FERTILIZER MANAGEMENT IN RICE VARIETY CHERADI

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THESIS
submitted in partial fulfilment of the
requirement for the degree
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

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COLLEGE OF AGRICULTURE
Vellayani, Trivandrum
1986

DECLARATION

I hereby declare that this thesis entitled "Fertilizer management in rice variety Cheradi" 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.

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Vellayani,
20th June, 1986.

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CERTIFICATE

Certified that this thesis, entitled "Fertilizer management in rice variety Cheradi" is a record of research work done independently by Smt. Vaijayanthi, C.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ACKNOWLEDGEMENT

My deep sense of gratitude and indebtedness to,

Sri V Ramachandran Nair, Professor of Agronomy and Chairman of the Advisory Committee, for suggesting the problem, his expert advice and constant encouragement throughout the course of the investigation,

Sri K P Madhavan Nair, Professor of Agronomy for his constructive criticisms and valuable suggestions,

Sri N Purushothaman Nair, Assistant Professor of Agronomy and Sri Abdul Hameed, Professor of Agricultural Chemistry and Soil Science for their valuable suggestions and help rendered as members of the advisory committee,

Dr V K Sasidhar, Dr V Muraleedharan Nair and Sri G Raghavan Pillai, Professors of Agronomy and Dr M Abdulsalam, Assistant Professor of Agronomy for their encouragement and invaluable help,

Sri P V Prabhakaran, Professor and Dr P Saraswathy, Associate Professor, Sri C T Mukundan, Technical Assistant and Sri C E Ajitkumar, Junior Programmer of the Department of Agricultural statistics for their help to carry out the statistical analysis, Sri P Suseelan, Director, Department of Agriculture, Kerala for providing the experimental site andother facilities,

The other staff members of the Department of Agronomy, the staff members of State Seed Farm, Kottarakara and to my friends for their many fold assistance,

the Government of Kerala for deputing me for the post-graduate course, to Mr C Rajendran Nair for the excellent typing work done and finally to my beloved husband Mr M P Ramachandran Thampy and children Rejina and Roshna for their inspiration and encouragement.

Vaijayanthi

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INTRODUCTION

I INTRODUCTION

Rice is the most important food grain in the diet of hundreds of millions of Asians, Africans and Latin Americans living in the tropics and sub-tropics. Improved rice production technologies developed in the past have increased the production considerably. Scientists are continuing their efforts to develop new varieties and technologies to boost productivity of rice still further to meet the demands of the ever increasing population.

Even now some of the local varieties are popular among the farmers and more favoured than the high yielding varieties under special situations. This warrants the standardisation of agro-techniques for such popular varieties to suit a specific environment. Cheradi, a local improved variety with an yield potential of more than 3-4 tonnes/ha is popular among the farmers of Quilon and Trivandrum districts. It is a long duration photo-sensitive variety which occupy a major area in Southern districts during Mundakan season. It matures in about 165 to 180 days and is well suited to deep ill drained soil conditions as well. The variety's, higher straw yield and the ability to thrive well in adverse conditions have always prompted the farmers to prefer this variety for the second crop season over other high yielding varieties. It's red kernel is another factor which weighs favourably with this variety among the farmers.

No scientific efforts have been made so far to standardise the agronomic requirements of Cheradi variety though there was a great demand from the farmers for the same. Recently this was brought to the notice of research workers through farmers seminars, departmental workshops and T & V regional conferences. As a primary effort it was felt necessary to standardise the fertiliser requirement and to fix up suitable time of application of Nitrogen for this variety. Hence, the present investigation was undertaken with the following objectives.

1. To find out a suitable fertilizer management schedule for the rice Var. cheradi under the prevailing agro-climatic conditions in Quilon district.

2. To find out the optimum time of application of Nitrogen.

3. To study the uptake of major nutrients as influenced by the different levels of N, P and K.

4. To find out the economics of the fertilizer management schedule.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Several research works have been undertaken in India and abroad to study the role of major nutrient elements in increasing the yield of rice. The variety used in the present investigation being a tall indica the research works mainly with tall and dwarf indicas are reviewed hereunder.

NITROGEN

Nutritional Importance of Nitrogen

Nitrogen is the most limiting nutrient for rice production; the key element to increased yield of rice.

According to Takahashi (1961) and Yamazaki (1965) the nitrogen that an ordinary rice plant absorbs to produce a unit grain yield is nearly constant at 19-21 kg N/t brown rice. Park et al. (1969) found that to produce 100 kg brown rice, the rice plants, regardless of soil type or time of transplanting, must absorb about 1.7 kg nitrogen. Ramamoorthy et al. (1971) reported that 1.8 kg nitrogen was required to produce 100 kg of rough rice.

An important consideration to improve grain yield as well as protein quality is the selection of the proper amount of nitrogen fertilizer and the optimum time and method of application. According to Uexkull (1976) nitrogen stimulates tillering, production of new leaves and increases the size of leaves. According to Tisdale and Nelson (1985) an adequate supply of nitrogen is associated with vegetative growth. Lack of nitrogen at tillering and shooting stages inhibits the development of panicle and lower its kernel content.

