05)
For levels of nitrogen	0.151	0.458
For methods of N application	0.107	NS
For plant population	0.183	0.527

Table 6d. Mean number of tillers per hill at harvest (First year)

Levels of Nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	5.50	6.97	8.32	6.93
n_2	6.03	7.43	9.75	7.74
n_3	6.43	7.99	9.23	7.88
n_4	6.50	7.85	9.54	7.96
Methods of N application				
m_1	6.21	7.77	9.02	7.67
m_2	6.01	7.35	9.40	7.59
Mean	6.11	7.56	9.54	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	6.88	6.97	6.93
n_2	7.97	7.51	7.74
n_3	7.84	7.92	7.88
n_4	7.97	7.96	7.96
Mean	7.67	7.59	

	SEm ±	CD (0.05)
For levels of nitrogen	0.167	0.516
For methods of N application	0.120	NS
For plant population	0.169	0.488

Table 6e. Mean number of tillers per hill at different stages of growth (summary for first year)

Treatments	Mean number of tillers per hill			
	30 DAT	60 DAT	90 DAT	At harvest
n_1	8.53	7.73	7.56	6.93
n_2	9.01	8.26	8.14	7.74
n_3	9.54	8.52	8.42	7.88
n_4	10.12	8.66	8.60	7.96
F	Sig	Sig	Sig	Sig
SEm ±	0.293	0.193	0.151	0.167
CD (0.05)	0.726	0.583	0.458	0.516
m_1	9.36	8.24	8.19	7.67
m_2	9.24	8.34	8.17	7.59
F	NS	NS	NS	NS
SEm ±	0.169	0.136	0.107	0.120
CD (0.05)	..	..	..	..
S_1	7.72	6.41	6.50	6.11
S_2	9.53	8.49	8.43	7.56
S_3	10.65	9.98	9.63	9.54
F	Sig	Sig	Sig	Sig
SEm ±	0.209	0.221	0.183	0.169
CD (0.05)	0.603	0.636	0.527	0.488

Table 7a. Mean number of tillers per hill at 30 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	8.15	9.76	11.94	9.95
n_2	8.03	10.38	13.25	10.55
n_3	8.74	10.45	13.60	10.93
n_4	9.22	11.24	12.73	11.06
Methods of N application				
m_1	8.83	10.58	12.57	10.66
m_2	8.24	10.33	13.19	10.59
Mean	8.53	10.46	12.88	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	9.99	9.91	9.95
n_2	10.73	10.38	10.55
n_3	10.82	11.04	10.93
n_4	11.11	11.02	11.06
Mean	10.66	10.59	

	SEm ±	CD (0.05)
For levels of nitrogen	0.405	NS
For methods of application	1.717	NS
For plant population	0.266	0.766

Table 7b. Mean number of tillers per hill at 60 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	9.03	10.45	11.79	10.42
n_2	8.03	10.56	13.63	10.74
n_3	8.84	11.10	12.65	10.86
n_4	8.84	10.23	12.31	10.51
Methods of N application				
m_1	8.82	10.73	12.81	10.78
m_2	8.38	10.44	12.63	10.48
Mean	8.60	10.59	12.72	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	10.29	10.56	10.42
n_2	10.97	10.51	10.74
n_3	10.56	11.17	10.86
n_4	11.31	9.71	10.51
Mean	10.78	10.48	

	SEm ±	CD (0.05)
For levels of nitrogen	0.337	NS
For methods of N application	0.238	NS
For plant population	0.250	0.721

Table 7c. Mean number of tillers per hill at 90 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	5.81	7.49	8.43	7.24
n_2	5.83	7.33	10.56	7.91
n_3	7.60	7.73	8.70	8.01
n_4	6.50	8.42	8.58	7.83
Methods of N application				
m_1	6.37	7.78	9.30	7.82
m_2	6.50	7.70	8.84	7.68
Mean	6.43	7.74	9.07	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	7.08	7.41	7.24
n_2	8.46	7.35	7.91
n_3	7.64	8.38	8.01
n_4	8.09	7.57	7.83
Mean	7.82	7.68	

	SEm ±	CD (0.05)
For levels of nitrogen	0.410	NS
For methods of N application	0.290	NS
For plant population	0.338	0.972

Table 7d. Mean number of tillers per hill at harvest (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	5.26	6.61	7.82	6.56
n_2	5.75	6.16	9.32	7.08
n_3	5.85	7.44	8.30	7.20
n_4	5.92	6.97	8.53	7.14
Methods of N application				
m_1	5.79	6.88	8.31	7.00
m_2	5.60	6.70	8.67	6.99
Mean	5.69	6.79	8.49	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	6.43	6.68	6.56
n_2	7.31	6.83	7.08
n_3	7.05	7.34	7.20
n_4	7.18	7.09	7.14
Mean	7.00	6.99	

	SEm ±	CD (0.05)
For levels of nitrogen	0.181	NS
For methods of N application	0.128	NS
For plant population	0.205	0.590

Table 7e. Mean number of tillers per hill at different stages of growth (summary for second year)

Treatments	Mean number of tillers per hill			
	30 DAT	60 DAT	90 DAT	At harvest
n_1	9.95	10.42	7.24	6.56
n_2	10.55	10.74	7.91	7.08
n_3	10.93	10.86	8.01	7.20
n_4	11.06	10.51	7.83	7.14
F	NS	NS	NS	NS
SEm ±	0.405	0.337	0.410	0.181
CD (0.05)	..	..	..	..
m_1	10.66	10.78	7.82	7.00
m_2	10.59	10.48	7.68	6.99
F	NS	NS	NS	NS
SEm ±	1.717	0.238	0.290	0.128
CD (0.05)	..	..	..	..
S_1	8.53	8.60	6.43	5.69
S_2	10.46	10.59	7.74	6.79
S_3	12.88	12.72	9.07	8.49
F	Sig	Sig	Sig	Sig
SEm ±	0.266	0.250	0.338	0.205
CD (0.05)	0.766	0.721	0.972	0.590

appreciably due to incremental doses of nitrogen but the magnitude of increase was less significant when compared to the first year.

Methods of nitrogen application did not show any significant difference in the number of tillers per hill during both the years.

The effect due to plant population was significant during both years. As the spacing increased, number of tillers per hill increased significantly at all the stages of growth.

None of the interaction effects was found to be significant. However, the lower level of nitrogen with closer spacing recorded lower values for number of tillers per hill whereas wider spacing with high doses of nitrogen resulted in higher number of tillers per hill.

In general, a reduction in the number of tillers, irrespective of the treatments, was noticed from the second stage of observation.

4.3. Number of tillers per unit area

The mean number of tillers per unit area (1.2 m^2) due to different treatments at the different stages of growth and the summary of the means for the two years are given in Tables 8a to 8e and 9a to 9e respectively.

Table 8a. Mean number of tillers per unit area (1.2 m^2) at 30 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	869.00	715.33	564.50	716.28
n_2	882.00	739.33	627.00	749.44
n_3	973.00	768.00	654.00	798.33
n_4	980.00	826.67	711.00	839.22
Methods of N application				
m_1	932.00	766.00	644.50	789.83
m_2	920.00	758.67	633.75	770.81
Mean	926.00	762.30	639.13	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	719.89	712.67	716.28
n_2	762.56	736.33	749.44
n_3	798.89	797.78	798.33
n_4	842.00	836.44	839.22
Mean	789.83	770.81	

	SEm ±	CD (0.05)
For levels of nitrogen	17.992	54.579
For methods of N application	12.722	NS
For plant population	16.309	46.988

Table 8b. Mean number of tillers per unit area (1.2 m^2) at 60 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	742.00	614.00	559.00	638.33
n_2	722.00	674.67	620.50	672.39
n_3	790.00	699.33	614.00	701.11
n_4	822.00	727.33	602.50	717.28
Methods of N application				
m_1	766.00	678.33	592.00	678.78
m_2	722.00	679.33	606.00	685.75
Mean	769.00	678.83	599.00	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	616.00	660.67	638.33
n_2	661.67	683.11	672.39
n_3	713.89	688.33	701.11
n_4	723.56	711.00	717.28
Mean	678.78	685.78	

	SEm ±	CD (0.05)
For levels of nitrogen	15.433	46.815
For methods of N application	10.913	NS
For plant population	18.941	54.563

Table 8c. Mean number of tillers per unit area (1.2 m^2) at 90 DAT (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	723.00	634.00	523.00	626.67
n_2	775.00	677.33	570.50	674.28
n_3	796.00	686.67	603.00	695.22
n_4	824.00	699.33	611.50	711.61
Methods of N application				
m_1	777.50	669.33	583.76	676.86
m_2	781.50	679.33	570.25	677.03
Mean	779.50	674.33	577.00	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	622.33	631.00	626.67
n_2	675.67	672.89	674.28
n_3	703.22	687.22	695.22
n_4	706.22	717.00	711.61
Mean	676.86	677.03	

	SEm ±	CD (0.05)
For levels of nitrogen	13.024	39.508
For methods of N application	9.209	NS
For plant population	15.569	44.851

Table 8d. Mean number of tillers per unit area (1.2 m^2) at harvest (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	660.00	557.33	499.00	572.11
n_2	723.00	594.67	585.00	634.22
n_3	771.00	639.33	554.00	654.78
n_4	780.00	628.00	572.00	660.17
Methods of N application				
m_1	745.50	621.33	541.00	635.94
m_2	721.50	588.33	564.25	624.99
Mean	733.50	604.83	552.63	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	569.56	574.67	572.11
n_2	654.11	614.33	634.22
n_3	656.11	653.44	654.78
n_4	664.00	656.33	660.17
Mean	635.94	624.99	

	SEm ±	CD (0.05)
For levels of nitrogen	14.219	43.133
For methods of N application	10.054	NS
For plant population	14.620	42.116

Table 8e. Mean number of tillers per unit area (1.2 m^2)
(Summary for first year)

Treatments	Mean number of tillers			
	30 DAT	60 DAT	90 DAT	At harvest
n_1	716.28	638.33	626.67	572.11
n_2	749.44	672.39	674.28	634.22
n_3	798.33	701.11	695.22	654.78
n_4	839.22	717.28	711.61	660.17
F	Sig	Sig	Sig	Sig
SEm ±	17.992	15.433	13.024	14.219
CD (0.05)	54.579	46.815	39.508	43.133
m_1	789.83	678.78	676.86	635.94
m_2	770.81	685.75	677.03	624.99
F	NS	NS	NS	NS
SEm ±	12.722	10.913	9.209	10.054
CD (0.05)	..	..	..	..
S_1	926.00	769.00	779.50	733.50
S_2	762.30	678.83	674.33	604.83
S_3	639.13	599.00	577.33	[illegible]
F	Sig	Sig	Sig	Sig
SEm ±	16.309	18.941	15.569	14.620
CD (0.05)	46.988	54.563	44.851	42.116

Table 9a. Mean number of tillers per unit area (1.2 m^2) at 30 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	977.67	779.33	716.50	824.50
n_2	964.00	830.00	795.00	863.00
n_3	1049.00	836.00	816.00	900.33
n_4	1106.00	899.33	764.00	923.11
Methods of N application				
m_1	1059.33	846.00	754.00	886.44
m_2	989.00	826.33	791.75	869.03
Mean	1024.17	836.17	772.88	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	837.44	811.56	824.50
n_2	883.67	842.33	863.00
n_3	892.89	907.78	900.33
n_4	931.78	914.44	923.11
Mean	886.44	869.03	

	SEm ±	CD (0.05)
For levels of nitrogen	34.071	NS
For methods of N application	24.092	NS
For plant population	21.054	60.664

Table 9b. Mean number of tillers per unit area (1.2 m^2) at 60 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	1084.00	836.00	707.50	875.83
n_2	963.00	844.67	818.00	875.22
n_3	1061.00	888.00	759.00	902.67
n_4	1018.00	818.67	768.50	868.39
Methods of N application				
m_1	1058.00	858.33	768.50	894.94
m_2	1005.00	835.33	758.00	866.11
Mean	1031.50	846.83	763.25	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	869.56	882.11	875.84
n_2	897.44	853.00	875.22
n_3	878.44	926.89	902.67
n_4	894.94	866.11	

	SEm ±	CD (0.05)
For levels of nitrogen	11.328	34.363
For methods of N application	8.010	NS
For plant population	13.712	39.502
For interaction between S x N	27.425	79.004

Table 9c. Mean number of tillers per unit area (1.2 m^2) at 90 DAT (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	697.00	599.33	506.00	600.78
n_2	699.00	586.60	633.50	639.72
n_3	912.00	618.67	522.00	684.22
n_4	780.00	673.33	515.00	656.11
Methods of N application				
m_1	764.50	622.67	558.00	648.39
m_2	779.50	616.33	530.25	642.03
Mean	772.00	619.50	544.13	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	594.33	607.22	600.78
n_2	685.00	594.44	639.72
n_3	649.89	718.56	684.22
n_4	664.33	647.89	656.11
Mean	648.39	642.03	

	SEm ±	CD (0.05)
For levels of nitrogen	7.642	23.181
For methods of N application	5.404	NS
For plant population	9.939	28.632

Table 9d. Mean number of tillers per unit area (1.2 m^2) at harvest (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	631.00	528.67	469.00	542.89
n_2	690.15	492.67	558.85	580.56
n_3	702.00	595.33	498.00	598.44
n_4	709.85	557.33	512.15	593.11
Methods of N application				
m_1	695.00	550.67	498.75	581.47
m_2	671.50	536.33	520.25	576.03
Mean	683.25	543.50	509.50	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	532.78	553.00	542.89
n_2	601.11	560.00	580.56
n_3	588.11	608.78	598.44
n_4	603.89	582.33	593.11
Mean	581.47	576.03	

	SEm ±	CD (0.05)
For levels of nitrogen	9.195	27.892
For methods of N application	6.502	NS
For plant population	9.168	26.412

Table 9e. Mean number of tillers per unit area (1.2 m^2)
(Summary for second year)

Treatments	Mean number of tillers			
	30 DAT	60 DAT	90 DAT	At harvest
n_1	824.50	875.83	600.78	542.89
n_2	863.00	875.22	639.72	580.56
n_3	900.33	902.67	684.22	598.44
n_4	923.11	868.39	656.11	593.11
F	NS	Sig	Sig	Sig
SEm ±	34.071	11.328	7.642	9.195
CD (0.05)	..	34.363	23.181	27.892
m_1	886.44	894.94	648.39	581.47
m_2	869.03	866.11	642.03	576.03
F	NS	NS	NS	NS
SEm ±	24.092	8.010	5.404	6.502
CD (0.05)	..	..	..	..
S_1	1024.17	1031.50	772.00	683.25
S_2	836.17	846.83	619.50	543.50
S_3	772.88	763.25	544.13	509.50
F	Sig	Sig	Sig	Sig
SEm ±	21.054	13.712	9.939	9.168
CD (0.05)	60.664	39.502	28.632	26.412

The number of tillers per unit area was significantly influenced by nitrogen application at all the stages of growth during both the years except the 30 DAT stage of the second year. At this stage also, there was an increasing trend in the number of tillers per unit area due to increasing levels of nitrogen. At the harvest stage in the first year, mean values of the number of tillers per unit area of 1.2 m^2 were 572.11 for 40 kg N/ha and 660.00 for 160 kg N/ha. The corresponding values for the second year were 542.89 and 593.11 respectively.

The effect due to different methods of application of nitrogen was not statistically significant at any stage of growth or year.

Different spacings (plant population) significantly influenced the number of tillers per unit area, the highest values being recorded for closer planting. As the spacing increased, the total number of tillers per unit area was decreased. During the first year, the closest spacing of 10 x 10 cm recorded an average of 733.50 tillers per 1.2 m^2 area at the harvest stage whereas the number was 552.63 for 10 x 20 cm spacing. The corresponding values for the second year were 683.25 and 509.50 respectively.

Interaction effects were not significant except at the 60 DAT during which the nitrogen x spacing interaction was significant. Among the nitrogen x spacing combinations, the lowest value was recorded by the n_1s_3 treatment and the highest by the n_4s_1 combination.

4.4. Leaf area index

The mean values of the leaf area indices at flowering as influenced by various treatments are given in Table 10 and 11 for the two years respectively.

There were significant differences in leaf area indices of plants at flowering due to different levels of nitrogen. The lowest level of nitrogen recorded the lowest value of LAI which was significantly inferior to the next higher level. However, the difference between n_2n_3 levels was not statistically significant, but there was an appreciable increase in LAI due to the effect of n_3 level when compared to the n_2 level. The highest value of LAI was recorded by the highest level of nitrogen application. The same trend was noticed during both the years. The values of LAI due to incremental doses of nitrogen ranged between 5.57 and 7.18 and between 5.55 and 6.52 respectively during the first and second years.

The effect due to the different methods of application of nitrogen was not statistically significant during both years.

Table 10. Mean Leaf Area Index at flowering (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	5.51	5.70	5.50	5.57
n_2	6.79	6.54	5.28	6.20
n_3	7.31	6.40	5.96	6.56
n_4	8.35	7.04	6.15	7.18
Methods of N application				
m_1	7.14	6.63	5.66	6.48
m_2	6.84	6.21	5.78	6.28
Mean	6.99	6.42	5.72	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	5.19	5.94	5.57
n_2	6.55	5.86	6.20
n_3	6.80	6.31	6.56
n_4	7.36	7.00	7.18
Mean	6.48	6.28	

	SEm ±	CD (0.05)
For levels of nitrogen	0.131	0.396
For methods of N application	0.092	NS
For plant population	0.135	0.385
For interaction N x M	0.185	0.560
For interaction N x S	0.267	0.770

Table 11. Mean Leaf Area Index at flowering (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	6.19	5.47	5.00	5.55
n_2	6.56	5.64	5.21	5.80
n_3	6.92	5.82	5.36	6.03
n_4	7.51	6.42	5.62	6.52
Methods of N application				
m_1	6.72	5.86	5.19	5.92
m_2	6.87	5.81	5.40	6.03
Mean	6.79	5.84	5.30	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	5.28	5.82	5.55
n_2	5.80	5.80	5.80
n_3	6.02	6.04	6.03
n_4	6.59	6.44	6.52
Mean	5.92	6.03	

	SEm $\pm$	CD (0.05)
For levels of nitrogen	0.155	0.471
For methods of N application	0.110	NS
For plant population	0.081	0.232

The influence of various plant populations on the LAI was significant. The minimum spacing of 10 x 10 cm recorded the highest values which was significantly superior to its next wider spacing (10 x 15 cm) which in turn was superior to 10 x 20 cm spacing.

The interaction effects due to nitrogen levels and methods of application and nitrogen levels and plant population on LAI were also significant during the first year. Among the combinations of nitrogen levels and methods of application, the highest value was recorded by n_4m_1. The treatment combination n_4s_1 resulted in the highest value among the nitrogen x spacing interaction.

4.5. Dry matter production at flowering

The mean values for dry matter production at flowering due to various treatments for the first and second years are given in Tables 12 and 13 respectively.

Dry matter production was significantly influenced by nitrogen levels. There was progressive increase in dry matter production due to the incremental doses of nitrogen at all the levels and years. The production of dry matter ranged from 47.9 q/ha for 40 kg N/ha to 59.8 q/ha for the 160 kg N/ha during the first year. For the second year the corresponding values were 43.7 q/ha and 57.2 q/ha respectively.

Table 12. Mean dry matter production (q/ha) at flowering (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	48.40	48.29	46.89	47.86
n_2	53.29	53.44	53.91	53.55
n_3	58.84	58.84	59.36	59.01
n_4	59.88	59.47	60.31	59.88
Methods of N application				
m_1	55.02	54.60	55.13	54.92
m_2	55.19	55.42	55.10	55.24
Mean	55.10	55.01	55.12	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	47.99	47.73	47.86
n_2	53.27	53.82	53.55
n_3	58.95	59.08	59.01
n_4	59.46	60.31	59.88
Mean	54.92	55.24	

	SEm ±	CD (0.05)
For levels of nitrogen	0.293	0.887
For methods of N application	0.207	NS
For plant population	0.385	NS

Table 13. Mean dry matter production (q/ha) at flowering (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	44.92	43.35	42.69	43.65
n_2	47.91	47.31	47.95	47.72
n_3	51.45	52.40	51.96	51.94
n_4	56.45	58.37	56.79	57.20
Methods of N application				
m_1	50.08	50.27	49.42	49.92
m_2	50.29	50.44	50.27	50.33
Mean	50.18	50.36	49.85	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	44.04	43.27	43.65
n_2	47.16	48.28	47.72
n_3	51.47	52.41	51.94
n_4	57.03	57.38	57.20
Mean	49.92	50.33	

	SEm ±	CD (0.05)
For levels of nitrogen	0.415	1.258
For methods of N application	0.293	NS
For plant population	0.509	NS

The method of nitrogen application or the spacing did not cause any statistically significant difference in dry matter production of plants at flowering.

None of the interaction effects was found to be significant in dry matter production.

4.6. Total dry matter production at harvest

The data on total dry matter production at maturity as influenced by various treatments for the two years are given in Tables 14 and 15.

There was significant progressive increase in dry matter production for every incremental dose of nitrogen during the first year. During the second year, the effect due to the higher two levels of nitrogen was on par but significantly superior to the lower two levels. The dry matter production for the different levels of nitrogen ranged between 83.91 q/ha for 40 kg N/ha and 115.65 q/ha for the 160 kg N/ha in the first year and the corresponding values for the second year were 74.25 q/ha and 93.85 q/ha respectively.

The effect due to the method of application of nitrogen on dry matter production at harvest was also significant for both years. Foliar application of nitrogen at the panicle initiation stage encouraged production of

Table 14. Total dry matter production (q/ha) at harvest (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	86.31	84.09	81.33	83.91
n_2	103.00	102.48	103.54	103.00
n_3	111.66	113.55	111.43	112.22
n_4	111.87	119.77	115.29	115.65
Methods of N application				
m_1	102.64	103.56	100.62	102.27
m_2	103.79	106.39	105.17	105.12
Mean	103.21	104.97	102.90	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	82.22	85.60	83.91
n_2	102.06	103.94	103.00
n_3	110.95	113.48	112.22
n_4	113.85	117.44	115.65
Mean	102.27	105.12	

	SEm ±	CD (0.05)
For levels of nitrogen	0.828	2.178
For methods of N application	0.585	1.775
For plant population	0.562	1.620
For the interaction N x S	1.124	3.240

Table 15. Total dry matter production (q/ha) at harvest (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	73.80	75.07	73.87	74.25
n_2	85.84	88.69	88.23	87.59
n_3	91.18	93.74	92.06	92.33
n_4	93.25	93.45	94.86	93.85
Methods of N application				
m_1	84.77	87.80	86.68	86.42
m_2	87.26	87.68	87.82	87.59
Mean	86.02	87.74	87.25	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	73.97	74.52	74.25
n_2	87.43	87.75	87.59
n_3	91.51	93.14	92.33
n_4	92.76	94.94	93.85
Mean	86.42	87.59	

	SEm ±	CD (0.05)
For levels of nitrogen	0.513	1.555
For methods of N application	0.363	1.100
For plant population	0.498	NS

significantly more dry matter than the soil application. The mean values for the soil and foliar applications were 102.27 q/ha and 105.12 q/ha for the first year and the corresponding values for the second year were 86.42 and 87.59 q/ha.