Excess nitrogen application weakens the plant, exposes it to various cryptogamic diseases, causes lodging, lowers the percentage of ripened grains and has an unfavourable effect on milling.

1. <u>Influence of nitrogen on growth characters and Growth analysis</u>.

Effect of nitrogen on growth and growth characters of rice, as reported by many workers, are detailed below:

a. Height of plants.

In an investigation, Lenka and Behera (1967) found a progressive increase in plant height with increased levels of nitrogen (0 to 120 kg/ha) in two long-strawed varieties. They also found that this character vary significantly only upto 80 kg N/ha.

Koyama and Niamsrichand (1973) obtained an increase in plant height with increasing levels of nitrogen up to 93 kg/ha in rice <u>cv PB 7663</u>. Sadayappan et al. (1974).

reported that plant height increased with increasing doses of nitrogen and that maximum height was obtained with 200 kg N/ha, which was however on par with 150 and 100 kg N/ha. Alexander et al. (1974) and Gunasena et al. (1979) also reported an increase in height of plants with increasing rate of applied nitrogen. Roy et al. (1980) reported that increase in supply of nitrogen increases height and a deficiency results in stunted growth of rice plant. In an experiment conducted at Rice Research Station, Kayamkulam with rice cv Jaya, Sushamakumari (1981) observed significant increase in height of plants at all highest levels of nitrogen. In the same location Sobhana (1983) also obtained similar trend on rice variety 'Mashuri'. In an investigation with rice variety Lekshmi, Surendran (1985) reported significant increase in plant height at all stages of growth with higher doses of nitrogen up to 80 kg/ha.

While investigating the fertilizer requirement of Lekshmi variety of rice at Rice Research Station, Kayamkulam Sreekumaran (1981) reported that plant height was not significantly increased with different levels of nitrogen. Based on the investigation carried out at Rice Research Station, Pattambi, Ajithkumar (1984) also reported similar results with Mashuri variety.

The review on height of plants indicates that the plant height is considerably influenced by nitrogen application.

b. Tiller count.

Lenka and Behera (1967) found that the number of tillers per plant was progressively increased with increased application of nitrogen. Sood and Singh (1972) observed an increase in ear-bearing tillers with increase in nitrogen dose in tall indica rice. In an experiment with dwarf indicas like ADT-27 and Co-33 Kalyanikutty and Morachan (1974) reported progressive increase in tiller number per hill with increased doses of nitrogen. Gunasena et al. (1979) and De Datta and Surjith (1981) observed an increase in the number of tillers per plant with increased rate of nitrogen application. Sreekumaran (1981) observed gradual increase in the number of tillers with higher levels of fertilizers in Lekshmi variety. Similarly Sushamakumari (1981) observed that nitrogen application had considerable influence on tiller production in all stages of growth. The findings of Ajitkumar (1984) and Surendran (1985) were also in conformity with the above observation.

In general the review shows that the tiller count increases with increase in levels of nitrogen.

c. Leaf area index.

Trials conducted at the International Rice Research Institute, Philippines to study the variability of leaf area index and leaf thickness at various nitrogen levels, revealed that the leaf area index was influenced with an increase in nitrogen levels, and was highest at flowering (Anon, 1965). Singh and Pande (1974) obtained increased leaf area at increased rate of nitrogen but cautioned that mutual shading may give a lower total photosynthetic activity. Effect of nitrogen fertilization on the development of LAI on two rice varieties IAC 47 and CICA 4 was studied by Stone and Steinmetz (1979) and they reported that nitrogen increased the LAI in the cultivars due to influence on the increment of the number of tillers and size of the leaves. Abdulgalil et al. (1979) studied the effect of nitrogen fertilization on the physiological behaviour of twelve rice varieties in which they found that nitrogen increased the LAI at all growth stages.

Similarly, Murthy and Murthy (1981) observed that enhanced application of nitrogen resulted in an increase in leaf area index. Results of the field experiment conducted by Sreekumaran (1981) showed that there was an increase in the leaf area index along with the increase in level of nutrition. So also, in her experiment with cv.<u>Jaya</u>

Sushamakumari (1981) observed that successive increments in nitrogen levels produced significant influence on leaf area index at tillering, panicle initiation, flowering and at harvest. Sobhana (1983) noticed a progressive increase in leaf area index by increasing the fertilizer levels from 50:25:25 kg/ha to 80:40:40 kg/ha of NPK. According to Surendran (1985) levels of nitrogen significantly increased leaf area index at active tillering, panicle initiation and flowering stages.

The review points out that there is a positive correlation between leaf area index and nitrogen rates.

d. Crop growth rate and relative growth rate.

In an investigation with two dwarf and two tall cultivars, Palit et al. (1976) obtained an increase in crop growth rate with increased application of nitrogen. Surendran (1985) also reported similar result with rice variety Lekshmi.

Rao and Ramanujam (1971) observed progressive increase in relative growth rate in response to nitrogen applied in rice cv. ADT-27. Surendran (1985) reported higher RGR values with application of nitrogen over control with no nitrogen in rice.

e. Dry matter production.

Based on an experiment to study the influence of nitrogen supply on growth factors Ramanujam and Rao (1971) reported that dry matter yield increased with increase in nitrogen application. In an investigation with three rice cultivars Singh and Pande (1974) also obtained similar results. Nair (1976) observed significant increase in dry matter production at harvest in direct sown Triveni crop when the level of nitrogen was raised from 50 to 70 kg/ha. Gunasena et al. (1979) obtained increase in dry matter production with increased application of nitrogen.

According to Nagre and Mahajan (1981) dry matter accumulation at 95-100 days after transplanting was significantly increased when the dose of nitrogen was enhanced from 50 to 150 kg/ha. Significant increases in dry matter production with increase in the level of nitrogen first from 45 to 60 and again from 60 to 90 kg/ha was observed at tillering, flowering and harvesting stages in an experiment with Jaya variety at Rice Research Station, Kayamkulam (Sushamakumari 1981). Upadhyay and Pathak (1981) reported an increase in dry matter production with an increase in the level of nitrogen from 0 to 180 kg (increment of 60) in rice cv. Ratna. Surendran (1985) reported progressive increase in dry matter production for Lekshmi variety when the level of nitrogen was raised from 20 to 80 kg/ha.

In general the review points out that the dry matter production was favourably influenced by increased levels of nitrogen.

2. Influence of nitrogen on yield attributes.

a. Number of productive tillers and panicles.

Nishi and Kaneki (1967) studied the effect of different levels of nitrogen in indica and japonica varieties of rice and reported that the yield differences in indica and japonica varieties were associated with increases in panicle number and that the indicas responded markedly to incremental rates of nitrogen. Ramanujam and Rao (1971) found that the number of panicles per hill increased at higher levels beyond 60 kg, when rice variety ADT-27 was given 0 to 180 kg N/ha. According to Muthuswamy et al. (1972) rice varieties Karuna, Kaveri and Kanchi showed increased number of productive tillers with higher rates of nitrogen application and the highest was observed at 160 kg/ha. Sood and Singh (1972) observed an increase in the number of ear-bearing tillers in tall indica with an increase in nitrogen levels from 0 to 90 kg/ha.

According to Koyama and Niamsrichand (1973) number of panicles per hill increased with increasing rate of nitrogen up to 94 kg/ha and tiller number was closely related to nitrogen rate during early but not the later stages of growth where the levels tried ranged from 0 to 131.2 kg/ha. Rethinam (1974) reported that increasing rates of nitrogen from zero to 160 kg/ha produced linear increases in average number of productive tillers per hill. Dixit and Singh (1979) observed that application of 80 kg N/ha significantly increased the number of ear bearing tillers in rice over 0 and 40 kg/ha. Sushama kumari (1981) observed significant effect of nitrogen levels upto 90 kg N/ha on the number of panicle per unit area. Balasubramaniyan(1984) reported that number of panicle per hill increased with increase in nitrogen application and were highest at 120 kg N/ha. Surendran (1985) reported progressive increase in number of panicles with enhanced application of nitrogen from 20 to 80 kg N/ha.

The review points out that the panicle production especially panicle number, was considerably increased by nitrogen application.

b. Length of panicle.

Trials conducted under the All India Co-ordinated Rice Improvement Project at 16 locations, showed that the panicle length was increased with application of nitrogen upto 100 kg/ha (Anon., 1969 a). Lenka (1969) observed that the length of panicle increased with the levels of nitrogen, viz., 0, 40, 80 and 120 kg/ha. From a trial with the rice variety ADT-27 Ramanujam and Rao (1971) reported that panicle length increased with increase in applied nitrogen upto 180 kg/ha. Singh (1971) reported an increase in panicle length of rice with increase in nitrogen levels from 0 to 160 kg/ha. Dixit and Singh (1979) reported an increase in the length of panicle with increased levels of nitrogen. Sushamakumari (1981) reported significant increase in panicle length due to increase in the level of nitrogen. Surendran (1985) reported a progressive increase in the length of panicle with enhanced application of nitrogen from 20 to 80 kg/ha in Lekshmi variety of rice.

On the otherhand, Sreekumaran (1981) while investigating the fertilizer requirement of Lekshmi variety of rice did not observe any significant difference in the length of panicle due to increased levels of fertilizers. Ajitkumar (1984) also obtained similar results with Mashuri variety.

The review points out that the length of panicle is favourably influenced by levels of nitrogen.

c. Weight of panicle.