The effect of plant population was significant during the first year and an increasing trend was noticed during the second year upto S_2 level. The highest dry matter production was observed at S_2 level of plant population during both years. A slight reduction in dry matter production was noticed at S_3 level.

The interaction between nitrogen and plant population was significant only in the first year. The highest dry matter production (119.77 q/ha) was recorded by n_4S_2 combination whereas the lowest (81.33 q/ha) was produced by n_1S_3 combination during the first year. During the second year also the same trend was observed.

4.7. Days to 50 per cent flowering

The data on average number of days taken for 50 per cent flowering as influenced by different treatments are given in Tables 16 and 17 for the first year and second year respectively.

Table 16. Mean number of days for 50 per cent flowering (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	100.33	100.50	100.17	100.33
n_2	101.83	101.50	101.50	101.61
n_3	103.17	103.50	104.33	103.67
n_4	104.33	105.00	105.00	104.78
Methods of N application				
m_1	102.75	102.67	102.83	102.75
m_2	102.08	102.58	102.67	102.44
Mean	102.42	102.63	102.75	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	100.78	99.89	100.33
n_2	102.00	101.22	101.61
n_3	103.56	103.78	103.67
n_4	104.67	104.89	104.78
Mean	102.75	102.44	

	SEm ±	CD (0.05)
For levels of nitrogen	0.159	0.483
For methods of N application	0.113	NS
For plant population	0.167	NS
For interaction N x M	0.225	0.682

Table 17. Mean number of days for 50 per cent flowering (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	99.17	99.83	99.50	99.50
n_2	100.67	100.67	100.50	100.61
n_3	102.00	102.00	102.83	102.28
n_4	103.67	104.00	103.83	103.83
Methods of N application				
m_1	101.58	101.58	101.50	101.47
m_2	101.42	101.67	101.83	101.63
Mean	101.38	101.63	101.67	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	99.56	99.44	99.50
n_2	100.67	100.56	100.61
n_3	101.89	102.67	102.28
n_4	103.78	103.89	103.83
Mean	101.47	101.63	

	SEm ±	CD (0.05)
For levels of nitrogen	0.158	0.478
For methods of N application	0.111	NS
For plant population	0.141	NS

It was seen that the number of days required for 50 per cent flowering was significantly influenced by the levels of nitrogen during both the seasons. As the levels increased, the flowering duration also increased progressively.

Method of nitrogen application did not affect the flowering duration to any appreciable extent.

Plant population also did not influence the flowering duration. However, an increasing trend in flowering duration due to wider spacing was noticed during both the years.

The nitrogen x method of application interaction was found to be significant during the first year only. The n_1m_2 combination resulted in the lowest number of days for flowering whereas the n_4m_2 combination recorded the highest duration for flowering during the first year.

4.8. Number of panicles per unit area

Data on mean number of panicles per unit area as influenced by the different treatments are given in Tables 18 and 19 for the first year and second year respectively.

Levels of nitrogen significantly influenced the number of panicles per unit area. It increased significantly

Table 18. Mean number of panicles per unit area (1.2 m^2) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	515.50	506.83	494.67	505.67
n_2	603.00	588.00	589.50	591.83
n_3	609.50	613.17	608.50	610.39
n_4	610.67	606.00	579.17	598.61
Methods of N application				
m_1	576.17	574.67	562.58	571.14
m_2	593.17	582.33	570.83	582.11
Mean	584.67	578.50	566.71	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	503.33	508.00	505.67
n_2	586.22	597.44	591.83
n_3	602.22	618.56	610.39
n_4	592.78	604.44	598.61
Mean	571.14	582.11	

	SEm ±	CD (0.05)
For levels of nitrogen	4.507	13.671
For methods of N application	3.187	9.667
For plant population	2.907	8.377

Table 19. Mean number of panicle per unit area (1.2 m^2) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	503.83	495.00	484.50	494.44
n_2	579.83	579.83	562.33	574.00
n_3	603.83	593.00	577.67	591.50
n_4	609.17	593.17	570.83	591.06
Methods of N application				
m_1	564.33	555.83	537.00	552.39
m_2	584.00	574.67	560.67	573.11
Mean	574.17	565.25	543.83	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	486.67	502.22	494.44
n_2	560.78	587.22	574.00
n_3	582.44	600.56	591.50
n_4	579.67	602.44	591.06
Mean	552.39	573.11	

	SEm ±	CD (0.05)
For levels of nitrogen	2.941	8.922
For methods of N application	2.080	6.309
For plant population	2.683	7.734

upto the n_3 level during both years. The level n_3 was on par with n_4 and n_4 was on par with n_2. During both years, the highest number of panicles per unit area was recorded by the n_3 level.

The effect of method of application of nitrogen was also significant during both years. Application of nitrogen at the panicle initiation stage through foliage appeared to be significantly superior to soil application in increasing the number of panicles per unit area.

Significant difference in the number of panicles per unit area was noticed due to the effect of different plant populations. In the first year, the S_1 level of population recorded the highest number of panicles per unit area which was on par with S_2 population. But these two levels were significantly superior to S_3. In the second year, the effect of all the 3 levels of population was significantly different from one another. S_1 level recorded the highest number of panicles per unit area whereas the lowest value was given by the S_3 level of population.

None of the interaction was found to be significant.

4.9. Length of panicle

Data on mean length of panicle due to various treatments are presented in Tables 20 and 21 for the two years.

Table 20. Mean length of panicle (cm) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	18.27	19.13	20.08	19.16
n_2	19.83	20.29	20.02	20.05
n_3	20.37	20.19	21.40	20.65
n_4	19.50	20.28	20.48	20.09
Method of N application				
m_1	19.68	19.97	20.60	20.08
m_2	19.30	19.98	20.40	19.89
Mean	19.49	19.97	20.50	

Level of nitrogen	Method of N application		
	m_1	m_2	Mean
n_1	19.21	19.12	19.16
n_2	19.97	20.12	20.05
n_3	20.93	20.38	20.65
n_4	20.22	19.96	20.09
Mean	20.08	19.89	

	SEm ±	CD (0.05)
For levels of nitrogen	0.199	0.602
For methods of N application	0.140	NS
For plant population	0.191	0.551

Table 21. Mean length of panicle (cm) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	18.13	18.63	19.98	18.91
n_2	19.87	20.07	20.04	19.99
n_3	20.28	20.45	21.58	20.77
n_4	20.00	20.39	20.67	20.35
Methods of N application				
m_1	19.69	19.98	20.53	20.07
m_2	19.44	19.79	20.60	19.94
Mean	19.57	19.88	20.54	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	18.89	18.92	18.91
n_2	19.89	20.09	19.99
n_3	20.98	20.56	20.77
n_4	20.50	20.21	20.35
Mean	20.07	19.94	

	SEm ±	CD (0.05)
For levels of nitrogen	0.117	0.355
For methods of N application	0.083	NS
For plant population	0.111	0.320

Panicle length was significantly influenced by the level of nitrogen. There was progressive increase in the length of panicle due to increasing levels of nitrogen upto n_3 level. A declining trend was noticed at n_4 level. The pattern was the same for both years.

Method of nitrogen application did not cause any significant difference in panicle length in both years.

Significant differences in panicle length were obtained due to different plant populations in both the years. In the first year, the lower two spacings (S_1 and S_2) were on par while S_3 was significantly superior to S_1 and on par with S_2. In the second year S_1 and S_2 were on par and both were significantly inferior to S_3. The treatment S_3 resulted in the longest panicle.

The nitrogen x spacing interaction was significant in the second year and the longest panicle was produced by the n_3S_3 treatment combination and the shortest by n_1S_1.

4.10. Weight of panicle

Mean values of the weight of panicle as affected by various treatments are presented in Tables 22 and 23.

The weight of panicle was significantly influenced by nitrogen at all the levels. There was progressive

Table 22. Weight of panicle (g) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	1.880	2.010	2.215	2.035
n_2	2.470	2.483	2.517	2.490
n_3	2.552	2.620	2.655	2.609
n_4	2.557	2.717	2.723	2.666
Methods of N application				
m_1	2.294	2.384	2.475	2.384
m_2	2.435	2.531	2.580	2.515
Mean	2.365	2.458	2.528	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	1.950	2.120	2.035
n_2	2.444	2.536	2.490
n_3	2.542	2.676	2.609
n_4	2.601	2.730	2.666
Mean	2.384	2.515	

	SEm $\pm$	CD (0.05)
For levels of nitrogen	0.0132	0.0399
For methods of N application	0.0093	0.0282
For plant population	0.0100	0.0288
N x S	0.0200	0.0576

Table 23. Weight of panicle (g) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	1.822	1.877	1.955	1.884
n_2	2.127	2.313	2.407	2.282
n_3	2.465	2.520	2.597	2.527
n_4	2.545	2.630	2.660	2.612
Methods of N application				
m_1	2.174	2.283	2.344	2.267
m_2	2.305	2.388	2.465	2.386
Mean	2.240	2.335	2.405	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	1.822	1.947	1.884
n_2	2.217	2.348	2.282
n_3	2.474	2.580	2.527
n_4	2.554	2.669	2.612
Mean	2.267	2.386	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0131	0.0396
For methods of N application	0.0092	0.0280
For plant population	0.0106	0.0305
N x S	0.0211	0.0609

increase in the weight of panicle due to the incremental doses of nitrogen upto the highest levels. The corresponding weights of panicle for the n_1, n_2, n_3 and n_4 levels were 2.035, 2.490, 2.609 and 2.666 g during the first year and 1.884, 2.282, 2.527 and 2.612 g for the second year respectively.

The effect of method of application on panicle weight was significant. The m_2 treatment was superior to the m_1.

Different plant populations influenced the panicle weight significantly. Highest value of panicle weight was recorded by the S_3 plant population and the lowest by the S_1. The same pattern in panicle weight was seen in both the years.

The interaction between nitrogen and spacing was also found to be significant. The treatment combination n_4S_3 recorded the highest value whereas the lowest value was observed in n_1S_1 combination.

4.11. Number of spikelets per panicle

Data pertaining to the mean number of spikelets per panicle as influenced by various treatments are given in Tables 24 and 25.

Table 24. Mean number of spikelets per panicle (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	79.67	88.83	91.83	86.78
n_2	90.17	93.17	98.33	93.89
n_3	91.67	98.83	102.50	97.67
n_4	93.83	104.67	106.83	101.78
Methods of N application				
m_1	89.33	96.08	98.67	94.69
m_2	88.33	96.67	101.08	95.36
Mean	88.83	96.38	99.88	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	86.11	87.44	86.78
n_2	93.67	94.11	93.89
n_3	97.56	97.78	97.67
n_4	101.44	102.11	101.78
Mean	94.69	95.36	

	SEm ±	CD (0.05)
For levels of nitrogen	0.610	1.850
For methods of N application	0.431	NS
For plant population	0.818	2.357

Table 25. Mean number of spikelets per panicle (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	78.67	88.00	91.00	85.89
n_2	89.33	92.33	98.17	93.28
n_3	90.83	98.00	101.67	96.83
n_4	93.00	101.17	104.83	99.67
Methods of N application				
m_1	88.58	94.83	97.75	93.72
m_2	87.33	94.92	100.08	94.11
Mean	87.96	94.88	98.92	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	85.33	86.44	85.89
n_2	93.33	93.22	93.28
n_3	96.78	96.89	96.83
n_4	94.44	99.89	99.67
Mean	93.72	94.11	

	SEm ±	CD (0.05)
For levels of nitrogen	0.578	1.752
For methods of N application	0.408	NS
For plant population	0.699	2.013

It was found that the different levels of nitrogen significantly influenced the number of spikelets per panicle and the effect was significant at all the levels for the two years. The average number of spikelets per panicle for n_1, n_2, n_3 and n_4 were 86.78, 93.89, 97.67 and 101.78 respectively for the first year. The corresponding values for the second year were 85.89, 93.28, 96.83 and 99.67 respectively.

Method of application of nitrogen did not influence the number of spikelets per panicle. However, an increasing trend was noticed due to foliar application of nitrogen.

The different plant populations significantly influenced the number of spikelets per panicle. Number of spikelets per panicle was significantly increased as the spacing increased upto the S_3 level during both years. The highest number of spikelets per panicle was observed in S_3 (99.88) and the minimum (88.83) in S_1 during the first year and the corresponding values for the second year were 98.92 and 87.96 respectively.

4.12. Number of filled grains per panicle

The data on the mean number of filled grains per panicle as influenced by the different treatments are given in Table 26 and 27.

Table 26. Mean number of filled grains per panicle (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	67.83	75.50	78.17	73.83
n_2	76.50	79.50	83.50	79.83
n_3	77.50	83.00	85.83	82.11
n_4	77.33	85.83	87.42	83.53
Methods of N application				
m_1	75.42	80.92	82.83	79.72
m_2	74.17	81.00	84.65	79.93
Mean	74.79	80.96	83.74	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	73.00	74.67	73.83
n_2	79.89	79.78	79.83
n_3	82.67	81.56	82.11
n_4	83.33	83.72	83.53
Mean	79.72	79.93	

	SEm ±	CD (0.05)
For levels of nitrogen	0.547	1.659
For methods of N application	0.387	NS
For plant population	0.738	2.127

Table 27. Mean number of filled grains per panicle (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	68.73	76.02	78.67	74.47
n_2	77.08	79.28	84.32	80.23
n_3	76.43	83.28	85.88	81.87
n_4	77.35	83.03	87.12	82.50
Methods of N application				
m_1	75.52	80.48	83.02	79.67
m_2	74.28	80.33	84.98	79.86
Mean	74.90	80.40	84.00	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	73.84	75.10	74.47
n_2	80.22	80.23	80.23
n_3	81.78	81.96	81.87
n_4	82.83	82.17	82.50
Mean	79.67	79.86	

	SEm ±	CD (0.05)
For levels of nitrogen	0.600	1.820
For methods of N application	0.424	NS
For plant population	0.614	1.771

There was significant difference in the number of filled grains per panicle due to levels of nitrogen. In the first year, the highest number was obtained by n_4 level and it was on par with the n_3 level. These two levels were significantly superior to the lower two levels. The lowest number of filled grains per panicle was observed in n_1 which was significantly inferior to n_2. In the second year, n_1 recorded the lowest and n_4 the highest values. The levels n_3 and n_4 were on par. The level n_3 was also on par with n_2.

Method of application did not influence the number of filled grains per panicle during both the years.

This character was significantly influenced by the plant population also. As the plant population was decreased or the spacing was increased, there was significant increase in the number of filled grains per panicle during both the years. The S_1 level of population recorded the lowest number of grains per panicle which was significantly inferior to S_2 which in turn was inferior to S_3. During both the years, the highest number of grains per panicle was recorded by the S_3 population.

4.13. Spikelet sterility

The data on mean spikelet sterility percentage as

Table 28. Mean spikelet sterility percentage (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	14.88	15.01	14.90	14.93
n_2	15.15	14.71	15.08	14.98
n_3	15.49	16.02	16.25	15.91
n_4	17.58	17.98	18.15	17.90
Methods of N application				
m_1	15.54	15.74	15.98	15.76
m_2	15.99	16.11	16.20	16.10
Mean	15.77	15.93	16.09	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	15.22	14.64	14.93
n_2	14.74	15.22	14.98
n_3	15.24	16.57	15.91
n_4	17.81	17.98	70.90
Mean	15.76	16.10	

	SEm ±	CD (0.05)
For levels of nitrogen	0.187	0.567
For methods of application	0.132	NS
For plant population	0.172	NS

Table 29. Mean spikelet sterility percentage (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	12.62	13.63	13.37	13.21
n_2	13.72	14.13	13.78	13.88
n_3	15.84	15.01	15.39	15.41
n_4	16.99	17.79	16.73	17.17
Methods of N application				
m_1	14.71	14.99	14.69	14.80
m_2	14.87	15.29	14.95	15.04
Mean	14.79	15.14	14.82	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	13.31	13.10	13.21
n_2	13.81	13.95	13.88
n_3	15.42	15.41	15.41
n_4	16.65	17.69	17.17
Mean	14.80	15.04	

	SEm ±	CD (0.05)
For levels of nitrogen	0.195	0.593
For methods of N application	0.138	NS
For plant population	0.160	NS

influenced by various treatments are presented in Tables 28 and 29.

It was seen that the sterility percentage was significantly influenced by the levels of nitrogen. In both years, the highest nitrogen level recorded the highest sterility percentage which was significantly different from that of the n_3 level. The effect of n_3 level was also significantly different from that of the n_2 level. But the effects due to n_2 and n_1 were on par only in the first year. However, n_1 recorded the lowest sterility percentage.

The effects due to methods of application of nitrogen and plant population were not significant. The nitrogen levels x method of application interaction was significant during the first year only. The maximum and minimum values in the nitrogen x method combinations were recorded by n_4m_2 and n_1m_2 respectively.

4.14. Number of grains per unit area

Data on mean number of grains x 100 per unit area of 1.2 m^2 as influenced by the various treatments are presented in Tables 30 and 31.

There was significant difference in the number of grains per unit area due to levels of nitrogen. There was

Table 30. Mean number of grains x 100 per unit area (1.2 m^2) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	349.65	381.70	387.95	373.10
n_2	457.95	467.20	487.87	471.01
n_3	478.78	506.28	517.90	500.99
n_4	474.95	515.75	506.25	498.98
Methods of N application				
m_1	443.46	467.05	467.97	459.49
m_2	437.21	468.42	482.02	462.55
Mean	440.33	467.73	474.99	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	367.79	378.41	373.10
n_2	468.90	473.11	471.01
n_3	503.13	498.84	500.99
n_4	498.14	499.82	498.98
Mean	459.49	462.55	

	SEm ±	CD (0.05)
For levels of nitrogen	3.701	11.227
For methods of N application	2.617	NS
For plant population	4.005	11.542

Table 31. Mean number of grains x 100 per unit area ($1.2\ m^2$) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	360.23	384.30	382.83	875.79
n_2	451.58	460.25	486.37	466.07
n_3	469.68	504.23	513.23	495.72
n_4	501.67	498.95	510.30	503.64
Methods of N application				
m_1	448.62	459.18	467.18	458.33
m_2	442.97	464.68	479.19	462.28
Mean	445.79	461.93	473.18	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	372.00	379.58	375.79
n_2	464.84	467.29	466.07
n_3	495.33	496.10	495.72
n_4	501.12	506.16	503.64
Mean	458.33	462.28	

	SEm ±	CD (0.05)
For levels of nitrogen	4.856	14.730
For methods of N application	3.434	NS
For plant population	5.109	14.723

progressive increase in the number of grains per unit area due to incremental doses of nitrogen upto n_3 level in the first year and upto the highest level in the second year. However, these two levels were on par during both years. The n_1 and n_2 levels were inferior to the n_3 and n_4 levels.

Different methods of application did not show any significant influence on the number of grains per unit area.

The effect due to different spacings was significant. The S_3 population recorded the highest number of grains per unit area and it was on par with S_2. The effect of S_1 spacing was significantly inferior to the other two plant populations.

4.15. Thousand grain weight

The data pertaining to 1000 grain weight as influenced by the different treatments are presented in Tables 32 and 33.

There was significant increase in the weight of grains due to incremental doses of nitrogen. The effect of each level of nitrogen was significantly different from its next higher or lower dose in both years upto the highest level tried. The values ranged from 24.0 g to 26.5 g/1000 grains in the first year and from 24.1 to 26.6 g/1000 grains in the second year respectively.

Table 32. Mean weight of 1000 grains (g) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	23.7	24.0	24.3	24.0
n_2	25.1	25.1	25.1	25.1
n_3	25.8	25.7	25.5	25.7
n_4	26.6	26.5	26.5	26.5
Methods of N application				
m_1	25.1	25.1	25.2	25.1
m_2	25.5	25.6	25.4	25.5
Mean	25.3	25.3	25.3	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	23.6	24.4	24.0
n_2	25.0	25.2	25.1
n_3	25.6	25.8	25.7
n_4	26.4	26.6	26.5
Mean	25.1	25.5	

	SEm ±	CD (0.05)
For levels of nitrogen	0.07	0.22
For methods of N application	0.05	0.15
For plant population	0.04	NS
For interaction N x S	0.09	0.22

Table 33. Mean weight of 1000 grains (g) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	24.0	24.0	24.2	24.1
n_2	24.9	24.8	25.1	24.9
n_3	26.1	26.2	26.2	26.2
n_4	26.6	26.6	26.7	26.6
Methods of N application				
m_1	25.3	25.3	25.4	25.3
m_2	25.5	25.6	25.7	25.6
Mean	25.4	25.4	25.5	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	24.0	24.2	24.1
n_2	24.8	25.1	24.9
n_3	26.0	26.3	26.2
n_4	26.4	26.8	26.6
Mean	25.3	25.6	

	SEm ±	CD (0.05)
For levels of nitrogen	0.08	0.24
Methods of N application	0.06	0.17
For plant population	0.04	0.11

The effect of method of nitrogen application was also found to be significant in both years. The second top dressing of nitrogen when given through foliar application increased the weight of grains as compared to the soil application. The respective values for soil and foliar applications were 25.1 and 25.5 g/1000 grains in the first year and 25.3 and 25.6 g/1000 grains in the second year.

Plant population did not result in any significant change in 1000 grain weight in the first year, but an increase was observed in the second year.

In the first year, the interaction effect between nitrogen and plant population was significant.

4.16. Yield of grain

The data on mean yield of grain as influenced by different treatments are given in Tables 34 to 37.