Sreekumaran (1981) observed significant increase in the weight of panicles due to different levels of nitrogen from 40 to 90 kg/ha. Sushamakumari (1981) also reported significant increase in the weight of panicles at 60 and 90 kg levels of nitrogen in Jaya variety.

But contrary to the above findings, Potty (1964) reported that nitrogen levels have no influence on panicle weight. Similarly, Ajitkumar (1984) and Surendran (1985) also did not observe any significant difference in the weight of panicles with levels of nitrogen.

In general the review points out that nitrogen favourably influences the weight of panicles.

d. Number of spikelets per panicle.

Panda and Leeuwrik (1972) observed an increase in the number of fertile and sterile spikelets per panicle upon increasing the nitrogen levels upto 200 kg/ha. Increase in Spikelet number per panicle with increased rate of nitrogen upto 94 kg/ha. was observed by Koyama and Niamsrichand (1973). In a trial conducted by Prasad and Sharma (1973) the higher nitrogen level of 225 kg/ha. more than doubled the total number of spikelets per panicle as against the control with no nitrogen. De Datta and Surjith (1981) reported that nitrogen increases the number of spikelets per panicle in rice. Sushamakumari (1981) observed that levels of nitrogen significantly influenced the number of spikelets per panicle when Jaya variety was given varying levels of nitrogen ranging from 45 to 90 kg/ha. Surendran (1985) observed significant increase in spikelet number at 40 kg N/ha compared to other levels in Lekshmi variety.

On the other hand Nair (1976) reported that the number of spikelets per panicle was not influenced by levels of nitrogen in direct sown Triveni variety of rice.

In general the review point out that nitrogen application is beneficial for increasing spikelet number.

e. Number of filled grains per panicle.

Ramanujam and Rao (1971), studying the effect of levels of nitrogen on yield components, found that the percentage of filled grains was not altered beyond 60 kg N/ha. Alexander et al. (1974) noticed that number of grains per panicle was increased by levels of nitrogen. De Datta and Surjith (1981) reported that nitrogen increases the filled spikelet percentage per panicle. Sobhana (1983) reported that the number of filled grains per panicle increased with increased nutrient supply. In an investigation with Lekshmi variety, Surendran (1985) observed significant increase in filled grains per panicle when the level of nitrogen was enhanced from 20 to 40 kg/ha.

Contrary to the above findings, Sreekumaran (1981) and Ajitkumar (1984) concluded that levels of fertilizers had no influence on number of grains per panicle either in

Lekshmi variety or in *Mashuri* variety.

The review points out that the application of nitrogen up to a certain level can definitely increase the filled grain production.

f. Percentage of unfilled grains.

Patel (1967) observed a linear increase in the percentage of unfilled spikelets with increasing levels of nitrogen. Kalyanikutty et al. (1968) reported higher percentage of chaffiness with enhanced application of nitrogen. Enus and Sadique (1978) also reported higher percentage of chaffiness with enhanced application of nitrogen. Surendran (1985) observed a linear decrease in the percentage of unfilled grains with increase in nitrogen dose from 20 to 60 kg/ha but at 80 kg level a marked increase in the percentage of unfilled grains was observed.

In general, percentage of unfilled grains increase with higher rates of nitrogen.

g. Thousand grain weight.

Nishi and Kaneki (1967) reported an increase in thousand grain weight both in indica and Japanica rice with increase in levels of nitrogen. Kalyanikutty and Morachan (1974) obtained highest thousand grain weight at 120 kg N/ha in Co-33, a dwarf indica rice variety and at 40 kg N/ha both in tall indica variety TKM-6 and in hybrid variety Adt-27. Nair (1976) observed significant increase in thousand grain weight when the level of nitrogen was enhanced from 50 to 70 kg/ha. Raju (1979) also obtained significant increase in thousand grain weight with increase in nitrogen application. Sushamakumari (1981) reported profound influence on thousand grain weight due to increased fertilizer application. But Ajitkumar (1984) did not obtain any significant increase in thousand grain weight with higher levels of fertilizers. Surendran (1985) reported that thousand grain weight increased due to application of nitrogen only upto 60 kg level in Lekshmi variety of rice.

Thousand grain weight increases with increase in level of nitrogen up to a certain level and this depends on variety.

3. Effect of nitrogen on yield.

a. Grain yield.

The performance of four short strawed, high tillering varieties and two local, long-strawed indica varieties with four levels of nitrogen (0, 40, 80 and 120 kg/ha) was studied by Lenka and Behera (1967) and they found a significant increase in grain yield up to 120 kg N/ha in dwarf varieties and up to 80 kg N/ha in tall local varieties. Nishi and Kanaki (1967) observed marked response in indica rice to increasing rate of applied nitrogen. The response of four varieties to different levels of nitrogen from 0 to 150 kg/ha was studied by Bathkal and Patil (1968) and found that TN-1 responded up to 100 kg N/ha where as Dodga, E.K.70 and Basumathi showed response upto 50 kg N/ha.