The yield of grain was significantly influenced by nitrogen levels in both years. There was positive significant increase in yield due to nitrogen levels upto n_3 in both years and the effects of n_3 and n_4 were on par. The average yields obtained under n_1, n_2, n_3 and n_4 levels of nitrogen during the first year were 3302, 4222, 4607 and 4481 kg/ha respectively. The corresponding values

Table 34. Mean yield of grain (kg/ha) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	3438.22	3299.12	3169.21	3302.18
n_2	4322.08	4172.71	4172.00	4222.26
n_3	4588.10	4673.91	4559.89	4607.30
n_4	4131.39	4849.03	4461.85	4480.76
Methods of N application				
m_1	4082.29	4151.57	3988.17	4074.01
m_2	4157.61	4345.81	4193.30	4232.24
Mean	4119.95	4248.69	4090.74	
Levels of nitrogen	Methods of N application			
	m_1	m_2	Mean	
n_1	3199.87	3404.49	3302.18	
n_2	4168.77	4275.76	4222.26	
n_3	4534.13	4680.47	4607.30	
n_4	4393.27	4568.25	4480.76	
Mean	4074.01	4232.24		

	SEm ±	CD (0.05)
For levels of nitrogen	69.540	210.948
For methods of N application	49.172	149.162
For interaction S x N	93.426	269.137
For plant population	46.713	NS

Table 35. Mean yield of grain kg/ha (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	2978.63	3053.22	2955.41	2995.75
n_2	3396.24	3485.43	3358.10	3413.26
n_3	3566.40	3670.36	3579.09	3605.28
n_4	3517.99	3576.87	3624.55	3573.14
Methods of N application				
m_1	3304.01	3412.14	3306.69	3340.95
m_2	3425.61	3480.80	3451.88	3452.76
Mean	3364.81	3446.47	3379.29	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	2959.30	3032.20	2995.75
n_2	3370.76	3455.75	3413.26
n_3	3537.61	3672.95	3605.28
n_4	3496.12	3650.15	3573.14
Mean	3340.95	3452.76	

	SEm ±	CD (0.05)
For levels of nitrogen	30.161	91.494
For methods of N application	21.327	64.696
For plant population	26.157	NS

Table 36. Yield of grain kg/ha (pooled data)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	3208	3176	3062	3149
n_2	3859	3829	3765	3818
n_3	4077	4172	4070	4106
n_4	3825	4213	4043	4027
Methods of N application				
m_1	3693	3782	3648	3708
m_2	3792	3913	3823	3843
Mean	3743	3848	3735	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	3080	3218	3149
n_2	3770	3866	3818
n_3	4036	4177	4106
n_4	3945	4109	4027
Mean	3708	3843	

	SEm ±	CD (0.05)
For levels of nitrogen	38.1	115.4
For methods of N application	26.9	81.6
For interaction between nitrogen and plant population	51.8	149.4
For plant population	25.9	74.7

Table 37. Mean yield of grain (kg/ha) due to various treatments (summary for both years) and their pooled mean

Treatments	Yield of grain (kg/ha)		
Levels of nitrogen	First year	Second year	Pooled Mean
n_1	3302	2995	3149
n_2	4222	3413	3818
n_3	4607	3605	4106
n_4	4481	3573	4027
F	Sig	Sig	Sig
SEm $\pm$	69.5	30.2	38.1
CD (0.05)	210.9	91.5	115.4
Methods of N application			
m_1	4074	3341	3708
m_2	4232	3453	3843
F	Sig	Sig	Sig
SEm $\pm$	49.2	21.3	26.9
CD (0.05)	149.2	64.7	81.6
Plant population			
S_1	4120	3365	3743
S_2	4249	3447	3848
S_3	4091	3379	3735
F	NS	NS	Sig
SEm $\pm$	46.7	26.2	25.9
CD (0.05)	..	..	74.7

for the second year were 2996, 3413, 3605 and 3573 kg/ha respectively. The average production of grain over the two years under these levels were 3149, 3818, 4106 and 4027 kg/ha.

The percentage increase in yield of grain due to the incremental doses of nitrogen over the lowest level was 27.9, 39.5 and 35.7 for n_2, n_3 and n_4 respectively during the first year. In the second year the percentage increase was only 14.0, 20.4 and 19.3 respectively for the n_2, n_3 and n_4 levels. From the pooled data it was found that the increase under n_2, n_3 and n_4 levels over n_1 was 21.0, 30.0 and 28.0 per cent respectively. There was a decrease in yield in the second year when compared to the first year.

The effect due to method of application of nitrogen was also significant for both years. Foliar application of nitrogen was superior to soil application. The percentage increase due to foliar application over soil application was 3.88 and 3.35 for the first and second year respectively.

The different plant populations tried in the experiment did not influence the yield of grain significantly in the individual years. But the pooled analysis showed significant influence on yield. It was seen that there was an increase in yield in S_2 when compared to S_1 and S_3 which were on par.

The interaction effect between nitrogen level and plant population was significant in the first year only. The highest grain production was noticed in n_4S_2 combination followed by n_3S_2 and the lowest was in n_1S_3. The results of the pooled analysis also revealed that the interaction effect between nitrogen level and plant population was significant. The highest yield of grain (4213 kg/ha) was obtained in the treatment combination n_4S_2 and the lowest (3062 kg/ha) in n_1S_3.

4.17. Yield of straw

The mean values on yield of straw as influenced by the various treatments are given in Tables 38, 39 and 40. The summary of the average production is presented in Table 41.

The straw yield was significantly influenced by the level of nitrogen during both years. For every incremental dose of nitrogen, there was a corresponding increase in straw upto the highest level tried. During the first year the mean values for n_1, n_2, n_3 and n_4 were 50.61, 60.78, 66.14 and 70.84 q/ha respectively and the corresponding values for the second year were 44.29, 53.42, 56.29 and

Table 38. Mean yield of straw (q/ha) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	51.93	50.27	49.63	50.61
n_2	59.78	60.75	61.82	60.78
n_3	65.78	66.82	65.83	66.14
n_4	70.57	71.28	70.67	70.84
Methods of N application				
m_1	61.82	62.04	60.74	61.53
m_2	62.22	62.52	63.23	62.66
Mean	62.02	62.28	61.99	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	50.22	51.00	50.61
n_2	60.38	61.19	60.78
n_3	65.61	66.68	66.14
n_4	69.92	71.76	70.84
Mean	61.53	62.66	

	SEm ±	CD (0.05)
For levels of nitrogen	0.285	0.864
For methods of N application	0.201	0.611
For plant population	0.320	NS
For interaction S x M	0.453	1.304

Table 39. Mean yield of straw (q/ha) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	44.02	44.53	44.32	44.29
n_2	51.88	53.83	54.55	53.42
n_3	55.57	57.03	56.27	56.29
n_4	58.07	58.18	58.62	58.29
Method of N application				
m_1	51.73	53.68	53.62	53.01
m_2	53.03	53.12	53.26	53.14
Mean	52.38	53.40	53.44	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	44.38	44.20	44.29
n_2	53.72	53.12	53.42
n_3	56.13	56.44	56.29
n_4	57.80	58.78	58.29
Mean	53.01	53.14	

	SEm ±	CD (0.05)
For levels of nitrogen	0.309	0.938
For methods of N application	0.219	NS
For plant population	0.287	0.827

Table 40. Mean yield of straw (q/ha) (Pooled data)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	47.98	47.42	46.98	47.46
n_2	55.83	57.29	58.18	57.10
n_3	60.68	61.93	61.05	61.22
n_4	64.32	64.73	64.63	64.56
Methods of N application				
m_1	56.78	57.87	57.18	57.27
m_2	57.63	57.81	58.25	57.90
Mean	57.20	57.84	57.71	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	47.31	47.60	47.46
n_2	57.05	57.16	57.10
n_3	60.87	61.56	61.22
n_4	63.86	65.26	64.56
Mean	57.27	57.90	

	SEm ±	CD (0.05)
For levels of nitrogen	0.160	0.487
For methods of N application	0.113	0.344
For plant population	0.207	NS
For interaction N x S	0.414	1.192

Table 41. Mean yield of straw (q/ha) (summary for two years)

Treatments	Yield of straw (q/ha)		
Levels of nitrogen	First year	Second year	Pooled mean
n_1	50.61	44.29	47.45
n_2	60.78	53.42	57.10
n_3	66.14	56.29	61.22
n_4	70.84	58.29	64.56
F	Sig	Sig	Sig
SEm ±	0.285	0.309	0.1604
CD (0.05)	0.864	0.938	0.4866
Methods of N application			
m_1	61.53	53.01	57.27
m_2	62.66	53.14	57.90
F	Sig	NS	Sig
SEm ±	0.201	0.219	0.1135
CD (0.05)	0.611	..	0.3441
Plant population			
S_1	62.02	52.38	57.20
S_2	62.28	53.40	57.84
S_3	61.99	53.44	57.71
F	NS	Sig	NS
SEm ±	0.320	0.287	0.2069
CD (0.05)	..	0.827	..

58.29 q/ha. The average yields of straw over the two years for different levels of nitrogen were 47.46, 57.10, 61.22 and 64.56 q/ha respectively. The average increase of straw at the n_2 level over n_1 was 20 per cent, at the n_3 level 29 per cent and it was 36 per cent at the n_4 level. It was also noticed that the straw yield at all the levels of nitrogen was more during the first year when compared to the second year.

The effect of method of application of nitrogen on straw yield was significant during the first year only. However, the pooled analysis also showed significant difference. Foliar application of nitrogen favoured increasing the yield of straw, but the magnitude of increase was not as that of the level of nitrogen. The average yield of straw obtained by the m_1 method was 57.27 q/ha while it was 57.90 q/ha for m_2.

Different plant populations influenced the straw yield during the second year only. On an average, the yield of straw was 57.20 q/ha for S_1, 57.84 for S_2 and 57.71 q/ha for S_3.

The pooled analysis also showed significant interaction effect between nitrogen levels and spacing. The highest average straw yield was recorded by n_4S_2 and the lowest by n_1S_3.

4.18. Grain : Straw ratio

The data on the mean values for grain : straw ratio as affected by various treatments are presented in Tables 42 and 43.

The grain : straw ratio was significantly influenced by nitrogen levels. In the first year there was a gradual increase upto the third level and then it decreased significantly giving the lowest grain : straw ratio at the n_4 level of nitrogen. In the second year also grain : straw ratio was the lowest in n_4.

The effect of method of application was not significant in the first year, but it was significant in the second year. Higher ratios were recorded by the m_2 method.

Different plant populations did not influence the grain : straw ratio.

The interaction N x S was also found significant in the first year. The highest ratio was noticed in the n_2S_1 combination and the lowest in n_4S_1.

4.19. Nitrogen content of plant at flowering

Data on mean nitrogen content of plant at flowering as affected by the different treatments are given in Tables 44 and 45.

Table 42. Grain : straw ratio (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.6633	0.6583	0.6383	0.6533
n_2	0.7250	0.6867	0.6733	0.6950
n_3	0.6983	0.7016	0.6933	0.6978
n_4	0.5850	0.6817	0.6300	0.6322
Methods of N application				
m_1	0.6625	0.6683	0.6550	0.6619
m_2	0.6733	0.6958	0.6625	0.6772
Mean	0.6679	0.6821	0.6588	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.6378	0.6689	0.6533
n_2	0.6900	0.7000	0.6950
n_3	0.6922	0.7033	0.6978
n_4	0.6278	0.6367	0.6322
Mean	0.6619	0.6772	

	SEm ±	CD (0.05)
For levels of nitrogen	0.01050	0.03201
For methods of N application	0.00745	NS
For plant population	0.00828	NS
For interaction N x S	0.01660	0.04781

Table 43. Grain : straw ratio (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.6767	0.6860	0.6680	0.6769
n_2	0.6542	0.6479	0.6161	0.6394
n_3	0.6413	0.6437	0.6361	0.6405
n_4	0.6057	0.6147	0.6182	0.6129
Methods of N application				
m_1	0.6413	0.6385	0.6178	0.6326
m_2	0.6478	0.6577	0.6514	0.6523
Mean	0.6446	0.6481	0.6346	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.6672	0.6866	0.6769
n_2	0.6279	0.6508	0.6394
n_3	0.6303	0.6508	0.6405
n_4	0.6048	0.6210	0.6129
Mean	0.6326		

	SEm ±	CD (0.05)
For levels of nitrogen	0.00564	0.01710
For methods of N application	0.00399	0.01209
For plant population	0.00473	NS

Table 44. Mean nitrogen content of plant (per cent) at flowering (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	1.0817	1.0417	1.0700	1.0644
n_2	1.2217	1.2733	1.2667	1.2506
n_3	1.4333	1.4450	1.4267	1.4350
n_4	1.5483	1.5883	1.5200	1.5522
Methods of N application				
m_1	1.2858	1.2908	1.2950	1.2906
m_2	1.3567	1.3833	1.3417	1.3606
Mean	1.3213	1.3371	1.3183	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	1.0256	1.1033	1.0644
n_2	1.2122	1.2889	1.2506
n_3	1.4067	1.4633	1.4350
n_4	1.5178	1.5867	1.5522
Mean	1.2906	1.3606	

	SEm ±	
For levels of nitrogen	0.02230	0.06766
For methods of N application	0.01577	0.04785
For plant population	0.00850	NS

Table 45. Mean nitrogen contents of plant (per cent) at flowering (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	1.0383	1.0400	1.0667	1.0483
n_2	1.2333	1.2633	1.2183	1.2383
n_3	1.4117	1.4117	1.4383	1.4206
n_4	1.5917	1.5717	1.5950	1.5861
Methods of N application				
m_1	1.2900	1.3017	1.3008	1.2975
m_2	1.3475	1.3417	1.3583	1.3492
Mean	1.3188	1.3217	1.3296	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	1.0144	1.0822	1.0483
n_2	1.2089	1.2678	1.2383
n_3	1.3978	1.4433	1.4206
n_4	1.5689	1.6033	1.5861
Mean	1.2975	1.3492	

	SEm ±	CD (0.05)
For levels of nitrogen	0.01102	0.03343
For methods of N application	0.00779	0.02364
For plant population	0.01548	NS

It was found that the effect of level of nitrogen was significant. As the level of nitrogen increased, the nitrogen content also increased upto the highest level, the response being linear. The effects were similar for both years. The nitrogen contents in plants at flowering at the n_1, n_2, n_3 and n_4 levels of nitrogen were 1.06, 1.25, 1.44 and 1.55 for the first year and 1.05, 1.24, 1.42 and 1.59 for the second year respectively.

Method of nitrogen application also influenced the nitrogen content of the plant at flowering. In both years, application of the second top dose of nitrogen through foliage increased the nitrogen content of plants when compared to the soil application. The mean values of nitrogen content in plants at flowering due to m_1 and m_2 were 1.29 and 1.36 for the first year and 1.30 and 1.35 for the second year respectively.

There was no significant influence on the nitrogen content of plants at flowering due to different plant populations.

4.20. Nitrogen content of straw at harvest

Data pertaining to the nitrogen content in straw for the two years are presented in Tables 46 and 47.

Table 46. Mean nitrogen content (per cent) of straw (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.5095	0.4980	0.5077	0.5051
n_2	0.5563	0.5697	0.5833	0.5698
n_3	0.6300	0.6212	0.6293	0.6268
n_4	0.7062	0.6913	0.6893	0.6956
Methods of N application				
m_1	0.5940	0.5917	0.5953	0.5937
m_2	0.6070	0.5984	0.6095	0.6050
Mean	0.6005	0.5950	0.6024	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.5026	0.5076	0.5051
n_2	0.5683	0.5712	0.5698
n_3	0.6131	0.6406	0.6268
n_4	0.6907	0.7006	0.6956
Mean	0.5937	0.6050	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0080	0.0244
For methods of N application	0.0057	NS
For plant population	0.0291	NS

Table 47. Mean nitrogen content (per cent) of straw (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.5065	0.4935	0.5070	0.5023
n_2	0.5683	0.5622	0.5873	0.5726
n_3	0.6230	0.6195	0.6310	0.6245
n_4	0.6937	0.6912	0.6925	0.6924
Methods of N application				
m_1	0.5917	0.5897	0.5958	0.5924
m_2	0.6041	0.5935	0.6132	0.6036
Mean	0.5979	0.5916	0.6045	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.4959	0.5088	0.5023
n_2	0.5742	0.5710	0.5726
n_3	0.6152	0.6338	0.6245
n_4	0.6841	0.7008	0.6924
Mean	0.5924	0.6036	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0065	0.0197
For methods of N application	0.0046	NS
For plant population	0.0053	NS

The influence of level of nitrogen was significant in the case of nitrogen content of straw during both years. As the level of nitrogen increased, there was a corresponding increase in the nitrogen content of straw also showing a linear response upto the highest level tried. The values of nitrogen content in straw for the levels n_1, n_2, n_3 and n_4 were 0.505, 0.570, 0.627 and 0.696 per cent for the first year and for the second year the corresponding values were 0.502, 0.573, 0.625 and 0.692 per cent respectively.

Method of application did not influence the nitrogen content to any significant extent. However, an increasing trend was observed in the nitrogen content of straw due to foliar application of nitrogen as compared to soil application.

The effect of various plant populations on the nitrogen content of straw was also not significant.

4.21. Protein content of grain

Data on mean protein content of grain as influenced by various treatments are presented in Tables 48 and 49.

Protein content of grain was significantly influenced by the levels of nitrogen. There was significant increase in the protein content of grain at all the successive incremental levels. The lowest protein content was observed

Table 48. Protein content of grain (per cent) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	6.94	6.88	7.13	6.98
n_2	7.82	7.81	7.84	7.83
n_3	8.46	8.67	8.63	8.58
n_4	9.72	9.07	9.49	9.43
Methods of N application				
m_1	8.15	8.00	8.11	8.09
m_2	8.32	8.21	8.43	8.32
Mean	8.23	8.11	8.27	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	6.94	7.01	6.98
n_2	7.75	7.90	7.82
n_3	8.42	8.74	8.58
n_4	9.23	9.63	9.43
Mean	8.09	8.32	

	SEm ±	CD (0.05)
For levels of nitrogen	0.068	0.205
For methods of N application	0.048	0.145
For plant population	0.073	NS

Table 49. Protein content of grain (per cent) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	7.02	7.10	7.16	7.09
n_2	7.85	7.84	7.89	7.86
n_3	8.36	8.49	8.46	8.44
n_4	9.44	9.20	9.47	9.37
Methods of N application				
m_1	8.02	7.98	8.08	8.03
m_2	8.32	8.33	8.41	8.35
Mean	8.17	8.16	8.24	
Levels of nitrogen	Methods of N application			
	m_1	m_2	Mean	
n_1	7.02	7.17	7.09	
n_2	7.72	8.01	7.86	
n_3	8.25	8.63	8.44	
n_4	9.13	9.61	9.37	
Mean	8.03	8.35		

	SEm ±	CD (0.05)
For levels of nitrogen	0.087	0.265
For methods of N application	0.062	0.188
For plant population	0.066	NS

for the lowest level of applied nitrogen. The mean values of protein content in grain for the n_1, n_2, n_3 and n_4 levels were 6.98, 7.83, 8.58 and 9.43 per cent respectively for the first year. The corresponding values for the second year were 7.09, 7.86, 8.44 and 9.37 per cent respectively.

The effect of the method of application was also significant during both years. Foliar application of nitrogen was superior to soil application at the panicle initiation stage. The values for the soil and foliar application of nitrogen were 8.09 and 8.32 in the first year and 8.03 and 8.35 in the second year.

Protein content of grain was not significantly affected in any of the years by the variations in plant population.

4.22. Nitrogen uptake at flowering

Mean values are presented in Tables 50 and 51.

The total uptake of nitrogen by plants at the flowering stage was significantly influenced by nitrogen levels. There was progressive increase in the uptake of nitrogen due to incremental doses of nitrogen upto the n_4 level, the effect being linear in both years. The highest uptake was in n_4 and the lowest in n_1.

Table 50. Nitrogen uptake at flowering (kg/ha) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	52.32	50.27	50.19	50.93
n_2	65.11	68.14	66.64	66.63
n_3	84.36	84.98	84.80	84.71
n_4	92.73	94.54	91.58	92.95
Methods of N application				
m_1	71.55	71.40	72.34	71.76
m_2	75.71	77.57	74.26	75.85
Mean	73.63	74.48	73.30	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	49.21	52.65	50.93
n_2	64.60	68.66	66.63
n_3	82.97	86.45	84.71
n_4	90.27	95.62	92.95
Mean	71.76	75.85	

	SEm ±	CD (0.05)
For levels of nitrogen	1.378	4.181
For methods of N application	0.975	2.957
For plant population	0.666	NS

Table 51. Nitrogen uptake at flowering (kg/ha) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	46.27	45.10	45.64	45.67
n_2	59.26	59.83	58.41	59.17
n_3	72.36	74.02	78.09	74.82
n_4	89.84	91.67	90.56	90.69
Methods of N application				
m_1	65.12	66.48	67.07	66.22
m_2	68.74	68.83	69.28	68.95
Mean	66.93	67.66	68.18	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	44.45	46.89	45.67
n_2	57.08	61.25	59.17
n_3	73.97	75.68	74.82
n_4	89.39	91.99	90.69
Mean	66.22	68.95	

	SEm ±	CD (0.05)
For levels of nitrogen	1.102	3.343
For methods of N application	0.779	2.364
For plant population	1.177	NS

Method of nitrogen application had also influenced the nitrogen uptake by plants. Foliar application was significantly superior to soil application in both years.

Plant population did not influence the uptake of nitrogen to any significant extent.

4.23. Nitrogen uptake at harvest

The mean data on uptake of nitrogen at harvest (grain + straw) as influenced by various treatments are presented in Tables 52 and 53.

The uptake of nitrogen at harvest was significantly influenced by level of nitrogen. There was progressive increase in the uptake due to incremental doses. The uptake values at n_1, n_2, n_3 and n_4 levels were 62.40, 87.51, 104.76 and 116.78 kg/ha during the first year and during the second year the corresponding values were 56.28, 73.55, 83.84 and 93.97 kg/ha respectively.

The effect of method of application of nitrogen was also significant. The m_2 treatment was significantly superior to m_1. The uptake values at m_1 and m_2 methods were 90.27 and 95.45 kg/ha for the first year and 74.88 and 78.93 for the second year respectively.

Plant population had no significant influence on the uptake of nitrogen.

Table 52. Nitrogen uptake at harvest kg/ha (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	64.57	61.28	61.35	62.40
n_2	87.32	86.79	88.41	87.51
n_3	103.55	106.31	104.43	104.76
n_4	114.11	119.74	116.50	116.78
Methods of N application				
m_1	90.79	91.05	88.99	90.27
m_2	93.99	96.00	96.36	95.45
Mean	92.39	93.53	92.67	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	60.72	64.08	62.40
n_2	85.97	89.04	87.51
n_3	101.33	108.19	104.76
n_4	113.08	120.48	116.78
Mean	90.27	95.45	

	SEm ±	CD (0.05)
For levels of nitrogen	1.253	3.800
For methods of N application	0.886	2.687
For plant population	0.922	NS

Table 53. Nitrogen uptake at harvest (kg/ha) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	55.76	56.70	56.34	56.28
n_2	72.23	74.01	74.41	73.55
n_3	82.33	85.20	83.98	83.84
n_4	93.45	92.93	95.52	93.97
Methods of N application				
m_1	73.50	75.83	75.32	74.88
m_2	78.39	78.58	79.81	78.93
Mean	75.94	77.21	77.56	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	55.28	57.26	56.27
n_2	72.46	74.64	73.55
n_3	81.22	86.45	83.84
n_4	90.57	97.36	93.97
Mean	74.88	78.93	

	SEm ±	CD (0.05)
For levels of nitrogen	0.926	2.807
For methods of N application	0.654	1.985
For plant population	0.600	NS

It was seen that, on an average, the uptake values were high in the first year as compared to the second year.

4.24. Phosphorus uptake at harvest

The mean values are furnished in Tables 54 and 55.

The uptake of phosphorus was significantly influenced by level of nitrogen. There was progressive increase in the uptake of phosphorus due to incremental doses of nitrogen upto the n_4 level. However, in the second year, the effects of n_4 and n_3 were on par. The highest values for both years were recorded by n_4 level and the lowest by n_1.

The effect of method of application was also significant in both years. Foliar application of nitrogen was superior to soil application. The values for m_1 and m_2 were 24.40 and 25.56 kg/ha for the first year and 21.51 and 22.47 kg/ha for the second year respectively. Plant population did not influence the phosphorus uptake to any significant extent in both years.

4.25. Potassium uptake at harvest

Mean values are given in Tables 56 and 57.