The study conducted by Ramanujam and Rao (1971) to assess the responsiveness of Adt-27 variety of rice to different levels of nitrogen ranging from 0 to 180 kg/ha. revealed that levels of nitrogen beyond 90 kg did not contribute to the yield. Sood and Singh (1972) obtained enhanced grain yield in tall-indica rice, with increasing rates of nitrogen (0 to 90 kg/ha). Rethinam (1974) observed 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.

Sharma and De (1976) found that increase in nitrogen rates from 0 to 150 kg/ha enhanced the average yields from 3.76 to 5.56 t/ha and further increase in nitrogen rates did not contribute to additional yield. Bhuiya et al. (1979) reported per hectare increase of 600 kg grain when the level of nitrogen was enhanced from 0 to 60 kg/ha. Gunasena et al. (1979) obtained increase in grain yield from 3.63 to 6.52/ha when the level of nitrogen was raised from 0 to 90 kg/ha during wet season in Sree Lanka. Surendran (1985) reported that an increase in the level of nitrogen from 20 to 60 Kg/ha has brought about a progressive increase in grain yield. He also reported that application of 60 kg N/ha gave highest grain yield of 3684 kg/ha where as it decreased to 3164 kg/ha with 80 kg level.

The review points out that the grain yield increases with increasing level of nitrogen up to a certain level and the response is more pronounced in dwarf indicas compared to tall indicas.

b. Straw yield.

Tanaka et al. (1964) reported that in the case of tall indica varieties, nitrogen acts as a vegetative growth stimulator resulting in higher straw production instead of correspondingly increasing the grain yield as in the case of dwarf indicas. In a study conducted by Patel (1967) it was found that the tall indica variety, '<u>Triple Burma cross</u>', produced significant increase in straw yield with enhanced rates of nitrogen application ranging from 0 to 60 lb per acre (0 to 67 kg/ha). Similarly, significant increase in straw yield to increased application of nitrogen was observed by Sahu and Lenka (1967). A progressive increase in straw yield with increased levels of nitrogen was reported by Sood and Singh (1968) with coarse and fine rice varieties and the difference in yield was highly significant. In a nitrogen-varietal trial it was found that the tall indicas produced distinctly higher straw yields at higher levels of nitrogen. (Anon., 1969 b). A curvilinear increase in straw yield with higher nitrogen rates was reported by Allen and Terman (1978). Sushamakumari (1981) observed that nitrogen at higher levels progressively increased the straw yield. She recorded the highest straw yield at 90 kg N/ha and it was significantly superior to 45 or 60 kg levels. Bhatti et al. (1982) revealed that straw yield increased from 5.72 to 12.77 t/ha with increased dose of nitrogen ranging from 0 to 120 kg/ha. Surendran (1985) reported an increase in straw yield with successive addition of nitrogen from 20 to 80 kg and was highest at 80 kg N/ha in Lekshmi variety.

In general the review points out that the straw yield increases with increasing nitrogen fertilization especially with tall indicas.

c. Grain to straw ratio.

Prasad (1981) reported a decrease in the harvest index with an increase in the level of nitrogen from 0 to 100 kg/ha. Sreekumaran (1981) observed significant reduction in grain to straw ratio with increasing levels of nitrogen; the highest level of 120 kg N/ha recording the lowest ratio. Sushamakumari (1981) reported a marked influence of nitrogen on grain straw ratio and obtained the highest value of 0.51 with 45 kg N/ha. Son et al. (1983) also reported decrease in harvest index with increased nitrogen application. Surendran (1985) noted the highest harvest index of 0.335 with 40 kg N/ha and beyond that a decrease was observed with 60 and 80 kg nitrogen levels.

In general a decrease in the harvest index is reported with an increase in the level of nitrogen.

d. Grain protein.

Kulkarni (1973) reported a 40 to 50 % increase in the grain protein content with increasing rates of nitrogen from 0 to 150 kg/ha in six tall indica and semi dwarf rice cultivars. Sadayappan and Kolandaiswamy (1974) recorded an increased protein content with increasing levels of nitrogen and the maximum content of 12.09 per cent protein in the grain was registered by 200 kg N/ha. Considerable increase in grain protein content with nitrogen application was reported by Nagarajan et al. (1975) and Rabindra et al. (1977). Singh and Prakash (1979) and Mahajan and Nagre (1981) also reported similar results.

Sreekumaran (1981) obtained significant difference in grain protein content with levels of nitrogen in Lekshmi variety. Ajitkumar (1984) also obtained significant increase in grain protein content with levels of nitrogen and recorded maximum percentage of 8.41 with 70 kg/ha. Surendran (1985) observed an increase in protein content of grain with increased nitrogen ratio ranging from 20 (6.42%) to 80 Kg/ha (8.02%).

In contrast to the above results, it was observed by Muthuswamy et al. (1973) that forms and levels of nitrogen had no effect on the crude protein content of grain. Subramanian et al. (1974) also observed no significant difference in protein content with nitrogen application.