The uptake of potassium at harvest was significantly influenced by the different levels of nitrogen. There was progressive and significant increase in the potassium uptake

Table 54. Phosphorus uptake (kg/ha) at harvest (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	19.15	18.59	18.08	18.60
n_2	24.43	24.46	25.23	24.71
n_3	27.68	26.11	28.23	27.34
n_4	27.84	30.55	29.42	29.27
Methods of N application				
m_1	24.26	24.68	24.27	24.40
m_2	25.29	25.17	26.21	25.56
Mean	24.78	24.93	25.24	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	18.12	19.09	18.60
n_2	23.77	25.65	24.71
n_3	27.36	27.32	27.34
n_4	28.36	30.18	29.27
Mean	24.40	25.56	

	SEm ±	CD (0.05)
For levels of nitrogen	0.391	1.186
For methods of N application	0.277	0.839
For plant population	0.371	NS

Table 55. Phosphorus uptake (kg/ha) at harvest (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	17.51	17.84	17.00	17.45
n_2	21.54	22.39	21.86	21.93
n_3	23.86	24.41	23.76	24.01
n_4	24.13	24.60	24.98	24.57
Methods of N application				
m_1	21.29	21.86	21.37	21.51
m_2	22.23	22.76	22.43	22.47
Mean	21.76	22.31	21.90	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	17.02	17.88	17.45
n_2	21.42	22.44	21.93
n_3	23.57	24.45	24.01
n_4	24.01	25.13	24.57
Mean	21.51	22.47	

	SEm ±	CD (0.05)
For levels of nitrogen	0.313	0.950
For methods of N application	0.222	0.672
For plant population	0.211	NS

Table 56. Potassium uptake (kg/ha) at harvest (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	95.29	89.49	91.31	92.03
n_2	118.13	119.52	119.38	119.01
n_3	132.27	135.91	132.20	133.46
n_4	140.54	145.55	144.09	143.39
Methods of N application				
m_1	119.10	119.29	119.42	119.27
m_2	124.02	125.94	124.07	124.68
Mean	121.56	122.62	121.75	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	87.41	96.65	92.03
n_2	117.33	120.70	119.01
n_3	131.60	135.32	133.46
n_4	140.74	146.05	143.39
Mean	119.27	124.68	

	SEm ±	CD (0.05)
For levels of nitrogen	1.081	3.278
For methods of N application	0.764	2.318
For plant population	0.899	NS

Table 57. Potassium uptake (kg/ha) at harvest (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	81.50	83.24	81.13	81.96
n_2	99.98	102.59	103.79	102.12
n_3	109.16	113.07	109.39	110.54
n_4	114.76	114.98	117.14	115.63
Methods of N application				
m_1	99.06	102.91	101.64	101.20
m_2	103.64	104.03	104.09	103.92
Mean	101.35	103.47	102.86	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	81.03	82.88	81.96
n_2	101.22	103.02	102.12
n_3	108.94	112.14	110.54
n_4	113.62	117.64	115.63
Mean	101.20	103.92	

	SEm ±	CD (0.05)
For levels of nitrogen	0.741	2.248
For methods of N application	0.524	1.589
For plant population	0.622	NS

due to incremental doses of nitrogen upto the highest level tried in both years. The uptake values corresponding to the n_1, n_2, n_3 and n_4 levels were 92.03, 119.01, 133.46 and 143.39 kg/ha in the first year and 81.96, 102.12, 110.54 and 115.63 kg/ha in the second year respectively.

The effect of method of application of nitrogen was also found significant in both the years. Foliar application recorded higher values when compared to soil application. The mean values for m_1 and m_2 were 119.27 and 124.68 kg/ha in the first year and 101.20 and 103.92 kg/ha in the second year respectively.

The different plant populations did not make any significant influence on the total uptake of potassium in both years. However, there was an increase upto the S_2 level.

4.26. Phosphorus content of grain

Data on mean values of phosphorus of grain are given in Tables 58 and 59.

It may be seen that the phosphorus content of grain was influenced by the level of nitrogen in both years. There was progressive and significant increase in the phosphorus content of grain due to incremental doses of nitrogen

Table 58. Phosphorus content of grain (per cent) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.317	0.322	0.322	0.320
n_2	0.342	0.348	0.358	0.349
n_3	0.365	0.367	0.380	0.371
n_4	0.388	0.382	0.393	0.388
Methods of N application				
m_1	0.347	0.350	0.354	0.350
m_2	0.359	0.359	0.373	0.364
Mean	0.353	0.355	0.363	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.319	0.321	0.320
n_2	0.336	0.363	0.349
n_3	0.367	0.374	0.371
n_4	0.380	0.396	0.388
Mean	0.350	0.364	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0052	0.0158
For methods of N application	0.0039	0.0117
For plant population	0.0049	NS

Table 59. Phosphorus content of grain (per cent) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.357	0.358	0.347	0.354
n_2	0.385	0.392	0.388	0.388
n_3	0.412	0.408	0.405	0.408
n_4	0.403	0.415	0.418	0.412
Methods of N application				
m_1	0.385	0.383	0.385	0.384
m_2	0.393	0.403	0.394	0.397
Mean	0.389	0.393	0.390	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.346	0.362	0.354
n_2	0.379	0.398	0.388
n_3	0.407	0.410	0.408
n_4	0.407	0.418	0.412
Mean	0.384	0.397	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0062	0.0187
For methods of N application	0.0044	0.0132
For plant population	0.0049	NS

upto n_4 level in the first year and upto n_3 level in the second year. In both years the highest values were recorded by n_4 level. Corresponding to the n_1, n_2, n_3 and n_4 levels, the phosphorus content of grain for the first and second years were 0.320, 0.349, 0.371 and 0.388 per cent, and 0.354, 0.388, 0.408 and 0.412 per cent respectively.

The method of nitrogen application also influenced the phosphorus content of grain. Foliar application of nitrogen was found to be superior to soil application. For the m_1 and m_2 treatments, the average values were 0.350 and 0.364 per cent respectively in the first year and 0.384 and 0.397 per cent respectively in the second year.

Plant population did not affect the phosphorus content of grain.

4.27. Potassium content in grain

Mean values are given in Tables 60 and 61.

Level of nitrogen significantly influenced the potassium content of grain. In the first year, there was a progressive increase in the potassium content upto n_3 level and in the second year upto n_4 level. However, n_3 and n_4 levels were on par during both years. The n_1 level was significantly inferior to n_2 in the first year, but was on par with n_2 in the second year. However, the lowest values

Table 60. Potassium content of grain (per cent) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.540	0.523	0.517	0.527
n_2	0.585	0.583	0.580	0.583
n_3	0.618	0.632	0.637	0.629
n_4	0.623	0.613	0.638	0.625
Methods of N application				
m_1	0.583	0.575	0.590	0.583
m_2	0.601	0.601	0.596	0.599
Mean	0.592	0.588	0.593	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.514	0.539	0.527
n_2	0.572	0.593	0.583
n_3	0.619	0.639	0.629
n_4	0.624	0.625	0.625
Mean	0.583	0.599	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0076	0.0230
For methods of N application	0.0054	0.0163
For plant population	0.0107	NS

Table 61. Potassium content (per cent) of grain (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.503	0.493	0.500	0.499
n_2	0.523	0.505	0.508	0.512
n_3	0.528	0.540	0.543	0.537
n_4	0.563	0.555	0.558	0.559
Methods of N application				
m_1	0.523	0.523	0.529	0.525
m_2	0.537	0.523	0.526	0.529
Mean	0.530	0.523	0.528	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.489	0.509	0.499
n_2	0.510	0.514	0.512
n_3	0.540	0.534	0.537
n_4	0. 561	0.557	0.559
Mean	0.525	0.529	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0077	0.0234
For methods of nitrogen application	0.0054	NS
For plant population	0.0066	NS

in both years (0.527 and 0.499 per cent) were recorded by n_1 level.

Method of application significantly influenced the potassium content of grain in the first year, but not in the second year though there was an increase due to foliar spray of nitrogen in both years. In the first year, the values were 0.583 and 0.599 per cent for m_1 and m_2 respectively while in the second year the values were 0.525 and 0.529 per cent.

Plant population did not influence the potassium content of grain in any of the years.

4.28. Phosphorus content of straw

The mean values are given in Tables 62 and 63.

The phosphorus content of straw was influenced by the level of nitrogen. There was an increase in the phosphorus content of straw due to incremental doses of nitrogen application. However each nitrogen level was on par with its immediate higher level in the first year. But in the second year n_2 was superior to n_1 but on par with n_3 which in turn was on par with n_4. In both years, highest values were noted in n_4 level.

Neither the method of application of nitrogen nor the plant population influenced the phosphorus content of straw.

Table 62. Phosphorus content of straw (per cent) (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.160	0.159	0.159	0.159
n_2	0.160	0.163	0.166	0.163
n_3	0.167	0.162	0.166	0.165
n_4	0.167	0.169	0.168	0.168
Methods of N application				
m_1	0.163	0.161	0.165	0.163
m_2	0.164	0.165	0.165	0.165
Mean	0.164	0.163	0.165	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.158	0.161	0.159
n_2	0.163	0.164	0.163
n_3	0.164	0.166	0.165
n_4	0.167	0.169	0.168
Mean	0.163	0.165	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0013	0.0040
For methods of N application	0.0009	NS
For plant population	0.0010	NS

Table 63. Phosphorus content of straw (per cent) (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	0.157	0.154	0.152	0.155
n_2	0.163	0.163	0.162	0.162
n_3	0.165	0.165	0.165	0.165
n_4	0.169	0.168	0.167	0.168
Methods of N application				
m_1	0.163	0.162	0.159	0.161
m_2	0.164	0.163	0.164	0.164
Mean	0.163	0.163	0.162	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	0.153	0.156	0.155
n_2	0.161	0.164	0.162
n_3	0.164	0.166	0.165
n_4	0.168	0.168	0.168
Mean	0.161	0.164	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0012	0.0036
For methods of N application	0.0008	NS
For plant population	0.0010	NS

4.29. Potassium content of straw

Mean data are presented in Tables 64 and 65.

The influence of nitrogen level on the potassium content of straw was significant. There was progressive increase upto n_4 level in both years. However, in the first year, n_2 and n_3 levels were on par. In both years, the highest values (1.629 and 1.641 per cent) were recorded by n_4 level whereas the lowest values (1.505 and 1.514 per cent) were in n_1.

Method of application of nitrogen influenced the potassium content in the second year only, though the highest values were recorded by the m_2 treatment in both years.

The effect of plant population on the potassium content of straw was not significant in both years.

4.30. Residual nutrient status of the soil

i. Available nitrogen in soil (kg/ha) after the experiments

The mean values of available nitrogen in soil after the experiment are presented in Table 66.

The available nitrogen content in the soil after the experiment was significantly increased by the incremental levels of nitrogen. However, the effect of n_1 was on par

Table 6.4. Potassium content (per cent) of straw (First year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	1.480	1.525	1.510	1.505
n_2	1.552	1.567	1.560	1.559
n_3	1.600	1.592	1.567	1.586
n_4	1.627	1.625	1.637	1.629
Methods of N application				
m_1	1.543	1.563	1.569	1.559
m_2	1.586	1.591	1.568	1.581
Mean	1.565	1.577	1.568	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	1.474	1.536	1.505
n_2	1.548	1.571	1.559
n_3	1.591	1.581	1.586
n_4	1.621	1.638	1.629
Mean	1.559	1.581	

	SEm ±	CD (0.05)
For levels of nitrogen	0.0114	0.0346
For methods of N application	0.0081	NS
For plant population	0.0091	NS

Table 65. Potassium content (per cent) of straw (Second year)

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	1.512	1.532	1.498	1.514
n_2	1.587	1.580	1.590	1.586
n_3	1.625	1.632	1.598	1.618
n_4	1.635	1.635	1.653	1.641
Methods of N application				
m_1	1.575	1.581	1.563	1.573
m_2	1.604	1.608	1.607	1.606
Mean	1.590	1.595	1.585	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	1.501	1.527	1.514
n_2	1.564	1.607	1.586
n_3	1.600	1.637	1.618
n_4	1.627	1.656	1.641
Mean	1.573	1.606	

	SEm $\pm$	CD (0.05)
For levels of nitrogen	0.0065	0.0196
For methods of N application	0.0046	0.0139
For plant population	0.0085	NS

Table 66. Available soil nitrogen (kg/ha) after the experiment

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	39.85	40.12	39.85	39.94
n_2	39.65	39.80	39.78	39.74
n_3	40.47	40.37	40.20	40.34
n_4	40.32	40.62	40.32	40.42
Methods of N application				
m_1	40.12	40.30	40.09	40.19
m_2	39.95	40.15	39.98	40.03
Mean	40.07	40.22	40.04	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	40.26	39.62	39.94
n_2	39.70	39.79	39.74
n_3	40.22	40.47	40.34
n_4	40.60	40.23	40.42
Mean	40.19	40.03	

	SEm ±	CD (0.05)
For levels of nitrogen	0.149	0.452
For methods of N application	0.105	NS
For plant population	0.184	NS

Table 67. Available phosphorus in soil kg/ha after the experiment

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	43.73	43.58	44.18	44.83
n_2	43.75	44.00	43.48	43.74
n_3	43.28	43.22	43.53	43.47
n_4	43.38	43.48	43.53	43.47
Methods of N application				
m_1	43.52	43.51	43.88	43.64
m_2	43.56	43.63	43.60	43.60
Mean	43.54	43.57	43.74	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	43.90	43.77	43.83
n_2	43.90	43.59	43.74
n_3	43.31	43.53	43.42
n_4	43.43	43.50	43.47
Mean	43.64	43.60	

	SEm ±	CD (0.05)
For levels of nitrogen	0.217	NS
For methods of N application	0.153	NS
For plant population	0.173	NS

Table 68. Available potassium in soil (kg/ha) after the experiment

Levels of nitrogen	Plant population			
	S_1	S_2	S_3	Mean
n_1	166.95	167.52	165.45	166.97
n_2	167.50	167.75	166.55	167.27
n_3	167.60	166.90	168.42	167.64
n_4	166.02	167.52	166.40	166.64
Methods of N application				
m_1	166.26	167.69	166.21	166.72
m_2	167.78	167.15	167.70	167.54
Mean	167.02	167.42	166.95	

Levels of nitrogen	Methods of N application		
	m_1	m_2	Mean
n_1	167.31	166.63	166.97
n_2	167.03	167.50	167.27
n_3	166.50	160.78	167.64
n_4	166.03	167.26	166.64
Mean	166.72	167.54	

	SEm ±	CD (0.05)
For levels of nitrogen	0.791	NS
For methods of N application	0.559	NS
For plant population	0.953	NS

with that of n_2 and these two levels were significantly inferior to n_4 level. It was found that n_3 and n_4 were also on par. The average values of available nitrogen for n_1, n_2, n_3 and n_4 levels were 39.94, 39.74, 40.34 and 40.42 kg/ha respectively.

The different methods of application of nitrogen and the different plant populations did not influence the available nitrogen content of the soil after the experiment.

ii. Available phosphorus and potassium in soil after the experiment

Data on mean values of available phosphorus and potassium in the soil after the experiment are shown in Tables 67 and 68.

There was no significant difference in the available phosphorus and available potassium in the soil after the experiment due to the level of nitrogen, method of application or plant population. The variation in the contents of these nutrients was negligible.

4.31. Response curves, physical optimum and economic optimum doses

The second degree polynomial, $Y = a + bx + cx^2$, where 'Y' is the grain yield in kg/ha corresponding to 'x' kg/ha of nitrogen, was found to be a suitable fit for studying

Table 69. Nitrogen response models under different methods of nitrogen application and plant population

Treatment		Response model	R^2(%)
First year	m_1	$Y = 1700.44 + 44.54\ x - 0.1734\ x^2$	99.89
	m_2	$Y = 2029.73 + 40.46\ x - 0.1536\ x^2$	99.72
	S_1	$Y = 1857.88 + 47.76\ x - 0.2095\ x^2$	99.81
	S_2	$Y = 2087.89 + 34.70\ x - 0.1091\ x^2$	99.95
	S_3	$Y = 1648.28 + 45.06\ x - 0.1720\ x^2$	99.83
	Mean	$Y = 1864.67 + 42.51\ x - 0.1635\ x^2$	99.98
Second year	m_1	$Y = 2330.43 + 18.60\ x - 0.0708\ x^2$	99.68
	m_2	$Y = 2377.06 + 19.13\ x - 0.0697\ x^2$	99.79
	S_1	$Y = 2335.25 + 19.03\ x - 0.0728\ x^2$	99.66
	S_2	$Y = 2350.39 + 20.82\ x - 0.0821\ x^2$	99.83
	S_3	$Y = 2375.64 + 16.73\ x - 0.0558\ x^2$	99.71
	Mean	$Y = 2353.74 + 18.86\ x - 0.0703\ x^2$	99.73
Pooled	m_1	$Y = 2015.13 + 31.57\ x - 0.1221\ x^2$	99.81
	m_2	$Y = 2203.64 + 29.78\ x - 0.1116\ x^2$	99.81
	S_1	$Y = 2097.00 + 33.38\ x - 0.1411\ x^2$	99.70
	S_2	$Y = 2219.02 + 27.76\ x - 0.0956\ x^2$	99.86
	S_3	$Y = 2012.64 + 30.88\ x - 0.1138\ x^2$	99.84
	Mean	$Y = 2109.27 + 30.68\ x - 0.1169\ x^2$	99.94

Table 70. Physical and economic optimum levels of nitrogen under various treatments

Treatment		Physical optimum N kg/ha	Economic optimum N kg/ha
First year	m_1	128.44	121.02
	m_2	131.69	123.31
	S_1	114.00	114.00
	S_2	159.00	147.20
	S_3	131.00	123.52
	Mean	129.97	122.10
Second year	m_1	131.39	113.02
	m_2	137.12	118.66
	S_1	130.70	113.02
	S_2	126.72	111.05
	S_3	149.90	126.83
	Mean	134.23	115.91
Pooled	m_1	129.29	118.38
	m_2	133.39	121.86
	S_1	118.30	109.18
	S_2	145.15	131.69
	S_3	135.66	124.35
	Mean	131.26	120.25

the relationship between grain yield and levels of nitrogen under different methods of application and plant population. The response equations fitted are shown in Table 69 along with the respective coefficient of determinations (R^2).

The physical optimum and the economic optimum doses under different situations were worked out and shown in Table 70.

On the basis of the fitted response curves, the expected yields under different levels of nitrogen with different methods of application and plant population are computed and presented in Table 71.

The economics of rice production under various treatments is presented in Table 72.

Table 71. Expected yields of grain under different treatments (kg/ha)

		n_1	n_2	n_3	n_4	Mean
First year	m_1	3205	4154	4549	4388	4074
	m_2	3402	4283	4673	4571	4232
	s_1	3433	4338	4572	4137	4120
	s_2	3301	4166	4681	4847	4249
	s_3	3177	4153	4579	4456	4091
	Mean	3304	4219	4611	4480	4153
Second year	m_1	2961	3365	3543	3494	3341
	m_2	3030	3461	3668	3652	3453
	s_1	2980	3392	3571	3516	3365
	s_2	3052	3490	3666	3578	3446
	s_3	2956	3357	3580	3624	3379
	Mean	2996	3413	3605	3573	3397
Pooled	m_1	3083	3760	4046	3941	3708
	m_2	3216	3872	4170	4111	3842
	s_1	3207	3865	4071	3826	3742
	s_2	3176	3828	4173	4213	3848
	s_3	3066	3755	4080	4040	3735
	Mean	3150	3816	4108	4026	3775

Table 72. Economics of rice production under different levels of nitrogen, methods of N application and different plant population

Treatment	General cost of cultivation excluding treatments Rs.	Cost of treatments Rs.	Total expenditure Rs.	Gross income (cost of grain + straw) Rs.	Net income Rs.	B/C ratio
n_1	5937.00	206.00	6143.00	8671.00	2528.00	1.41
n_2	5937.00	412.00	6349.00	10491.00	4142.00	1.65
n_3	5937.00	618.00	6555.00	11273.00	4718.00	1.72
n_4	5937.00	824.00	6761.00	11282.00	4521.00	1.67
m_1	6401.00	-	6401.00	10279.50	3878.50	1.61
m_2	6401.00	200.00	6601.00	10581.00	3980.00	1.60
S_1	6161.00	862.00	7023.00	10346.00	3323.00	1.47
S_2	6161.00	694.00	6855.00	10588.00	3733.00	1.54
S_3	6161.00	562.00	6723.00	10355.00	3632.00	1.54

Note: Cost of Nitrogen = Rs.5.15/kg Cost of P_2O_5 = Rs.3.43/kg Cost of K_2O = Rs.2.22/kg
Cost of paddy = Rs.2.00/kg Cost of straw= Re.0.50/kg Cost of paddy seeds = Rs.3.00/kg
Additional labour for spraying (average) Rs.80/ha
Cost of labour: Men = Rs.20/day, Women = Rs.18/day

Table 73. Values of simple correlation coefficients

Sl. No.	Characters correlated	Correlation coefficient
1.	Grain yield with DMP at flowering	0.6294**
2.	" DMP at harvest	0.3810**
3.	" LAI at flowering	0.3300**
4.	" number of panicles/unit area	0.8832**
5.	" panicle length	0.7091**
6.	" number of spikelets/ panicle	0.7939**
7.	" number of filled grain	0.7725**
8.	" N uptake at flowering	0.6660**
9.	" N uptake at harvest	0.4982**
10.	" K_2O uptake at harvest	0.8603**
11.	" Straw yield	0.6495**
12.	LAI at flowering with DMP at flowering	0.4526**
13.	" DMP at harvest	0.2995*
14.	" number of panicles/ unit area	0.3520**
15.	" N uptake at flowering	0.4885**
16.	" N uptake at harvest	0.4194**
17.	" P_2O_5 uptake at harvest	0.2773*
18.	" K_2O uptake at harvest	0.4879**
19.	" straw yield	0.5080**

Sl. No.	Characters correlated	Correlation coefficient
20.	DMP at flowering with number of panicles/unit area	0.5468**
21.	" panicle length	0.3239**
22.	" number of spikelets/ panicle	0.4677**
23.	" number of filled grains	0.4306**
24.	" N uptake at flowering	0.6801**
25.	" N uptake at harvest	0.7532**
26.	" P_2O_5 uptake at harvest	0.5251**
27.	" K_2O uptake at harvest	0.7190**
28.	" straw yield	0.7251**
29.	Panicle length with N uptake at flowering	0.3284**
30.	" N uptake at harvest	0.2732**
31.	" K_2O uptake at harvest	0.5275**
32.	" number of spikelets/ panicle	0.8081**
33.	" number of filled grains/ panicle	0.8206**
34.	Number of filled grains per panicle with N uptake at flowering	0.4565**
35.	" N uptake at harvest	0.3644**
36.	" K_2O uptake at harvest	0.6376**
37.	Straw yield with N uptake at flowering	0.8832**
38.	" N uptake at harvest	0.6545**
39.	" P_2O_5 uptake at harvest	0.7570**
40.	" K_2O uptake at harvest	0.8909**
41.	DMP at harvest with N uptake at harvest	0.7026**

* Significant at 0.05 level

** " 0.01 "

DISCUSSION

5. DISCUSSION

The present study is an attempt to ascertain the influence of different levels of nitrogen, soil vs foliar application of the second top dose of nitrogen and different plant populations on the performance of the high yielding rice variety Sabari in a sandy loam soil of South Kerala. The results obtained in the investigation are discussed under the following titles.

1. Growth characters
2. Yield components
3. Yield of grain
4. Yield of straw
5. Grain : straw ratio
6. Quality of grain and straw
7. Uptake of nutrients
8. Residual fertility status
9. Economics of rice production

5.1. Growth characters

a. Height of plant (Tables 4a to 4e and 5a to 5e)

The height of plant was increased due to increased nitrogen application. The differences were very conspicuous during the first year and the same trend was seen in the second year also. At all the stages of growth, there was progressive increase in plant height corresponding to the increased levels of nitrogen (Fig. 3). The influence of nitrogen in increasing the vegetative growth of plants is well known. Nitrogen is a constituent of plant protein and several other physiologically indispensable compounds. Availability of adequate quantities of N facilitates rapid formation of protoplasm, cell multiplication and its enlargement resulting in quick growth leading to increased plant height. The high yielding rice plant has the capacity to absorb higher amount of nitrogen which can be utilised for rapid growth. In the present investigation, phosphorus and potash were not limiting and under such a condition the rice plants absorbed more nitrogen and utilised for rapid growth in proportion to its supply and caused significant increases in plant height at higher rates. The results obtained in the present investigation confirm the findings of Mani (1979), Iruthayaraj and Morachan (1980), Singh and Singh (1986), Singh and Sharma (1987) and Thangamuthu et al. (1987).

The effect of method of application was not significantly different in both years.

The data also show that the different plant populations significantly influenced the plant height during both years. Increase in height is related to the receipt of

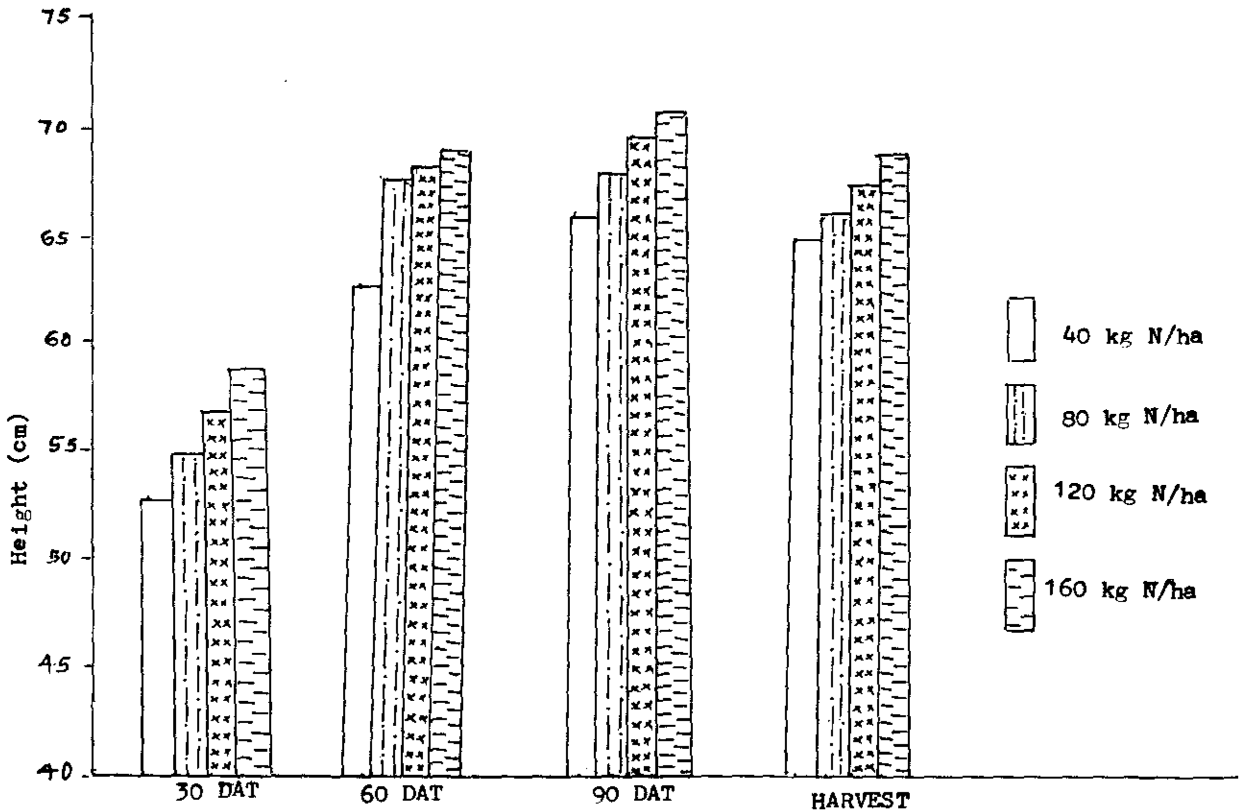

Fig. 3. Height of plant at different stages of growth (first year)

radiant energy. Wider spacing facilitated more sunlight to enter into the plant canopy reaching even to the basal portions of the clump. Planting at wider intervals reduces mutual shading, avoids over crowding and consequent inter-hill competition. The per plant availability of nutrients in wider spacing is more. Other requirements for growth and development of plant being not limiting, more sunlight results in more photosynthesis which in turn accelerates growth resulting from a greater contribution of photosynthates. The influence of spacing on increasing plant height has been stressed by Fagundo et al. (1978), Ibrahim et al. (1980) and Sobhana (1983).

b. Number of tillers (Tables 6a to 6e and 7a to 7e)

The effect on number of tillers per hill was significant in the first year upto 160 kg N/ha (Fig. 4) and in the second year also there was progressive increase upto 120 kg N/ha. This is in conformity with the findings of Ramaswamy (1982). In rice, each node of a culm has a tiller primordium and the development of the primordium into a tiller depends on factors such as the nutritional status of the plant. Tillering is highly impaired by N and hence the nutrient status of the plant should be related to tillering (Yoshida, 1981). Balasubramanian (1980) pointed out that tillering is associated with the nutritional condition

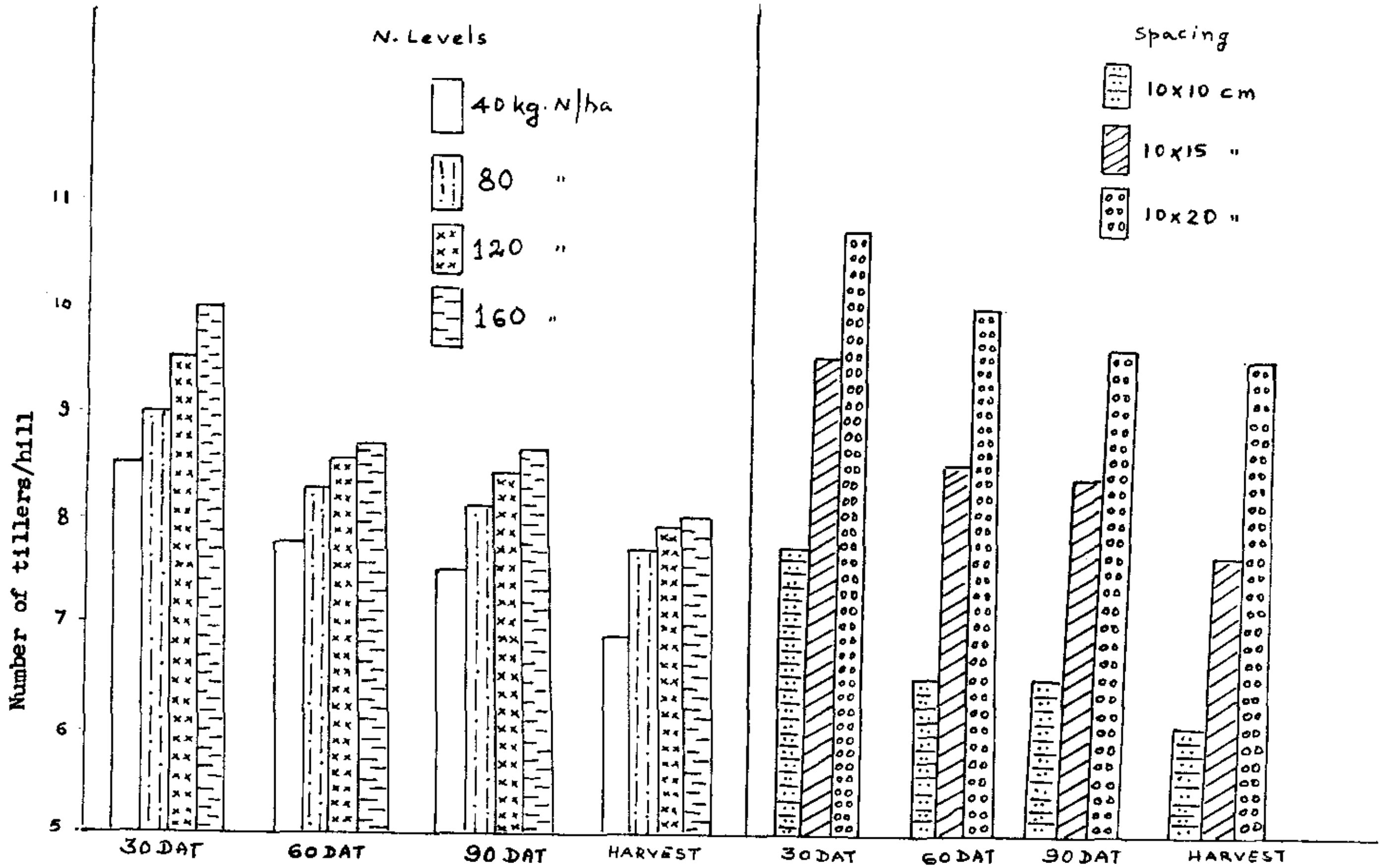

Fig. 4. Effect of nitrogen and spacing on tillers/hill (First year)

of the mother culm which supplies carbohydrates and other nutrients to the developing tillers in the early stages. In the present study plants absorbed N in accordance with the availability and produced significant differences in tiller production.

The influence of spacing on the number of tillers per hill was very conspicuous in both years. As the spacing is widened, the number of tillers per hill is increased. In general, under poor fertility conditions, spacing between hills should be somewhat narrower so as to obtain enough production of tillers per unit area regardless of plant type. On the other hand, under high fertility level, plant type characteristics become more important in deciding the optimum spacing. Yoshida (1981) stated that spacing and light are the essential factors for tillering in rice. In wider spacing, formation of more tillers per hill is encouraged probably because of the lesser competition between hills for the various growth requirements. The results obtained in the present investigation are in agreement with the findings of Baccam et al. (1975), Ibrahim et al. (1980) and Sobhana (1983).

The interaction effects were found to be not significant. However, it was found that the lowest level of nitrogen with closer planting recorded the lower values.

It was seen that nitrogen levels as well as wider spacing encouraged tiller production. Hence the higher values noticed in the treatment combination of higher nitrogen dose and wider spacing are due to the additive effects of these treatments.

It was also seen that the total number of tillers per unit area (Tables 8a to 8e and 9a to 9e) was significantly influenced by spacing. It was observed that the 10 x 10 cm spacing recorded the maximum number of tillers per unit area whereas the 10 x 20 cm spacing the lowest number. Though the tiller production per hill was high in wider spacing due to favourable environmental conditions, this increase could not compensate for the large number of hills per unit area in the narrow spacing. In an area of 1.2 m^2, the number of hills under 10 x 10 cm spacing was 120, in 10 x 15 cm it was 80 and in 10 x 20 cm it was only 60. This difference in the number of hills per unit area could not be compensated for by the increase in the tillering capacity of the plants under wider spacing. The results of the present investigation are in agreement with the findings of Shieh Yuh-Jang (1977), Ibrahim *et al*. (1980) and Sobhana (1983).

e. Leaf area index (Tables 10 and 11)

Significant differences were noticed in the LAI of plants at flowering due to levels of nitrogen during both years. The highest value of LAI was obtained under 160 kg N/ha and the lowest in 40 kg N/ha. However, the effects of 80 kg N/ha and 120 kg N/ha were on par but significantly inferior to 160 kg N/ha. Yoshida (1981) has reported a similar increase in LAI due to increase in N application. LAI, being a function of the number of tillers and size of leaves, an increase in any one or both of these produces a corresponding increase in LAI. As the level of N increases there is appreciable increase in the number of tillers and plant height. Plant height at the vegetative stage is a resultant of increased size of leaves. Hence it is logical that the treatments which are responsible for increase in plant height and tillering produce the highest LAI. LAI is an indicator of the total photosynthetic area available to a plant for the production of photosynthates, part of which accumulates in the grain. LAI values imply the magnitude of leaf area relative to ground area. High yielding rice plants need an additional supply of nitrogen to maintain a high level of photosynthetic activity for assimilating a larger amount of carbohydrate and to supply more nitrogen compounds to grain during the filling period. Increases in LAI due to increase in N levels have been reported by Aleshin (1977), Balasubramanian (1980), Yoshida (1981), Ramaswamy (1982), Sadayappan (1982) and Abdul Salam (1984).

The influence of different plant populations on the LAI was also significant. The spacing of 10 x 10 cm recorded the highest LAI value which was significantly superior to 10 x 15 cm which in turn was superior to 10 x 20 cm spacing. It was seen that the tiller number per unit area was maximum in narrow spacing and this increase in the number of tillers might have contributed to the higher LAI. The results of the present investigation are in conformity with the findings of Panda and Mahapatra (1977), Pothiraj et al. (1977), Shieh Yuh-Jang (1977), Wells and Faw (1978), Ghosh et al. (1979), Murty and Murty (1980) and Sobhana (1983).

The interaction effect between nitrogen and plant population was also significant. The combination of 160 kg N/ha and 10 x 10 cm spacing resulted in maximum LAI in both the years. This is due to the additive effects of N and plant population in increasing the LAI. The combined effect of these treatments gave significantly higher value over all other treatment combinations.

In agronomic practice, spacing and nitrogen application are the two major factors influencing leaf area under most conditions. Spacing determines the number of hills per unit ground area and both nitrogen application and spacing affect average leaf size and number of leaves per shoot. In addition, tillering capacity of plant is modified by the influence of spacing and nitrogen application.

d. Days to 50 per cent flowering (Tables 14 and 15)

The number of days taken for 50 per cent flowering was significantly influenced by the levels of nitrogen during both the years. The minimum number of days was noticed in plants receiving 40 kg N/ha and the highest in 160 kg N/ha. The delay in flowering is attributed to the luxuriant vegetative growth of the plants under a heavy supply of the nutrient. Similar results of longer period for flowering in rice due to higher levels of nitrogen application have been reported earlier by Bhaskaran (1970), Kuriakose and George (1974) and Prasad (1981) and the results obtained in the present investigation confirm the above findings.

Though plant population did not influence the flowering duration significantly, an increasing trend in the flowering duration due to wider spacing was noticed in both years. At the wider spacing, with less competition for nutrients and sunlight, luxuriant vegetative growth continued, resulting in delayed flowering. However, the effect was not so conspicuous as that of nitrogen. Mishra (1976) and Rao and Raju (1987) obtained similar results of earlier flowering under closer spacing.

Though the effect of method of application was not significant, the interaction effect nitrogen x method of application was significant in the first year and a similar trend was noticed in the second year as well. The treatment combination of 40 kg N/ha with foliar application of the second top dose resulted in the minimum number of days for flowering whereas the combination of 160 kg N/ha with foliar application of the second top dose recorded the highest duration. Here also it is seen that the influence of higher levels of N in delaying flowering is dominating.

e. Dry matter production (Tables 12, 13, 14 and 15)

There was progressive increase in dry matter production at flowering and at harvest due to increasing levels of nitrogen. The dry matter production at flowering ranged between 47.9 q/ha at 40 kg N/ha and 59.9 q/ha at 160 kg N/ha during the first year and 43.7 and 57.2 q/ha during the second year respectively. At harvest the total dry matter productions corresponding to 40, 80, 120 and 160 kg N/ha were 83.9, 103.0, 112.2 and 115.7 q/ha respectively for the first year. During the second year, the corresponding values were 74.3, 87.6, 92.3 and 93.9 respectively. The dry matter accumulation increased with increasing nitrogen levels and the maximum was recorded at 160 kg N/ha in all the cases. The progressive increase noted at the higher levels of N

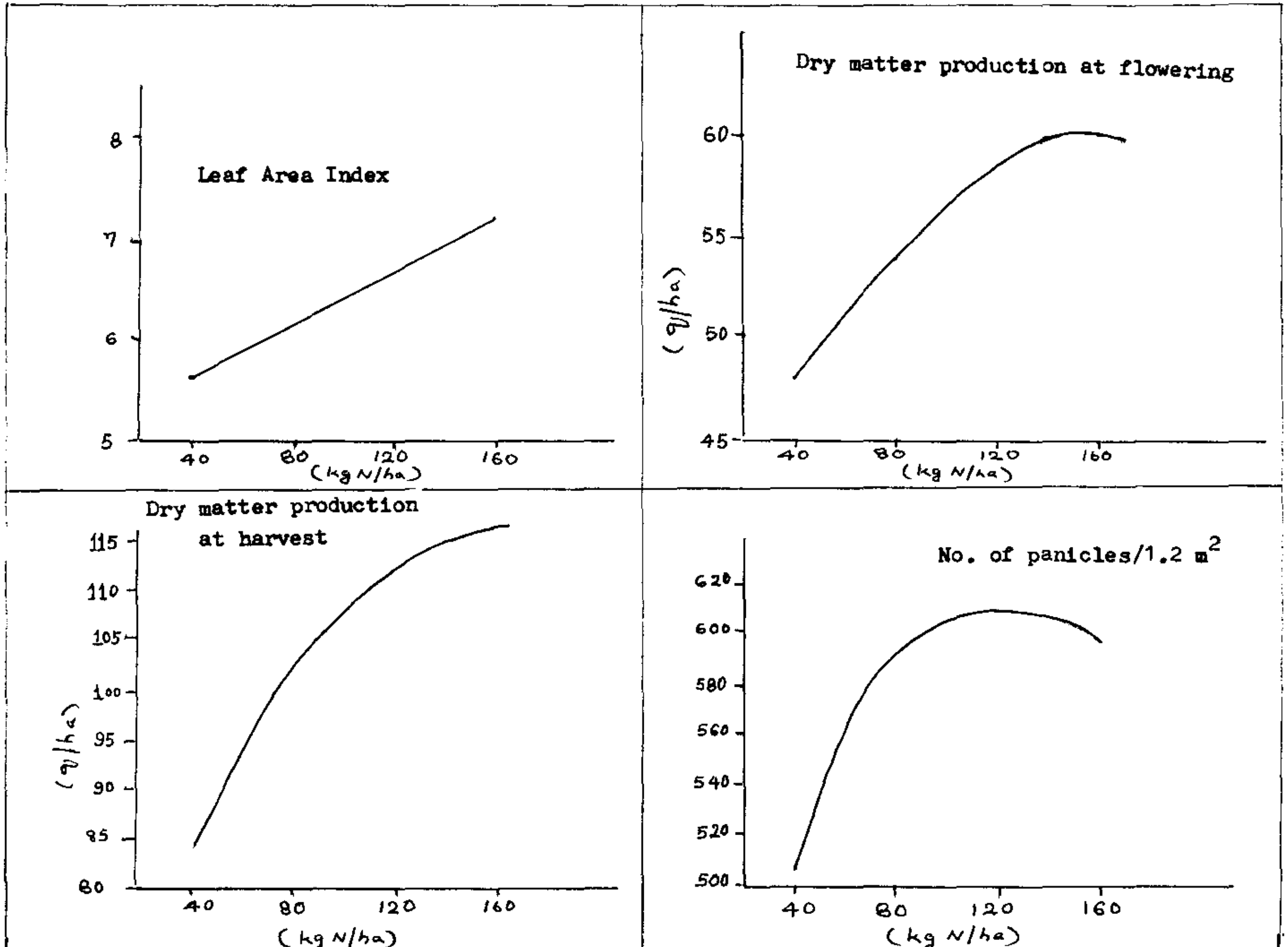

Fig. 5. LAI, DMP at flowering, DMP at harvest and number of panicles per unit area due to N levels during the first year

might be due to the better utilisation of fertilizer nitrogen under the favourable environmental condition which prevailed during the growth period. It is an established fact that nitrogenous compounds contribute significantly to the total dry matter production of the plant. According to Black (1968) about 10 per cent of the total plant weight is constituted by nitrogen compounds. Thus it is obvious that a higher supply of nitrogen tends to increase the plant weight. Further, increasing quantities of nitrogen produce taller plants with more tillers and leaves causing an increase in the overall vegetative growth. The combined result of all these together increased the total dry matter production with the increasing levels of nitrogen. At harvest, the average increases in dry matter production between the levels 40 and 80, 80 and 120, and 120 and 160 kg N/ha were 47.7, 23.0 and 8.6 kg per kg of applied nitrogen respectively in the first year. The corresponding values for the second year were 33.3, 11.9 and 3.8 kg per kg of applied nitrogen. The average per day production of dry matter at harvest under the 40, 80, 120 and 160 kg N/ha levels were 64.5, 79.2, 86.3 and 89.0 kg per kg of N in the first year and during the second year the corresponding values were 57.1, 67.4, 71.0 and 72.2 kg/kg N respectively. Similar increases in dry matter production due to incremental levels of nitrogen have been reported by Singh and

Modgal (1978a), Balasubramanian (1980), Iruthayaraj and Morachan (1980), De Datta (1981), Sadayappan (1982), Ramaswamy (1982), Ghosh et al. (1987) and Thakur and Singh (1987). Chinnaswami and Chandrasekharan (1977) found that the dry matter production progressively increased with nitrogen application upto 160 kg/ha and suggested that plants suitable for heavy manuring could maintain high efficiency of dry matter production through high photosynthetic efficiency with added nitrogen. The results of the present investigation are in conformity with the above findings. Further, it is also seen from Table 73 that the LAI and dry matter production are positively and significantly correlated with each other (r = 0.2995). Increased levels of nitrogen increased LAI. Under the higher levels of nitrogen plant organs developed fully in early stages which promoted proper plant functions in later stages resulting in increased dry matter production at harvest (Bhaskaran, 1970). Yoshida (1972) stated that the total dry matter production is the integral of crop growth rate, over the entire growth period. Increasing LAI increases dry matter production generally and the gross photosynthesis of a canopy increases curvilinearly with increasing LAI. The effect due to method of nitrogen application on dry matter production was not significant at flowering though a positive trend was noticed towards increase due to foliar application of the second top dose of nitrogen. But at harvest the dry matter production was significantly influenced by the method of application of nitrogen. Foliar application gave significantly higher dry matter production at harvest. The nitrogen applied through foliage was readily available and metabolised for tissue development and grain formation. The favourable effect of foliar application on increasing dry matter production at harvest noticed in the present investigation is in agreement with the findings of Dhua and Ray (1968) and Bhaskaran (1970). This observation further confirms the better efficiency and utilization of nitrogen in the case of foliar application.

The results also showed that the effect of spacing on dry matter production at flowering was not significant. The increased dry matter production of individual clumps under wider spacing would have been compensated by the increased number of hills in the closer spacing which ultimately resulted in a non-significant influence. However, at the harvest stage, there was significant increase in dry matter production upto the 10 x 15 cm spacing in the first year and a similar trend was noticed during the second year also. In both the years maximum dry matter production was at the 10 x 15 cm spacing. Increased plant height and tiller production in this treatment would have resulted in increased dry matter production at harvest stage. The spacing of 10 x 15 cm was found to be the optimum for dry matter production.