In general nitrogen increases the protein content in grain and there by improve its quality.

4. Uptake of nitrogen.

An investigation undertaken by Sims and Place (1968) to study the nutrient uptake of rice at different nitrogen levels revealed that increasing nitrogen application increased nitrogen uptake in three rice cultivars tried, viz., Vegold, Nato and Bomet-50. Gopalaswamy and Raj (1977) reported that increasing the rates of applied nitrogen from 0 to 200 kg/ha produced linear increases in the uptake of nitrogen.

Application of nitrogen upto 120 kg/ha increased the uptake as reported by Agarwal (1978). Similar increases were also noticed by Raju (1978) and Singh and Modgal (1978).

Significant increases in nitrogen uptake with rates upto 80 kg/ha was reported by Rai and Murthy (1979). Sushamakumari (1981) also reported that levels of nitrogen significantly influenced nitrogen uptake at all stages of growth. Ajitkumar (1984) reported that uptake of nitrogen was significant between levels of nitrogen in Mashuri variety of rice. Surendran (1985) also reported similar results with Lekshmi variety.

Krishnaswamy et al. (1974) reported increased uptake of nitrogen with increase in the levels of phosphorus. Gupta et al. (1975) reported from pot trials on five rice cultivars that the uptake of nitrogen increased with an increase in rates of phosphorus. Suseelan et al. (1978) also reported similar results. Singh and Prakash (1979) reported significant increase in the uptake of nitrogen with increase in the levels of phosphorus and potassium.

In general the review points out that nitrogen uptake is favourably influenced by increase in the levels of major nutrients.

PHOSPHORUS

Nutritional Importance of Phosphorus

Phosphorus is referred as the "key to life". The importance of phosphorus nutrition in crop production is recognised by the fact that a deficiency of this element is very often a limiting factor in many soil types. At the same time it is very critical in the plant nutrition in as much as it controls several vital metabolic processes with in the plant. Phosphorus is required for root development and early maturity. It is involved in plant metabolism, energy transformation and photosynthesis and induces disease resistance.

Venkatarao and Govindarajan (1956) found that phosphorus had a decisively beneficial influence on the formation of grain as against purely vegetative growth induced by nitrogen and the recovery of added nitrogen and phosphorus depend on the optimum level of phosphorus in relation to nitrogen. According to Chaversia (1980) phosphorus allows the use of optimum nitrogen without detriment to straw strength, fertile ears or maturation of grain and the specific weight of the grain depend on the phosphate fertilization to a certain extent. De Datta and Surjith (1981) propounded that phosphorus encourages active tillering and stimulates root development. They added that it gives food value in addition to the promoting of good grain development.

It has been estimated that to produce one kg of grain the rice crop removes 3-11 kg phosphorus.

1. Influence of phosphorus on growth characters.

a. Height of plants.

Jagadeeschandran (1968) reported that the height of rice plants increased significantly with increase in the levels of phosphorus from 25 to 75 kg P_2O_5/ha. Aaron et al. (1971) reported that increased application of phosphorus increased the plant height in rice variety IR-8. Chowdhury et al. (1978) observed that the plant height increased with increasing phosphorus application in rice.

However trials conducted by Nair et al. (1972) at the Rice Research Station, Pattambi, revealed that phosphorus application did not have any significant influence on the mean height of the plant at maturity. Field investigations by Rao et al. (1974) to study the response of IR-5 rice for phosphorus showed that height of the plant was not significantly influenced by the application of phosphorus up to 80 kg/ha. Usha (1985) revealed that phosphorus had no significant influence on the height of plant at any of the growth stages in rice variety, Triveni.

Review on plant height indicated that the height of plants was not considerably influenced by phosphorus application.

b. Tiller count.

Terman and Allen (1970) observed that tiller numbers on rice increased markedly with amount of applied phosphorus on the low-P soil and slightly on the medium-P soil and there was no response on the high - P soil. Nair et al. (1972) noted that tillering was markedly influenced by phosphorus application. Katyal et al. (1975) observed that tillering in many rice cultivars increased with increasing rates of applied P_2O_5 from 20 to 40 kg/ha. Bhattacharya and Chatterjee (1978) found that application of phosphorus with nitrogen aided early tillering. Chowdhury et al. (1978) observed that tiller number per plant increased with increasing phosphorus application. Fageria et al. (1982) reported increase in the number of tillers/m^2 with increase in the level of phosphorus from 0 to 66 kg/ha.

Contrary to these results, Alexander et al. (1974) reported that phosphorus had no effect on the number of tillers per hill. Kalyanikutty and Morachan (1974) reported that phosphoric acid did not seem to have any marked effect on the number of tillers. Suseelan et al. (1978) observed that phosphorus did not significantly affect tiller production.

Usha (1985) also reported that phosphorus did not significantly influence the number of tillers at any stages of growth in rice variety Triveni.

In general, phosphorus increases the tiller count to a certain extent.