The interaction between nitrogen and plant population in dry matter production was significant in the first year and a similar trend was noted in the second year also. The highest dry matter production of 119.8 q/ha at harvest was recorded by 160 kg N/ha with 10 x 15 cm spacing and the lowest (81.3 q/ha) by 40 kg N/ha with 10 x 20 cm spacing. Dry matter productions were high in 160 kg N/ha and in 10 x 15 cm spacing when considered separately. The complimentary and cumulative effects of these treatments might have resulted to record the maximum dry matter production in the above treatment combination. In general, better availability of sunshine and nutrient enhanced the growth of plants resulting in increased dry matter production at harvest. In terms of total dry matter production by a crop, LAI, leaf photosynthetic rate and leaf angle appear to be the major determinants of crop growth. Of these LAI is the most variable and it can be widely changed by manipulating plant density and application of fertilizers (Yoshida, 1972).

5.2. Yield components

a. Number of panicle per unit area (Tables 18 and 19)

Ear number per unit area is one of the major factors deciding yield. Levels of nitrogen significantly influenced the number of panicles per unit area. The effect of 120 kg N/ha was on par with that of 160 kg N/ha and the highest number of panicles per unit area was obtained in 120 kg N/ha during both years. Nitrogen nutrition had a profound influence in increasing the number of panicles per unit area. Nitrogen increased the number of tillers and the ear-bearing capacity of the late tillers (Chatterjee and Maiti, 1981). Tillers possessing more than 3 leaves at the time of initiation of the flag leaves become panicle bearing tillers, while those possessing one leaf or less become non-bearing. The role of nitrogen in increasing leaf number is well known. This has contributed to more number of tillers to produce panicles resulting in more number of panicles per unit area. The results obtained in the present investigation are in conformity with the findings of Ishizuka and Tanaka (1960), Gupta et al. (1970), Eunus and Sadeque (1974), Subbiah and Morachan (1974), Mani (1979), Pillai et al. (1984), Balasubramanian and Dawood (1987) and Dalai and Dixit (1987).

It was also seen that application of the second top dose of nitrogen through foliage increased the number of panicles per unit area. The availability of nitrogen from foliar application is faster when compared to its application through soil. The nitrogen so absorbed might have been effectively utilised for increased panicle production in the plant. Ramiah and Morachan (1976) noticed an increase in the number of effective tillers in plots which received aerial application of urea at the panicle initiation stage.

The number of panicles per unit area is also significantly influenced by spacing. In both years, the lowest spacing of 10 x 10 cm recorded the highest number of panicles per unit area followed by 10 x 15 cm spacing. Chatterjee and Maiti (1981) remarked that in wider spacing formation of more tillers per plant is encouraged, but with narrower spacing formation of more ear bearing tillers per unit area is encouraged. The results of the present investigation are in agreement with the findings of the above workers.

Early tillers produce most of the panicles. Panicles of early tillers are heavier than those derived from late tillers. Close planting thus favours to produce more ear-bearing tillers.

b. Length of panicle (Tables 20 and 21)

There was progressive increase in the length of panicle due to increasing levels of nitrogen upto 120 kg N/ha beyond which a declining trend was noticed. The pattern was similar for both years. Chang and Su (1977) reported that length of panicle increased with increasing rates of nitrogen. Length of panicle is an attribute much dependent on the genetic character of the plant, but it can also be manipulated by providing nutritional status and other environmental conditions. The total length of the panicle is contributed mainly by the length of the basal internodes. The elongation of these internodes was found to be regulated by nitrogen supply. By providing good nutritional conditions, the length of these internodes can be enhanced. The improvement in nutrient status of plant during panicle primordia initiation to spikelet differentiation stage was reported to induce growth of panicle. In the present investigation nitrogen supplied to the plants at this stage might have been utilised for increasing the panicle length. Increase in panicle length was noticed due to incremental rates of nitrogen only upto 150 kg/ha while at 200 kg N/ha a reducing trend was noticed (AICRIP, 1968). The results obtained in the present investigation agree with the findings of Subbiah et al. (1977), Mani (1979) and Raju (1979).

Method of application did not bring about any significant difference in panicle length.

The influence of spacing on panicle length was significant in both years. The widest spacing produced the longest panicle. The plants in the wider spacing enjoyed more favourable environments with regard to nutrition and sunlight with less competition. All these are responsible for increasing the length of panicle in wider spacing.

Interaction effects between nitrogen and spacing was also found to be significant. Plants spaced at 10 x 15 cm and which received 120 kg N/ha produced the longest panicles whereas those which received only 40 kg N/ha and which were planted at closer spacing of 10 x 10 cm resulted in the smallest panicles. This is in conformity with the findings of Subbiah et al. (1975), Chang and Su (1977) and Sobhana (1983).

c. Weight of panicle (Tables 22 and 23)

There was progressive increase in weight of panicle due to increase in nitrogen application upto 160 kg/ha during both years. Application of higher doses of nitrogen encouraged formation of early tillers. It is an established fact that early tillers produce heavier panicles. Increase in panicle weight due to increasing doses of nitrogen has been reported by Padmaja (1976). Chang and Su (1977), Balachandran Nair (1979), Singh and Singh (1986) and Ghosh et al. (1987).

There was also significant increase in weight of panicle due to method of application of nitrogen. Giving the second top dose of nitrogen through foliage at the panicle initiation stage was found to be superior to the supply of the same quantity of nitrogen through soil during the same period. The beneficial effect of foliar application of nitrogen on filling of the spikelets and increasing maturity percentage has been reported by Bhaskaran (1970) and these characters finally increase the final weight of panicle.

Panicle weight was significantly increased by increasing spacing. The maximum weight was in 10 x 20 cm spacing while the lowest weight was recorded in 10 x 10 cm spacing. Under wider spacing, there was less competition for nutrients and space, and the environmental conditions were more favourable for the plants to absorb and utilise more nutrients for grain filling which might have been reflected in the weight of panicle also. Increase in the weight of panicle due to increased spacing was earlier reported by Chang and Su (1977) and Sobhana (1983). The results obtained in the present investigation are in conformity with the findings of the above workers.

It was also seen that the nitrogen x spacing interaction was significant. The highest panicle weight was recorded by the treatment combination of 160 kg N/ha and 10 x 20 cm spacing and the lowest by 40 kg N/ha with

10 x 10 cm spacing. The fertilizer levels and the spacing producing the heaviest panicles individually proved to be the best combination for increasing panicle weight owing to their cumulative effects.

d. Number of spikelets per panicle (Tables 24 and 25)

The different levels of nitrogen significantly influenced the number of spikelets per panicle in both years. The average number of spikelets per panicle at the 40, 80, 120 and 160 kg N/ha levels were 86.8, 93.9, 97.7 and 101.8 respectively during the first year and 85.9, 93.3, 96.8 and 99.7 during the second year, showing that the number of spikelets per panicle increased with increasing nitrogen supply. The rice plant produces spikelets in accordance with the amount of nitrogen absorbed (Murayama, 1967). Among the nutrients, nitrogen has a major effect in increasing the number of spikelets per panicle. Ghose et al. (1960) suggested that increased absorption of nitrogen especially at the panicle initiation stage favoured increased production of spikelets per panicle. High nitrogen content during the middle of the growing period ensures the number of spikelets required to achieve good yield (Murayama, 1967). Close relationship exists between the number of spikelets per unit area and the amount of nitrogen absorbed by the plant upto heading. More nitrogen must be absorbed until the heading stage to increase the number of spikelets. Yoshida (1981) reported that the nitrogen absorbed at panicle initiation stage is efficiently utilized to increase spikelet number. Increase in spikelet number per panicle due to increasing levels of nitrogen has been reported by Matsushima (1966), Panda and Leeuwrik (1972), Dixit and Singh (1979) and by Dalai and Dixit (1987).

The influence of spacing was found to be significant in the case of number of spikelets per panicle. In other words, spikelet number per panicle is affected by spacing. In the present investigation, the trend observed was that wider spacing increased the spikelet number per panicle. At an optimum combination of nitrogen level and solar radiation, the spikelet number per unit area is strongly influenced by spacing (Yoshida, 1981). The result obtained in the present study is in agreement with the findings of Varma (1972) and Srinivasulu Reddy (1986).

In rice production, the number of spikelets per unit area could be considered as a valuable indicator of whether the limiting factor is source or sink. When spikelet numbers are low, their increase will directly increase the yield. When spikelet numbers are high, however, the photosynthetic rate of the stands should receive attention because the amount of assimilates is considered as the determinant of yield. The role of nitrogen is extremely great in either case.

e. Number of filled grains per panicle and per unit area (Tables 26, 27, 30 and 31)

The effect of nitrogen levels was significant with respect to the number of filled grains/panicle. During both years, the highest number of grains per panicle was obtained in 160 kg N/ha which was on par with 120 kg N/ha. The lowest value was recorded by 40 kg N/ha. In the case of number of grains per unit area also there was progressive increase due to increasing levels of nitrogen. The maximum number of grains was recorded by 120 kg N/ha during the first year and by 160 kg N/ha during the second year and these two levels were on par. As the level of nitrogen increased there was corresponding increase in the length of panicle and number of spikelets. When the levels increased there was more uptake (Tables 50, 51, 52 and 53) of nitrogen and other nutrients upto the grain filling stage and the increased amounts of nutrients so absorbed might have been utilised for carbohydrate metabolism. The increased photosynthates produced would have been stored in the grain resulting in increased number of filled grains in treatments where increasing levels of nitrogen were applied. The number of filled grains indicates the actual capacity of the sink to receive and store the photosynthates produced by the plant. Similar increases in the number of filled grains per panicle due to increasing doses of nitrogen were earlier reported by Pillai et al. (1984), Srinivasulu Reddy (1986), Dalai and Dixit (1987), Ghosh et al. (1987), Mandal et al. (1987) and by Sudhakara et al. (1987).

No difference could be noticed in the number of filled grains per panicle or per unit area due to the method of application of urea either through foliage or through soil.

Plant population significantly influenced the number of grains per panicle. As the spacing increased the number of grains per panicle also increased. The highest number of grains was recorded by 10 x 20 cm spacing. The number of grains per unit area was also high in the 10 x 20 cm spacing, but it was on par with 10 x 15 cm. Greater availability of feeding zone per clump due to wider spacing might have positively influenced the uptake and effective utilization of nutrient elements upto grain filling stage which in turn was responsible for improvement in the number of filled grains. The results obtained in the present study are in conformity with the findings of Sewa Ram et al. (1973), Chang and Su (1977) and Rao and Raju (1987).

f. Spikelet sterility (Tables 28 and 29)

The results revealed that application of increasing levels of nitrogen increased the sterility percentage in both years. Maximum sterility percentage was noted in 160 kg N/ha. Under higher nutritional status, plants continued to produce more number of tillers. The tillers produced later would have flowered late giving an increased number of total spikelets. But filling of the increased number of spikelets could not cope with the photosynthates manufactured, with the result, that a good number of spikelets remained sterile thereby increasing the sterility percentage. In other words, as the nitrogen level was increased, the yield container was also increased, but the photosynthate was not correspondingly increased resulting in higher sterility percentage. The higher sterility percentage noted at high nitrogen levels may also be the consequence of mutual shading. It was also noticed that the total number of spikelets per panicle increased as the nitrogen level increased. But the increase in total spikelet number in treatments receiving higher doses of nitrogen was not followed by a corresponding increase in the number of filled grains. This resulted in the increased count of unfilled grains and consequently a higher sterility percentage under increasing nitrogen levels. Similar results were earlier reported by Ota and Yamada (1965), Togari and Kashiwakura

(1968), Bhaskaran (1970), Muthuswamy *et al*. (1972) and by Padmaja (1976).

The effects due to method of application of nitrogen and plant population were not significant.

g. Thousand grain weight (Tables 32 and 33)

The weight of 1000 grains was significantly influenced by nitrogen levels. There were increases in the test weight due to increasing levels of nitrogen upto 160 kg N/ha in both years. The favourable effect noted is attributed to the beneficial effect of top dressing. Improvement in the apparent contribution rate of carbohydrates to grain and the increase in size of hull are the other factors responsible for the increase in test weight. Matsushima (1967) observed that nitrogen supply at reduction division stage increased the capacity of the 'yield container' and this benefit might have been derived in this case. The beneficial effect of nitrogen in increasing the size and weight of grain is well known. Grain size is controlled by hull size. It is natural that increased application of nitrogen causes the weight of 1000 grains to increase through an increase in the weight of individual grain. Increases in weight of 1000 grains due to increasing levels of nitrogen were earlier reported by Panda and Leeuwrik (1972), Sadayappan (1982), Ali Ahmad *et al*. (1985) and by Sudhakara *et al*. (1987).

Method of nitrogen application also influenced the test weight of grain. Application of the second top dose of nitrogen through foliage at the panicle initiation stage improved the weight of grains significantly in both years. The favourable effect of foliar spray of nitrogen at the panicle initiation stage on increasing the weight of 1000 grains was observed by Matsushima (1969) and Bhaskaran (1970).

Plant population did not result in any change in the 1000 grain weight during the first year, but in the second year a slight increase in the test weight of grain due to wider spacing was noticed. Under most conditions, the 1000 grain weight is mainly a varietal character (Yoshida, 1981). Varma (1972), Pothiraj (1973), Singh and Modgal (1977), Shobhana (1983) and Sharma and Warsi (1987) also reported that the 1000 grain weight was not influenced appreciably by differences in spacing. The results obtained in the present investigation are in agreement with the findings of the above workers.

5.3. Yield of grain (Tables 34, 35, 36 and 37; Fig. 6)

Levels of nitrogen significantly influenced the grain yield. There was positive and significant increase in yield due to nitrogen application upto 120 kg/ha in both years, beyond which the effect was not significant and in

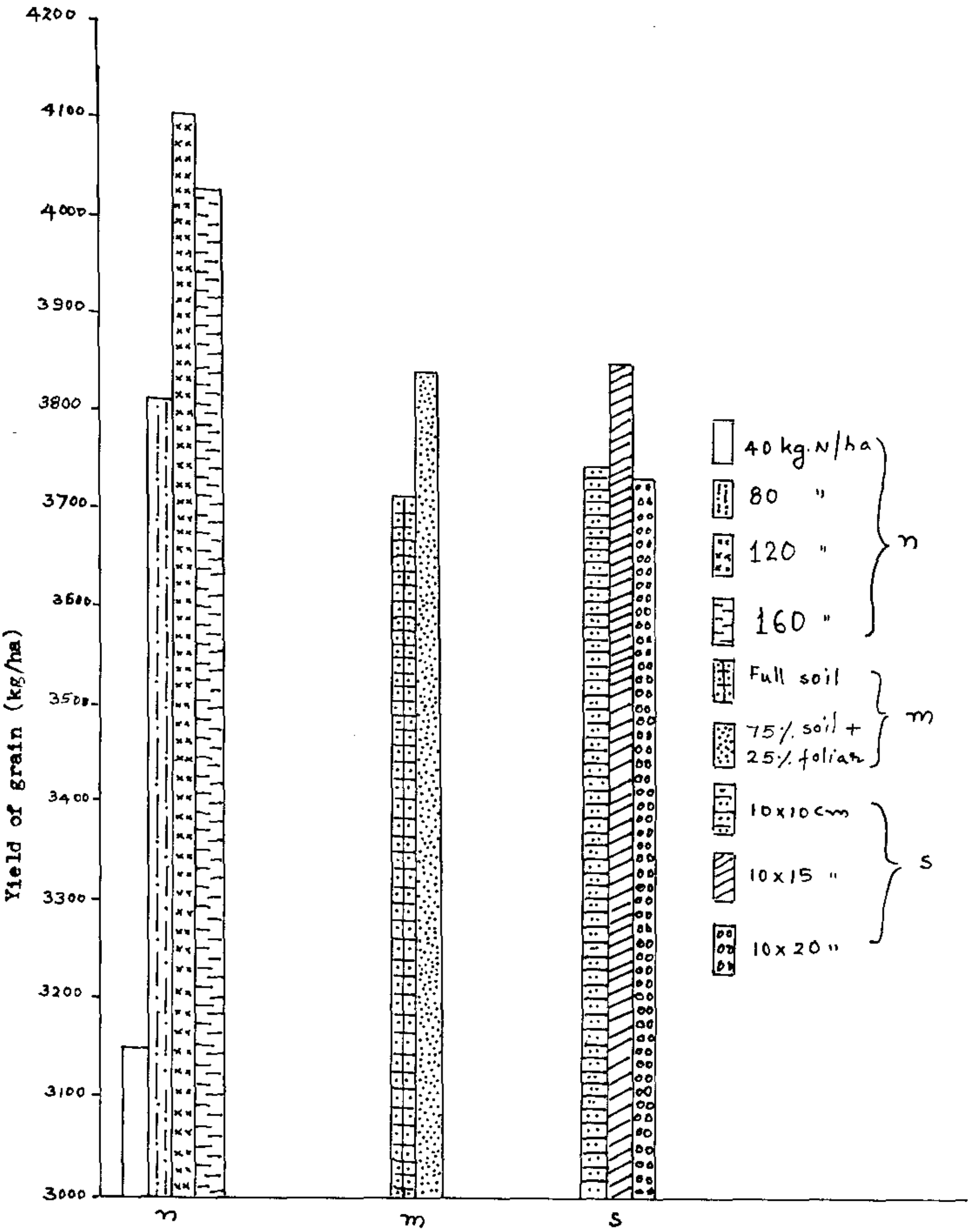

Fig. 6. Yield of grain under different treatments (Pooled data)

fact a decline was noticed. The average yields obtained under 40, 80, 120 and 160 kg N/ha were 3302, 4222, 4607 and 4481 kg/ha respectively during the first year. The corresponding values for the second year were 2996, 3413, 3605 and 3573 kg/ha respectively. The average grain production over the two years under these levels were 3149, 3818, 4106 and 4027 kg/ha. The data presented above show that nitrogen produces significant increases in total yield of grain. A close perusal of the data on characters like number of tillers, leaf area index, number of panicles per unit area, length of panicle, weight of panicle, number of filled grains per unit area and thousand grain weight indicates that all these characters showed significant improvement with increasing levels of nitrogen. In short, nitrogen supply greatly influenced the above mentioned growth characters and yield components. The favourable effects of nitrogen application on all these compounded to give the highest grain yield at 120 kg N/ha. Further, the augmentative effect of applied nitrogen on various growth factors resulted in greater uptake of nutrients which again favourably influenced the yield components like number of panicles per unit area, number of grain per panicle, 1000 grain weight etc. The cumulative effect on yield components with applied nitrogen is reflected on the grain yield finally. Ramanathan and Krishnamurthy (1971), Kulandaivelu and Kaliappa (1971), Sadyappan (1972), Purushothaman and Morachan (1974), Singh and Kumar (1983), Pillai et al. (1984), Harbir Singh et al. (1985), Mohankumar and Singh (1985), Khader et al. (1986), Raghuwanshi et al. (1986), Singh and Singh (1986), Ghosh et al. (1987), Thangamuthu et al. (1987) and Om et al. (1988) obtained increases in grain yield due to increasing levels of nitrogen application.

The beneficial effect of nitrogen in increasing the yield of grain needs no emphasis. Nitrogen has a definite role in photosynthesis which is directly related to the photosynthetic activity of the leaves. It is a constituent of proteins, which in turn are constituents of protoplasm, chloroplasts and enzymes. Nitrogen affects photosynthetic rate of rice plant in two ways - development of leaf area (capacity factor) and photosynthetic rate per unit leaf area (efficiency factor). The higher the nitrogen content, the higher is the photosynthetic rate. In general, leaf photosynthetic rate is correlated linearly or curvilinearly with leaf nitrogen. Beneficial effect of supplying nitrogen at all stages of growth is often attributed to increased nitrogen content of leaves thereby increasing the photosynthetic rate of the plant. Higher nitrogen content of leaves thus directly increases yield. Yield of crops directly depends on dry matter production.

Practically all dry matter of higher plants originates from photosynthesis. It is also reported that nitrogen absorbed at later stages of growth is mainly used to produce more grain than straw in rice. Photosynthesis produces carbohydrates, part of which is translocated to the grain.

The non-responsiveness of the variety Sabari to nitrogen application beyond 120 kg/ha under the agro-climatic conditions of South Kerala is evident in the present investigation. The yield components like number of panicles per unit area, length of panicle and number of filled grains per unit area show the superiority of 120 kg N/ha over 160 kg N/ha which is reflected in the final yield. At very high LAI, the chances for droopiness of leaves and for mutual shading are more and these conditions reduce the photosynthetic rate of the plant as a whole and result finally in reduced yield (Chatterjee and Maiti, 1981 and Yoshida, 1981).

It was also seen that the method of application of nitrogen significantly influenced the yield of grain during both years. Supply of the second top dose of nitrogen at the panicle initiation stage was found beneficial in increasing yield of grain when compared to the supply of the same dose of nitrogen through soil at the same time. The increase in grain yield due to foliar application over soil application was 3.88 per cent and 3.35 per cent for the first and second years respectively. The beneficial effects of foliar application obtained in the case of yield components like number of panicles per unit area, weight of panicle and test weight of 1000 grains together contributed to this increase. Increase in yield of grain due to foliar application was reported by Bhaskaran and De (1971) who obtained an yield increase of 2.5 per cent due to this practice. Similar increase by supplying 25 per cent of the total nitrogen through foliage at the panicle initiation stage was also reported by Sharma and De (1976). Beneficial effects of foliar application of nitrogen in increasing yield of rice have been reported by De et al. (1967), AICRIP (1968), Mahapatra (1969), Veeraraja Urs and Havanagi (1969), Bhuiya et al. (1975), Ramiah and Morachan (1976), Sharma and De (1976), Subramanian and Kangasabai (1977), Mahapatra and Gupta (1978) and by Sharma and Rajat De (1979).

Increase in grain yield due to spacing upto 10 x 15 cm was noticed during both years though statistically not significant. But the analysis of the pooled data brought about significant difference. The highest yield was recorded by 10 x 15 cm spacing and it was significantly superior to the other two spacings. The second highest yield was produced by the 10 x 10 cm spacing and the lowest yield by the widest spacing of 10 x 20 cm. From the pooled data it was calculated that at the 10 x 15 cm spacing, the yield was increased by 2.8 per cent over 10 x 10 cm spacing and 3.0 per cent over 10 x 20 cm spacing. Spacing influenced the various growth and yield attributing characters, the cumulative effect of which resulted in an increased yield in this treatment. Increase in yield of grain at closer spacings was earlier reported by Sewa Ram et al. (1973), Singh and Singh (1973), Barthakur and Gogoi (1974), Kumar et al. (1975), Majid et al. (1976), Parashar (1976), Ojo (1977), Moody et al. (1983), Hakansson (1984), Thorat and Patil (1986), Sawant et al. (1986) and by Srinivasulu Reddy (1986).

The interaction between nitrogen level and spacing was significant. The highest yield of 4213 kg/ha was obtained in the treatment combination of 160 kg N/ha with 10 x 15 cm spacing. While nitrogen and spacing levels are considered individually it is evident that 120 kg N and 10 x 15 cm spacing are superior. Under the interaction effect also it is found that combination of 120 kg N with 10 x 15 cm spacing (4172 kg grain/ha) was on par with 160 kg N with 10 x 15 cm spacing. Therefore it is to be taken into consideration that 120 kg N/ha with 10 x 15 cm spacing is enough to obtain higher yield in this variety. Further, in studying the economics also, it is found that by adding

40 kg additional nitrogen over 120 kg N/ha, the increase in grain yield is only 41 kg which is economically not viable.

Response studies (Tables 69, 70 and 71)

The data on yield of grain further revealed that the response of the variety Sabari to applied nitrogen, in general, was only upto 120 kg N/ha. Further increase in N application resulted in a decreasing trend. At the 40, 80, 120 and 160 kg N/ha levels, the rates of grain production per kg of applied nitrogen were 82.55, 52.78, 38.39 and 28.01 kg respectively during the first year. The corresponding values for the second year were 74.90, 42.66, 30.04 and 22.33 kg grain/kg of applied N. For the pooled data, the average values were 78.73, 47.33, 34.22 and 25.17 kg/kg nitrogen applied.

The average response at the 80, 120, and 160 kg N/ha over the lowest level of 40 kg N/ha worked out to 23.0, 16.3 and 9.8 kg grain for the first year and 10.4, 7.6 and 4.8 kg for the second year. The corresponding values for the pooled data are 16.7, 12.0 and 7.3 kg respectively. As the dose of nitrogen increased the grain production per kg extra nitrogen supplied progressively decreased in accordance with the law of diminishing returns.

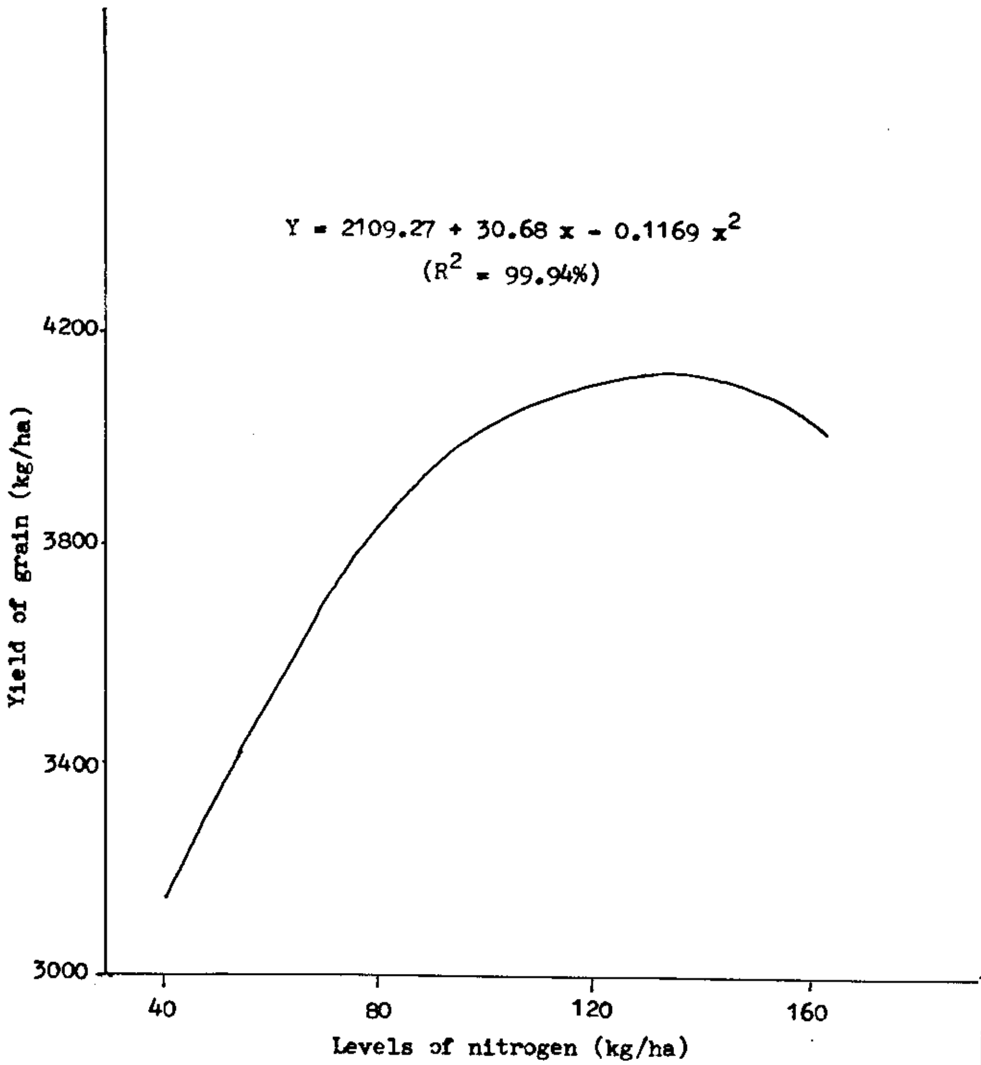

Fig. 7. Response curve to nitrogen application (pooled data)

The second degree polynomial $Y = a + bx + cx^2$ where 'Y' is the grain yield in kg per hectare corresponding to 'x' kg/ha of nitrogen was found to be a suitable fit for studying the relationship between grain yield and levels of nitrogen under different methods of nitrogen application and plant population. The response equation so fitted for the nitrogen levels is $Y = 1864.67 + 42.51\ x - 0.1635\ x^2$ with a coefficient of determination (R^2) of 99.98 per cent for the first year. Based on this, the expected yields of grain calculated for the 40, 80, 120 and 160 kg N/ha are 3304, 4219, 4611 and 4480 kg/ha respectively (Table 71). During this year, the physical optimum or the yield maximising dose of nitrogen worked out to 130 kg/ha and the most economic optimum dose 122 kg N/ha (Table 70).

The response equation calculated for the second year is $Y = 2253.74 + 18.86\ x - 0.0703\ x^2$ with R^2 of 99.73 per cent. Accordingly the expected yield of grain for the four levels of nitrogen application worked out as 2996, 3413, 3605 and 3573 kg/ha respectively. The physical optimum and economic optimum doses of N for this year are 134 and 116 kg/ha.

The response equation worked out for the pooled data is given below.

$Y = 2109.27 + 30.68\ x - 0.1169\ x^2$ with a coefficient of determination (R^2) of 99.94 per cent. The expected yields

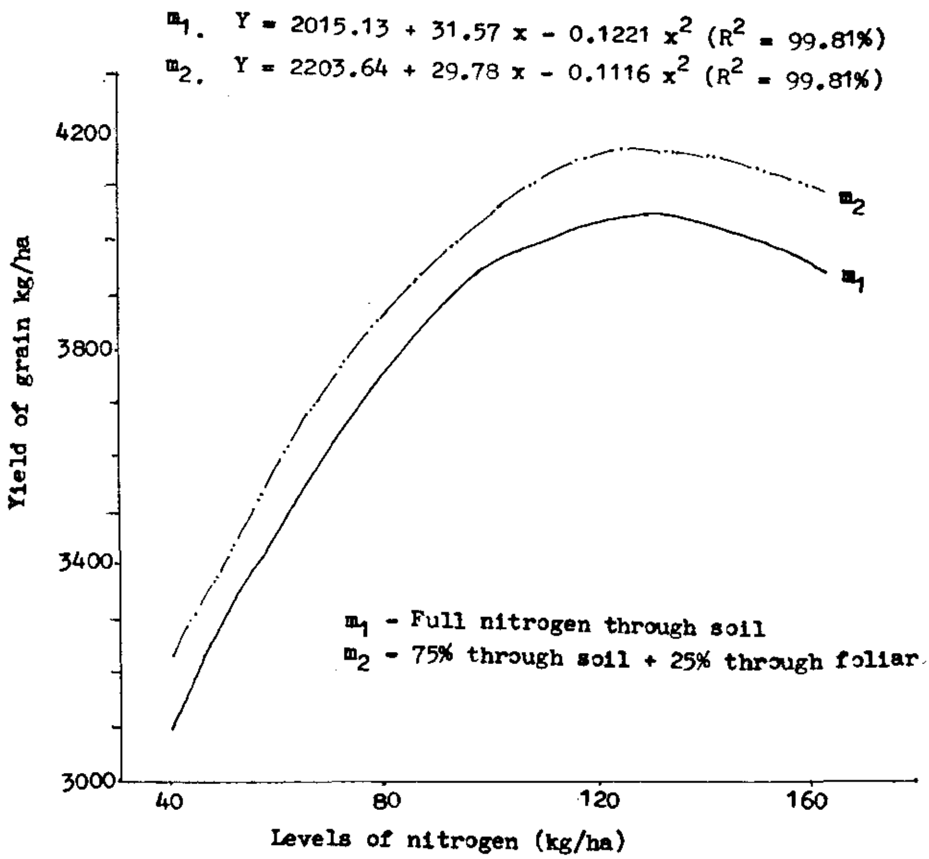

Fig. 8. Curve showing estimated yields due to different methods of nitrogen application under different levels

on the basis of this are 3150, 3816, 4108 and 4026 kg/ha for the 40, 80, 120 and 160 kg N/ha respectively (Fig. 7). The physical optimum and economic optimum doses of nitrogen are 131 and 120 kg/ha.

Response equations are also worked out for the two methods of application of the second top dose of nitrogen from the pooled data. For the method m_1, ie soil application of nitrogen the equation is Y = 2015.13 + 31.57 x - 0.1221 x^2 with a coefficient of determination of 99.81 per cent. The physical optimum and economic optimum doses of nitrogen for this method worked out to 129 and 118 kg N/ha respectively. The expected yields for the different levels under this method are 3083, 3760, 4046 and 3941 for 40, 80, 120 and 160 kg N/ha respectively. For the method m_2 ie application of the second top dose of nitrogen through foliage the equation is as follows.

$Y = 2203.64 + 29.78x - 0.1116x^2$ with $R^2 = 99.81$ per cent.

The expected yields under the different levels of nitrogen are 3116, 3872, 4170 and 4111 kg/ha for the 40, 80, 120 and 160 kg N/ha respectively. The physical and optimum doses of nitrogen in this situation are 133 and 122 kg N/ha. The relationship between the estimated yields and the nitrogen levels under the m_1 and m_2 methods is represented in Fig. 8.

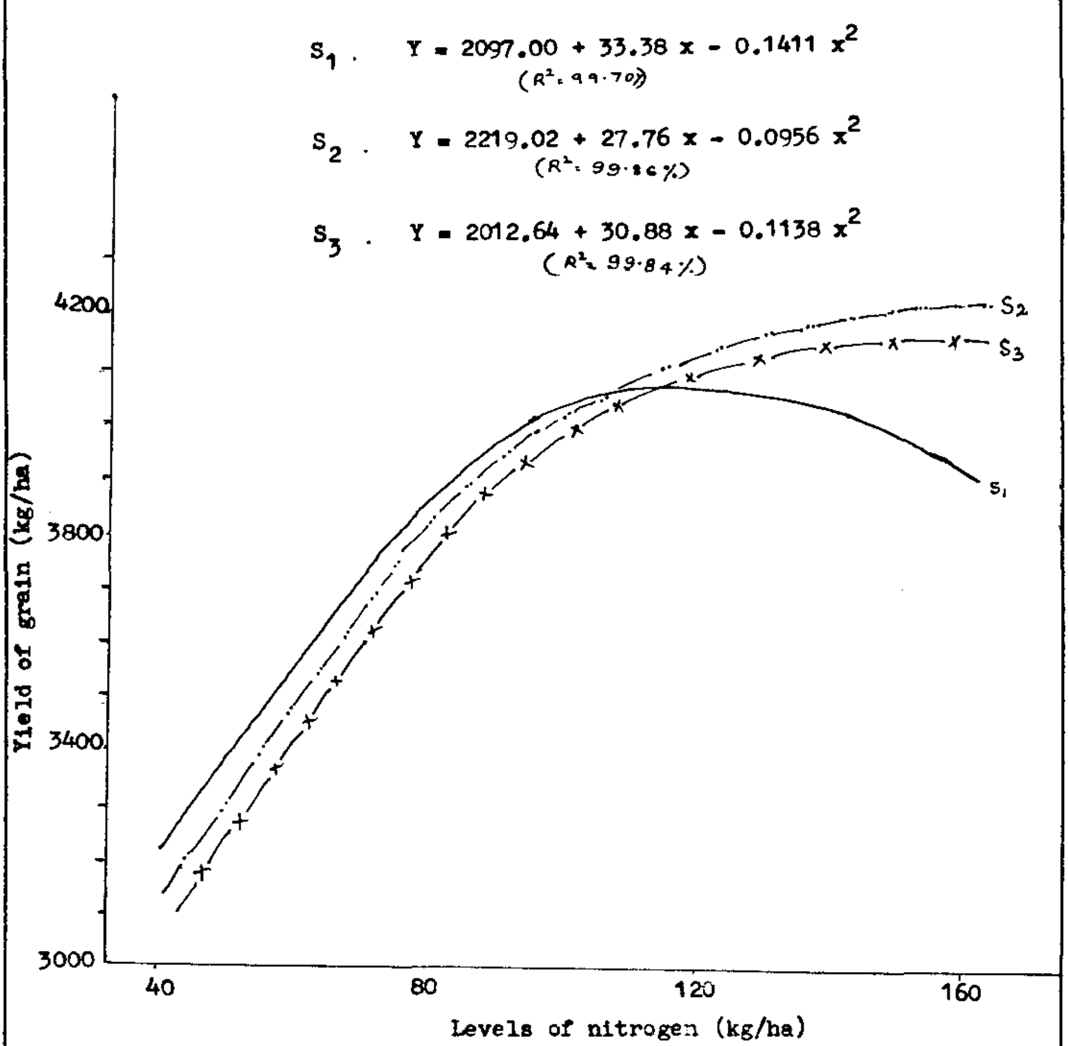

Fig. 9. Curve showing estimated yields due to different spacings under various nitrogen levels

The relationship between grain yield and plant population under different nitrogen levels was also worked out from the pooled data. The curve obtained for the 10 x 10 cm spacing (S_1) is $Y = 2097.00 + 33.38\ x - 0.1411\ x^2$ with $R^2 = 99.70$ per cent. The physical and economic optimum doses of N are 118 and 109 kg/ha respectively. For the spacing 10 x 15 cm (S_2) the curve is $Y = 2219.02 + 27.76\ x - 0.0956\ x^2$ with $R^2 = 99.86$ per cent. The physical optimum and economic optimum doses of N under S_2 are 145 and 132 kg N/ha. For 10 x 20 cm spacing (S_3) the equation is $Y = 2012.64 + 30.88\ x - 0.1138\ x^2$ with $R^2 = 99.84$ per cent. The physical and economic optimum doses of nitrogen for S_3 are 136 and 124 kg N/ha respectively. The above relationships are represented in Fig. 9.

From the discussions on grain yield and response to nitrogen it can be concluded that

i. the overall optimum economic dose of nitrogen to <u>Sabari</u> is 120 kg/ha,

ii. application of 75 per cent nitrogen through soil and 25 per cent through foliage at the panicle initiation stage is more beneficial,

iii. the spacing 10 x 15 cm (67 hills per m^2) is more advantageous for obtaining higher yields of grain, and

iv. the economic optimum dose of nitrogen will be low at closer spacing and high at wider spacing.

A high grain yield can therefore be achieved only when the proper combination of variety, environment and agronomic practices is provided.

5.4. Yield of straw (Tables 38 to 41 and Fig. 10)

Increasing doses of nitrogen application increased the yield of straw during both years. The average yields of straw over the two years for the 40, 80, 120 and 160 kg/ha levels of nitrogen were 47.5, 57.1, 61.2 and 64.6 q/ha respectively. The effect of nitrogen in increasing straw yield is well known. A perusal of the data on growth characters (Tables 4 to 15) will reveal the tremendous influence of this nutrient on vegetative characters, the ultimate result being a substantial increase in straw yield. Similar increases in straw yield due to increasing doses of nitrogen have been shown by Sadayappan (1972), Somasundaram (1981), Mohankumar and Singh (1985), Srinivasulu Reddy (1986), Dalai and Dixit (1987) and by Om et al. (1988).

Foliar application of the second top dose of nitrogen was found to influence the straw yield significantly. However, the magnitude of increase is not as that of the effect of nitrogen doses. The increase in straw yield due to the

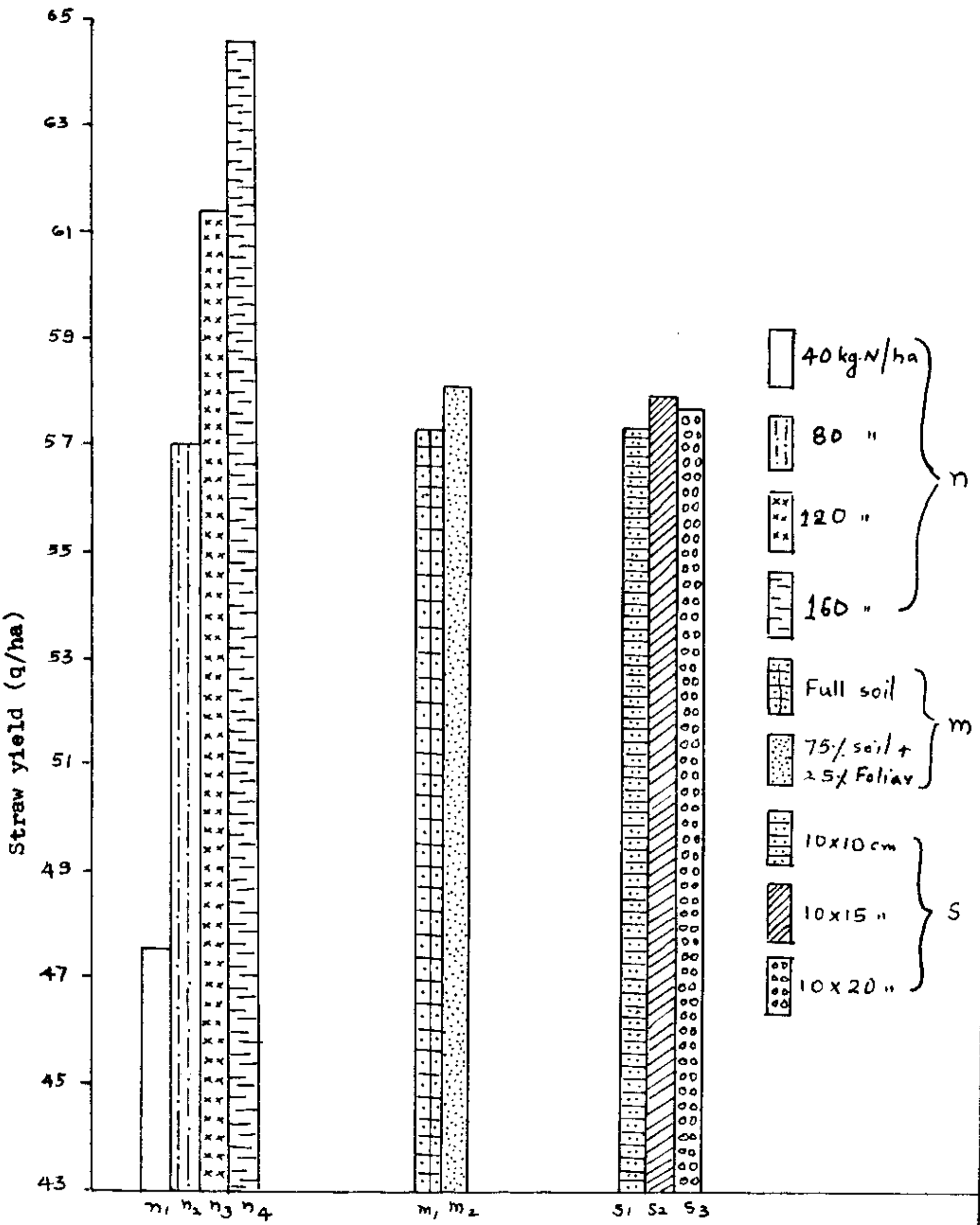

Fig. 10. Yield of straw under different treatments (pooled data)

foliar application is 2.9 per cent over soil application. Increase in straw yield due to foliar application of nitrogen has been reported earlier by Dhua and Ray (1968), Bhuiya *et al*. (1975) and by Ramiah and Morachan (1976). The results obtained in the present investigation are in conformity with those of the above workers.

Different plant populations did not cause any significant effect in straw yield except in the second year when there was an increase in straw yield due to increase in spacing. But the magnitude of increase was only 2 per cent over the lowest yield. Though the growth characters were more beneficially influenced in plants with wider spacings than those with narrow spacing, these increases in the former were not sufficient to compensate for the increased number of hills under narrow spacing, with the result that the differences are not significant. Similar results were reported earlier by Srinivasulu Reddy (1986) and by Rao and Raju (1987).

5.5. Grain : Straw ratio (Tables 42 and 43)

Levels of nitrogen significantly influenced the grain : straw ratio. During both years, the lowest grain : straw ratio was recorded by the highest level of nitrogen application. The nitrogen absorbed at the lower levels would have been effectively utilised for grain formation and grain filling rather than for vegetative growth resulting in a higher grain : straw ratio. Kalyanikutty and Morachan (1974) obtained high grain : straw ratio at 40 kg N/ha and the ratio got lowered at higher levels of nitrogen. The grain : straw ratio is an indication of the ultimate partitioning of dry matter between grain and straw. It is thus noticed that at higher levels of nitrogen, the rate of increase of straw is higher than that of the grain which ultimately results in a lowering of the grain : straw ratio.

Method of application also influenced the grain : straw ratio. Application of the second top dressing of nitrogen through foliage increased the grain yield through its influence on the number of panicles per unit area, weight of panicle and the test weight of grain whereas this method did not increase straw yield correspondingly resulting in a high grain : straw ratio in this treatment.

The effect due to plant population was not significant. Yoshida (1972) stated that grain : straw ratio is clearly correlated to varietal characteristics.

A common way of examining rice grain yield is to find out the ratio of the dry weight of grain to the dry weight of straw. The grain : straw ratio of rice crop ranges from about 0.5 for traditional tall varieties to about 1.0 for improved short varieties. This ratio is subject to manipulation by agronomic practices.

5.6. Quality of grain and straw

a. Protein content of grain (Tables 48 and 49)

Increasing levels of nitrogen increased the protein content of grain. The percentage increases of grain protein at the 80, 120 and 160 kg N/ha over the lowest level of 40 kg N/ha were 12, 23 and 35 per cent respectively for the first year and 11, 19 and 32 per cent respectively for the second year. Nitrogen is the most important constituent of protein. The higher protein content of grain noted at higher nitrogen levels may be due to the accelerated protein biosynthesis under the increased and continued absorption of nitrogen. Increase in the rate of nitrogen availability especially at the later stages of growth of the plant coupled with the inability of the plant to utilise it for further growth and redistribution might have also helped to accumulate more nitrogen in grain resulting in increased protein percentage at the increasing levels of nitrogen. Such increases in the protein content of grain due to increasing levels of nitrogen application have been reported earlier by Rabindra _et al_. (1977), Dutta and Barua (1978), Sharma and Mishra (1986), Ghosh _et al_. (1987), Sudhakara _et al_. (1987) and by Thakur and Singh (1987). The results obtained in the present investigation are in conformity with the above findings.