2. Influence of phosphorus on yield attributes.

a. Number of productive tillers and panicles.

In field trials with increasing rates of applied phosphorus from 0 to 90 kg/ha, Place et al. (1970) reported that the number of panicles was increased with increase in the levels of phosphorus. Majumdar (1971) reported that phosphorus nutrition effected a significant increase in the number of productive tillers by an application of 59.7 kg phosphorus per hectare. Investigations by Nair et al. (1972) revealed that phosphorus application resulted in significantly higher number of productive tillers over the control. Kuo (1973) reported that application of 72 kg P_2O_5/ha gave the highest increase in the number of panicles per hill over the control (36 kg P_2O_5/ha). Bhattacharya and Chatterjee (1978) observed an increase in the production of early tillers with phosphorus application which resulted in more number of productive tillers per hill. Bhatti et al. (1985) obtained highest number of panicles/m^2 with 85 kg phosphorus per hectare.

However, Aaron et al. (1971) reported that there was no increase in the number of panicles per plant with applied phosphorus beyond 30 kg P_2O_5/ha. Studies conducted by Alexander et al. (1974) on the rice cv. Triveni showed that the number of fertile tillers remained unaffected by phosphate application. Rao et al. (1974) observed that the number of productive tillers was not significantly influenced by the levels of phosphorus. Sadanandan and Sasidhar (1976) also observed that increasing the rate of applied phosphorus had no significant effect on the number of productive tillers per plant. Usha (1985) also reported similar results with Triveni variety.

In general phosphorus application favours the production of productive tillers and thereby panicles in rice.

b. Length of panicle.

Potty (1964) observed that the length of earhead was positively influenced by phosphorus at 30 lb per acre (34 kg/ha). Majumdar (1971) reported that panicle length was significantly enhanced with higher levels of phosphorus application up to 59.7 kg per hectare.

Singh and Varma (1971) reported that the length of panicle was not influenced by phosphorus nutrition at 60 or 90 kg per hectare. Rao et al. (1974) reported that length of panicle was not significantly influenced by levels of phosphorus. Usha (1985) also reported that the application of phosphorus did not significantly influence the length of panicle.

In general the length of panicle is not significantly influenced by phosphorus application.

c. Weight of panicle.

Investigations by Place et al. (1970) revealed that increasing the levels of phosphorus application from 0 to 56 kg P_2O_5/ha increased the panicle weight. Chowdhury and Mian (1978) reported that panicle weight increased with increasing levels of applied phosphorus. Usha (1985) obtained significant influence on the weight of panicle with phosphorus application in Triveni variety.

In general phosphorus application favourably influences the weight of panicle in rice.

d. Number of grains per panicle.

Aaron et al. (1971) reported that increased dressing of phosphorus increased the number of grains per panicle. Majumdar (1971) revealed that the number of grains per panicle was significantly increased by application of 59.7 kg phosphorus per hectare. Singh and Varma (1971) observed distinct increase in the number of grains per panicle by the application of 90 and 60 kg P_2O_5 over 30 kg/ha.

Sasaki and Wada (1975) reported that low levels of phosphorus increased the percentage of sterile grains and can be altered by the addition of phosphorus. Uexkull (1976) propounded that phosphorus increases the percentage of filled grains. Bhattacharya and Chatterjee (1978) reported that phosphorus application induced early tillering which inturn gave more number of filled spikelets per panicle.

Reddy (1967) stated that there was no significant effect of phosphorus on the number of filled or unfilled grains. Suseelan (1969) obtained no effect of phosphorus on percentage sterility in rice. Rao et al. (1974) found that the number of filled and chaffy grains was not significantly influenced by the levels of phosphorus. Sadanandan and Sasidhar (1976) found no significant effect on the number of filled grains per panicle with increased rates of applied phosphorus. Suseelan et al. (1978) did not observe any significant effect on the number of filled grains per panicle with increasing rate of applied phosphorus. Usha (1985) reported that the number of grains per panicle and sterility percentage were not influenced by the levels of phosphorus application.

In general phosphorus favours early tillering in rice and there by increase the number of grains per panicle.

e. Thousand grain weight.

Halappa et al. (1970) reported that application of 60 kg P_2O_5/ha resulted in highest thousand grain weight (29.8 g). Majumdar (1971) noticed that application of 59.7 kg/ha caused an increase in thousand grain weight. Singh and Varma (1971) could observe a distinct increase in the weight of thousand grains with the application of 60 and 90 kg phosphorus over 30 kg phosphorus per hectare. Kuo (1973) observed that application of 72 kg P_2O_5/ha resulted in an increase in thousand grain weight. Research reports of Thandapani and Rao (1976) revealed that increasing the levels of phosphorus from 0 to 45 kg/ha increased thousand grain weight where as further application decreased it. Chowdhury et al. (1978) reported that thousand grain weight increased with increasing phosphorus application.