It was also found that application of the second top dose of nitrogen through foliage is significantly superior to the soil application of the same dose of nitrogen at the same stage of growth. The percentage increase in the protein content of grain due to foliar application over soil application was 2.8 during the first year and 4.0 during the second year. In rice quick absorption and distribution of nitrogen applied through foliage takes place. Further, foliar application has significant influence on the recovery of applied nitrogen and its translocation to the grain portion in addition to its increased absorption. The protein improvement noticed due to foliar application might be due to the collective influence of the above phenomena. Similar increases in protein content of grain due to foliar application have been reported earlier by Bhaskaran (1970), Jha _et_ _al_. (1974), Nishizawa _et_ _al_. (1977), Singh and Modgal (1978a) and Sharma and Rajat De (1979).

b. Nitrogen content of straw (Tables 46 and 47)

The nitrogen content of straw was increased by increasing levels of nitrogen during both years. The effects were significant at all the levels showing a linear response for this character. As the levels of nitrogen application increased the availability and uptake were also increased. Part of the nitrogen so absorbed would have accumulated in the straw due to non-utilization and redistribution for further growth resulting in increased nitrogen content. The results obtained in the present study are in conformity with the findings of Kulkarni (1973), Bhargava et al. (1975) and Ghosh et al. (1987).

Though there was no significant difference in the nitrogen content of straw due to different methods of application of the second top dose of nitrogen, it was found that the foliar application resulted in an enhancing trend in the nitrogen content of straw. It is evident that efficiency of absorption of nitrogen sprayed on foliage is high when compared to the soil application of the same dose. A portion of the nitrogen thus absorbed efficiently by the plant through foliage would have accumulated in straw giving a higher nitrogen content. Similar observations were made earlier by Bhaskaran (1970).

Spacing had no significant effect on nitrogen content of straw which may be due to the uniform utilization of the absorbed nitrogen for straw production and grain formation.

5.7. Uptake of nutrients

a. Nitrogen uptake at flowering (Tables 50 and 51)

Increasing levels of nitrogen increased the uptake of nitrogen progressively upto 160 kg/ha. It is seen from Tables 44 and 45 that the nitrogen content of plants was increased due to higher levels of nitrogen. Increased supply of the nutrient to the crop facilitates the plants to absorb more nitrogen which is translocated to different plant parts. The increase in dry matter production coupled with increase in the nitrogen content of the plant resulted in significant increase in the nitrogen uptake by rice at flowering. It was also noted that positive correlation ($r = 0.6801$) exists between dry matter production at flowering and nitrogen uptake. Increases in nitrogen uptake due to increasing levels of nitrogen application have been reported earlier by Gopalaswamy and Raj (1977), Mani (1979) and by Thakur and Singh (1987).

Methods of application also influenced the nitrogen uptake in rice. When the second top dose of nitrogen was applied to foliage, quick absorption of the nutrient might have taken place increasing the nitrogen content of plants when compared to soil application of the same dose at the same time (Table 44 and 45). The dry matter production was also comparatively more in the plots where the second top dose of nitrogen was given through foliage (Tables 12 and 13). The cumulative effects of all these together increased the total uptake of nitrogen at flowering in this treatment. The results obtained in the present investigation are in agreement with the results of Bhaskaran (1970), Jha et al. (1974) and Singh and Modgal (1977).

Spacing did not affect the uptake of nitrogen at flowering. The increased quantities of nitrogen absorbed by individual plants in the wider spacing was compensated by the increased number of hills in the narrower spacings, resulting in a non-significant effect in the uptake of nitrogen at flowering.

b. Uptake of nutrients at harvest

i. Nitrogen uptake (Tables 52 and 53)

The uptake of nitrogen at harvest appears to be similar to that at the flowering stage. The increasing levels of nitrogen application enhanced the uptake of nitrogen upto the highest level tried showing a linear nature. It was found that the total dry matter production at harvest was increased due to increasing levels of nitrogen (Tables 14 and 15). Significant positive correlation exists between total dry matter production at harvest ($r = 0.7026$) and the uptake of nitrogen. Thus, the increasing levels of nitrogen increased the dry matter and apparently increased the uptake of nitrogen at harvest. Increased nitrogen uptake due to increased nitrogen application is an established fact and the results obtained in the present study are in conformity with the results of Mani (1979), Srinivasulu Reddy (1986), Ghosh et al. (1987), Sudhakara et al. (1987) and Velu et al. (1987).

The effect of method of application of nitrogen was also significant. The percentage increases in the uptake of nitrogen due to foliar application over soil application were 5.7 and 5.4 for the first and second years respectively. As stated earlier, the absorption of nitrogen through foliage is rapid and consequently the nutrient loss is minimum resulting in an increased uptake of nitrogen. Increased uptake of nitrogen due to foliar application of a part of the total nitrogen to rice crop has been shown earlier by Bhaskaran (1970) and Jha et al. (1974).

Uptake of nitrogen at harvest was not affected by spacing for the reasons stated in the case of nitrogen uptake at flowering.

Generally, the high yielding rice plant has high nitrogen concentration throughout its growth.

ii. Phosphorus uptake at harvest (Tables 54 and 55)

It was seen that increasing levels of nitrogen application significantly increased the phosphorus content of the grain and straw at harvest (Tables 58 and 62). Increased levels of nitrogen supply facilitated the plants to absorb more of phosphorus and accumulate it in the plant parts. It was noted that the uptake of phosphorus by grain was more when compared to that by straw and nitrogen enabled the increased uptake of phosphorus in both cases. Similar findings were reported earlier by Alexander et al. (1974). Agarwal (1978) also reported that grain phosphorus contents were increased by increased application of nitrogen. Trials conducted by Iruthayaraj and Morachan (1980) revealed that phosphorus uptake was higher with higher levels of nitrogen. This is in accordance with the observations of Singh and Modgal (1978a), Sadayappan (1982), Srinivasulu Reddy (1986) and Velu et al. (1987).

Application of the second top dose of nitrogen through foliage increased the total uptake of phosphorus when compared to the soil application. It was also noticed that the total dry matter production at harvest was increased by foliar application which in turn resulted in an increased value of phosphorus uptake by the crop.

Different spacings did not affect the uptake of phosphorus for the reasons mentioned earlier in the case of nitrogen uptake at flowering.

iii. Potassium uptake (Tables 56 and 57)

Increasing levels of nitrogen application significantly influenced the potassium uptake at harvest. The significant influence of nitrogen in increasing the total dry matter production is seen in Tables 14 and 15. Further, the potassium content of grain and straw are also influenced by nitrogen application (Tables 60, 61, 64 and 65). The increased uptake of nitrogen at higher doses enabled the plant to absorb higher quantities of potassium also. All these factors are responsible for the final increased uptake of potassium by plants at higher levels of nitrogen. The observation that the total uptake of potassium increased with higher rates of nitrogen application is in agreement with the findings of Subramanian (1976), Singh and Modgal (1978a), Sadayappan (1982) and Srinivasulu Reddy (1986).

Foliar application of the second top dose of nitrogen at the panicle initiation stage was favourable for increased uptake when compared to the soil application of the same dose of nitrogen. As seen from Tables 14 and 15, the total dry matter production at harvest was increased by this treatment. The influence of this method in increasing the potassium content of the grain or straw was not of any great magnitude, though there was an increasing trend (Tables 60, 61, 64 and 65) due to foliar application. Thus the influence of foliar application in increasing the uptake of potassium is mainly manifested through its influence on dry matter production at harvest.

5.8. Residual nutrient status of the soil (Tables 66, 67 and 68)

The results on residual nutrient status of the soil reveal that, of the three major nutrients, nitrogen alone is seen influenced by treatments. Application of increasing doses of nitrogen resulted in a marginal increase in the available nitrogen status of the soil after the experiment.

There was no significant difference in the available phosphorus or available potassium due to any of the treatments. The soil in the experimental area belongs to the sandy loam type. A good fraction of the nutrients applied to the soil might have been lost through various processes like leaching and fixation in addition to crop removal retaining more or less equal quantities of the nutrients in all the plots resulting in non-significant differences among the treatments.

5.9. Economics of rice production (Table 72 and Fig. 11)

It is observed from the Table that the total expenditure for rice production under the different levels of

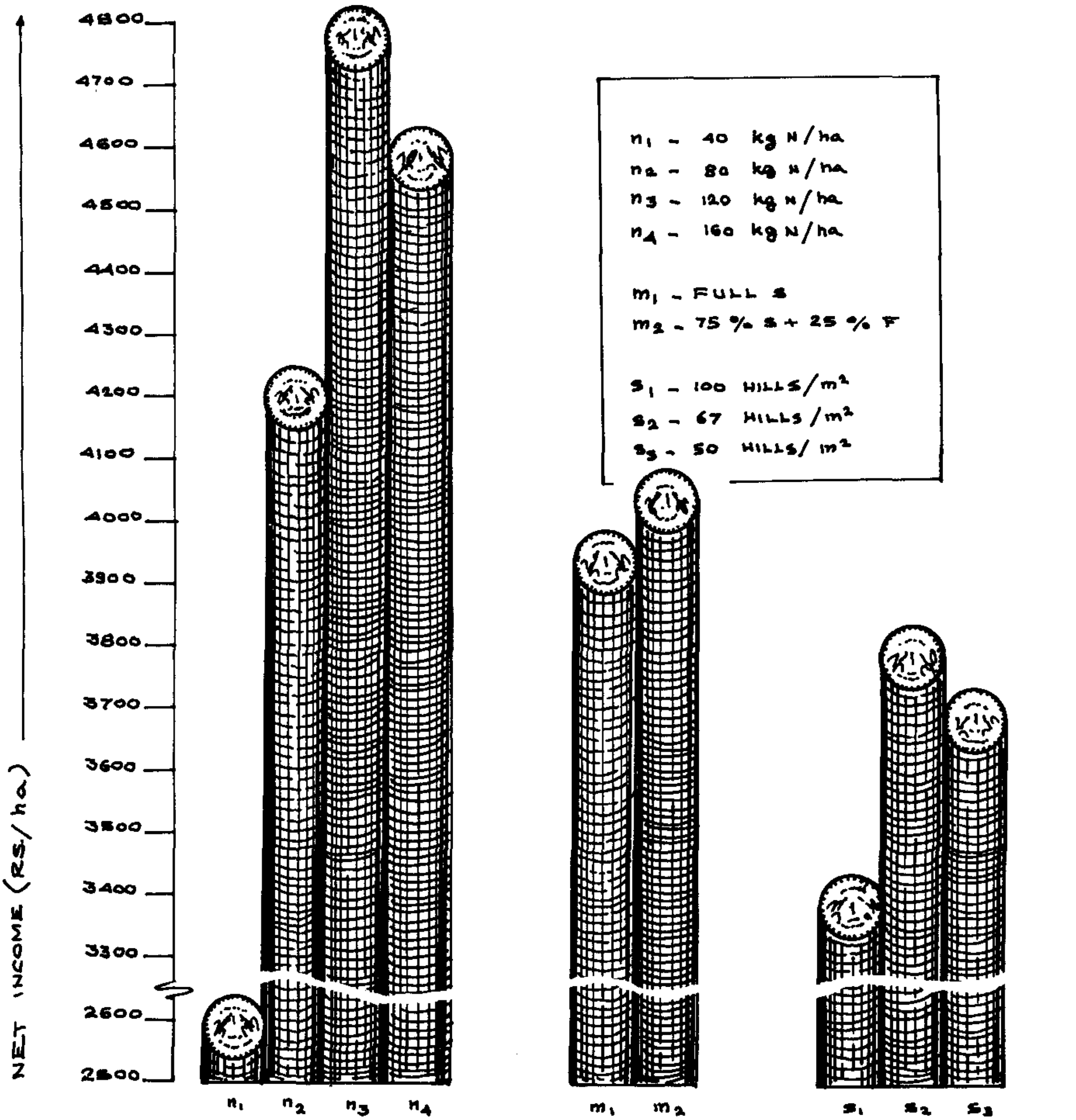

Fig. 11. Net income under different levels of nitrogen, methods of N application and different plant population

nitrogen ranged between Rs.8671/- for 40 kg N/ha and Rs.11282/- for 160 kg N/ha based on the wage rates prevailed and price of inputs. The net income from 40, 80, 120 and 160 kg N/ha are Rs.2528/-, Rs.4142/-, Rs.4718/- and Rs.4521/- respectively. The benefit/cost ratios for these treatments were 1.41, 1.65, 1.72 and 1.67. The highest net income as well as benefit/cost ratio was recorded by 120 kg N/ha. Neither the net income nor the B/C ratio increased beyond 120 kg N/ha, instead, a declining trend was exhibited. The net income and B/C ratio are low at 160 kg/ha for the simple reason that grain yield has not increased beyond 120 kg N/ha. From the response studies the economic optimum level of nitrogen for this variety has worked out to 120 kg/ha and the net income and B/C ratio are also maximum in this level.

Between the two methods of application of nitrogen there is no difference in the B/C ratio. But it is found that both the gross and net incomes are high in m_2 ie spraying the second top dose of nitrogen through foliage. By spending an additional expenditure of Rs.200/- towards labour cost for spraying, an additional income of Rs.302/- is generated, thereby showing its superiority over the application of the same dose through soil.

The gross income, net income and B/C ratio are high in the 10 x 15 cm spacing. Thus from the present investigation, it can be concluded that a combination of 120 kg N/ha of which 25 per cent applied through foliar spray at the panicle initiation stage with 10 x 15 cm spacing is ideal for maximum benefit for the rice variety Sabari under the agro-ecological situations of the Southern Region of Kerala.

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

An investigation was undertaken to study the influence of different levels and methods of nitrogen application and different plant populations on the growth, yield and quality of the rice variety Sabari in the sandy loam soil of South Kerala. The experiment was conducted with four levels of nitrogen (40, 80, 120 and 160 kg/ha), two methods of application of nitrogen (i. application of the entire dose through soil, and ii. 75 per cent through soil and 25 per cent through foliage at the panicle initiation stage), and with three levels of spacing - 10 x 10 cm (1.00 million hills/ha), 10 x 15 cm (0.67 million hills/ha) and 10 x 20 cm (0.50 million hills/ha). The trial was laid out in split plot design replicated thrice with combinations of levels and methods of nitrogen application in the main plots and plant population in the sub plots for two years at the Instructional Farm, College of Agriculture, Vellayani. The results of the investigation are summarised below.

Height of plant was increased with increased nitrogen application upto 160 kg/ha. It was not influenced by method of application of nitrogen. Closer spacing resulted in shorter plants and the wider spacing resulted in taller plants.

Number of tillers per hill increased with incremental levels of nitrogen, whereas the method of application did not influence this character. As the spacing increased the number of tillers per hill increased.

Number of tillers per unit land area was increased with increasing nitrogen levels and decreasing spacing.

Leaf area index was increased progressively upto 160 kg N/ha but method of application did not change the LAI. The lowest spacing of 10 x 10 cm recorded the highest LAI while the lowest value of LAI was given by the widest spacing of 10 x 20 cm. The treatment combination of 160 kg N/ha with 10 x 10 cm spacing resulted in the highest LAI at flowering.

Dry matter production at flowering increased progressively with increased nitrogen application upto 160 kg/ha. The method of application of nitrogen and the different spacings did not affect the dry matter production at flowering appreciably.

Dry matter production at harvest was also increased progressively with increasing levels of nitrogen application. Application of the second top dose of nitrogen through foliage at the panicle initiation stage increased the dry matter production when compared to soil application. Dry matter production at harvest was increased upto 10 x 15 cm spacing. The treatment combination of 160 kg N/ha with the spacing of 10 x 15 cm resulted in the maximum dry matter production at harvest and the minimum was recorded by 40 kg N/ha with 10 x 20 cm spacing.

Number of days required for 50 per cent flowering was increased with increasing levels of nitrogen but not influenced by method of application or spacing. Lowest number of days for flowering was recorded by the treatment combination of 40 kg N/ha with application of the second top dose at panicle initiation stage through foliage.

Number of panicles per unit area was increased upto 120 kg N/ha and it was on par with 160 kg/ha. Application of the second top dose of nitrogen through foliage at panicle initiation stage increased the panicle number when compared to the soil application of the same dose at the same stage. The lowest spacing of 10 x 10 cm recorded the highest number of panicles per unit area followed by 10 x 15 cm spacing. The minimum number of panicles per unit area was obtained in the 10 x 20 cm spacing.

Length of panicle was increased by increasing levels of nitrogen and the maximum length was obtained in the 120 kg N/ha treatment. Method of nitrogen application did not influence the length of panicle. Panicle length was more at 10 x 20 cm spacing. The longest panicle was produced by the treatment combination of 120 kg N/ha with 10 x 20 cm spacing and the shortest by 40 kg N/ha with 10 x 10 cm.

Weight of panicle was increased by the increasing levels of nitrogen along with the foliar application. The panicle weight was more in 10 x 20 cm spacing. The maximum weight of panicle was recorded by 160 kg N/ha with 10 x 20 cm spacing and the lowest by 40 kg N/ha with 10 x 10 cm spacing.

Number of spikelets per panicle was more in 160 kg N/ha. Method of application did not influence the number of spikelets per panicle. The 10 x 20 cm spacing recorded the highest number of spikelets per panicle.

Number of filled grains per panicle was increased with increasing levels of nitrogen and the highest two levels were on par. There was an increasing trend in the number of filled grains per panicle due to foliar application of the second top dose of nitrogen. Among the different spacings, 10 x 20 cm gave the maximum number of filled grains per panicle.

Spikelet sterility percentage was low in lower levels of nitrogen. Method of application and spacing did not influence the spikelet sterility.

Number of grains per unit area was increased with increasing nitrogen levels and the maximum was in 120 kg N/ha and it was on par with 160 kg N/ha. Method of application did not influence this character appreciably, though there was an increasing trend due to foliar application. The effects of 10 x 15 cm and 10 x 20 cm spacings were on par.

Test weight of grain was maximum in 160 kg N/ha. Foliar application also increased the weight of 1000 grains. Spacing did not change the weight.

Grain yield was increased with increasing levels of nitrogen application. Maximum yield of grain was obtained at 120 kg N/ha and it was on par with 160 kg N/ha. The average yield of grain at the 40, 80, 120 and 160 kg N/ha levels were 3149, 3818, 4106 and 4027 kg/ha respectively. Foliar application of the second top dose of nitrogen was superior to soil application of the same dose at the same stage of growth. Higher grain yield was obtained in the 10 x 15 cm spacing.

The overall economic optimum level of nitrogen was calculated to be 120 kg/ha. The economic optimum dose of nitrogen was low (109 kg/ha) at closer spacing and high (124 kg/ha) at wider spacing.

Straw yield was maximum at 160 kg N/ha. Foli application also increased the straw yield and spaci: not change the straw yield appreciably.

The lowest grain : straw ratio was recorded at th highest nitrogen level. Foliar application resulted in higher grain : straw ratio. Spacing had no effect on this character.

Increasing levels and foliar method of application increased the nitrogen content of plants at flowering. Spacing had no significant effect on this character at flowering.

Nitrogen content of straw at harvest was increased at higher levels of nitrogen application. An increasing trend in nitrogen content was noticed due to foliar application of the second top dose. Spacing did not cause any significant effect.

Protein content of grain was high at higher levels of nitrogen application. Foliar application of the second top dose of nitrogen also gave similar effect. Spacing had no influence on the protein content of grain.

Increasing nitrogen levels and foliar application of the second top dose of nitrogen increased the nitrogen uptake at flowering and at harvest. At harvest, the phosphorus uptake was increased by both increasing levels of ni and foliar application. Potassium uptake was also i due to increasing levels of nitrogen. Spacing did not influence the potassium uptake.

Application of higher levels of nitrogen caused only a marginal increase in the residual available nitrogen status of the soil. Residual available phosphorus and potassium are not influenced by any of the treatments.

The highest net income and benefit : cost ratio were recorded by the 120 kg N/ha. Foliar application also increased the net income. The gross income and net income were maximum in 10 x 15 cm spacing.

Thus, from the present investigation it is concluded that a combination of 120 kg N/ha of which 25 per cent is applied through foliage at the panicle initiation stage with 10 x 15 cm spacing is the most ideal for maximum benefit from the rice variety Sabari under the agro-ecological situations of the Southern Region of Kerala.

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* Originals not seen

INFLUENCE OF LEVELS OF NITROGEN, METHODS OF APPLICATION AND PLANT POPULATION ON THE PERFORMANCE OF THE HIGH YIELDING RICE VARIETY 'SABARI'

BY

U. MOHAMED KUNJU

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ABSTRACT

An investigation was undertaken to study the effect of different levels and methods of nitrogen application and different plant populations on the growth, yield and quality of the rice variety Sabari in the Southern Region of Kerala. The treatments consisted of four levels of nitrogen (40, 80, 120 and 160 kg/ha), two methods of application of nitrogen (application of the entire dose through soil and 75 per cent through soil plus 25 per cent through foliage) and three levels of spacing viz. 10 x 10 cm (100 hills/m^2), 10 x 15 cm (67 hills/m^2) and 10 x 20 cm (50 hills/m^2). The experiment was laid out in split-plot design, replicated thrice and conducted for two years at the Instructional Farm, College of Agriculture, Vellayani.

Growth characters like plant height, number of tillers per hill, leaf area index and dry matter production at different stages of growth increased with incremental doses of nitrogen. Closer planting resulted in smaller plants and higher number of tillers per unit area. The leaf area index was high in closer planting. Total dry matter production at harvest was more in 10 x 15 cm spacing. Foliar application of nitrogen (25 per cent) increased the total dry matter production at harvest. Increasing levels of nitrogen delayed flowering.

Number of panicles per unit area, length of panicle, weight of panicle, number of spikelets per panicle, number of filled grains per panicle and number of grains per unit area were increased due to incremental levels of nitrogen. Application of the second top dose of nitrogen through foliage produced more number of panicles. It also increased the weight of panicle, number of filled grains per panicle and number of filled grains per unit area. Test weight of grain was more at higher levels of nitrogen. Foliar application also increased the test weight of grain.

Maximum yield of grain was recorded at 120 kg N/ha which was on par with 160 kg N/ha. The average yields of grain at the 40, 80, 120 and 160 kg N levels were 3149, 3818, 4106 and 4027 kg/ha respectively. Foliar application of the second top dose of nitrogen was superior to soil application in increasing grain yield. Higher grain yield was obtained at 10 x 15 cm spacing. Quadratic response curve was found to be a suitable fit for nitrogen dose. The overall economic optimum level of nitrogen was 120 kg/ha. It was low (109 kg N/ha) at closer spacing and high (124 kg N/ha) at wider spacing.

Straw yield was increased with increasing levels of nitrogen application. Foliar application also increased the straw yield. Foliar application of nitrogen resulted in higher grain : straw ratio while higher levels of nitrogen decreased the ratio.

Increasing doses and foliar method of nitrogen application increased the nitrogen content of plants at flowering and of straw and grain at harvest. Protein content of grain was high at higher levels of nitrogen. It was also increased due to foliar application.

The uptakes of nitrogen, phosphorus and potassium were more at higher levels of nitrogen and foliar application. This was not influenced by different spacings.

Increasing levels of nitrogen application resulted in only a marginal increase in the residual available nitrogen status of the soil. Residual available phosphorus and potassium in the soil were not appreciably influenced by any of the treatments.

Net income and benefit : cost ratio were highest at 120 kg N/ha. Foliar application also increased the net income. Among the different spacings 10 x 15 cm spacing recorded the maximum net income.

A combination of 120 kg N/ha of which 25 per cent applied through foliage at the panicle initiation stage with 10 x 15 cm spacing was found to be the most ideal for maximum benefit from the rice variety Sabari under the agro-ecological situations of the Southern Region of Kerala.