Padmakumari et al. (1969) reported that phosphorus had no consistent effect on thousand grain weight. Place et al. (1970) recorded a decrease in thousand grain weight with increase in the levels of phosphorus applied from 0 to 56 kg/ha. Alexander et al. (1974) observed that different levels of phosphorus did not have any positive effect on thousand grain weight. Usha (1985) noticed that thousand grain weight was not influenced by the levels of phosphorus application.

In general phosphorus favourably influences the grain development and thereby increases thousand grain weight.

3. <u>Effect of phosphorus on yield.</u>

a. Grain yield.

Naphade (1969) obtained significant grain yield responses to 45 and 90 kg P_2O_5/ha. Padmakumari et al. (1969) reported from pot trials with an acid peat soil that phosphorus rates upto 100 kg/ha gave significant increase in the grain yield over 0 kg P_2O_5/ha. Dev et al. (1970) observed that increases in the rates of applied P_2O_5 from 30 to 90 kg/ha were accompanied by linear increases in the average paddy yields from 3.0 to 4.32 t/ha at Ramba. According to Khatua and Sahu (1970) application of 40 kg P_2O_5/ha resulted in increased paddy yields compared to no phosphorus application. Trials by Aaron et al. (1971) showed that increased dressing of phosphorus increased the yields of paddy. Majumdar (1971) noted a trend towards increased grain yield with high dose of phosphorus upto 59.4 kg P_2O_5/ha. Rao et al. (1974) showed that paddy yield obtained with 40 kg P_2O_5/ha was not further significantly increased by increasing the rate to 80 kg P_2O_5/ha.

According to Gopalakrishnan et al. (1975) grain yield was influenced by phosphorus application. Katyal et al.(1975)

observed that paddy yields in many cultivars increased with increasing rates of applied P_2O_5 from 20 to 40 kg/ha. Prabha et al. (1975) reported that at higher doses of 80 and 100 kg P_2O_5/ha paddy yields decreased slightly in IR-8 variety. Long term fertility experiments at IRRI revealed that rice cultivars IR-8, IR-36 and IR-26 gave no significant response to added phosphorus (Anon 1976). Field trials by Dixit and Singh (1977) showed that grain yield increased from 2.4 t/ha with no phosphorus application to 2.7 t/ha with 40 kg P_2O_5/ha. Suseelan et al. (1978) revealed that grain yield was not influenced by phosphorus application.

Ageeb and Yousif (1978) reported that application of phosphorus produced significantly higher grain yield in rice with an optimum economic level of 42.8 kg P_2O_5/ha. Increase in grain yield with increasing level of applied phosphorus up to 100 kg/ha was noticed by Rabindra (1978). Agarwal (1980) reported significant increase in grain yield with P_2O_5 upto 180 kg/ha. Dargan et al. (1980) reported that applied phosphorus had no effect on the grain yield. Abrol (1980) revealed that application of 50 kg P/ha had no effect on the yields of rice. Upadhyay and Pathak (1981) reported an increase in the grain yield with an increase in the level of phosphorus from 0 to 60 kg P_2O_5/ha in rice cv. Ratna. The results of 20 field trials by Rajas and Alvarado (1982) revealed that phosphorus had no effect on the yield. Ghobrial (1982) reported an increase in grain yield with an increase in the level of phosphorus from 0 to 52 kg/ha. Rice yield response to phosphorus application was investigated by Bhatti et al. (1985) and they obtained the highest grain yield of 7.4 t/ha with 34 kg phosphorus per hectare. According to Usha (1985) levels of phosphorus had no effect on the grain yield.

In general increased dressing of phosphorus increases the paddy yield.

b. Straw yield.

Patel (1967) in a field experiment given 20, 40 and 60 kg P/ha reported that straw yield increased with increasing levels of phosphorus. Place et al. (1970) reported an increase in straw yield with increasing levels of phosphorus. In a pot trial given 0, 20, 40, 60, 80 and 100 kg phosphorus per hectare, Prabha et al. (1975) reported an increase in straw yield with an increase in the application of phosphorus from 0 to 100 kg P_2O_5/ha. Singh and Prakash (1979) noticed that the crop showed significant response to phosphorus application. Increase in straw yield due to application of 40 and 80 kg P_2O_5/ha over no phosphorus was in the order of

11.0 and 15.4 percent respectively. Rastogi et al. (1981) also reported increase in straw yield with phosphorus application.

However Loganathan and Raj (1971) reported that straw yields were not affected by the application rates of phosphorus. Alexander et al. (1974) observed no significant effect on straw yield by the application of different levels of phosphorus. Rao et al. (1974) reported that there was no significant effect on straw yield due to phosphorus application. Sadanandan and Sasidhar (1976) found that increasing the level of applied phosphorus had no significant effect on the yield of straw. The straw yield was not influenced by phosphorus application as observed by Suseelan et al. (1978) Bhatti et al. (1985) and Usha (1985).

Even though phosphorus favours the production of straw the effect is not as marked as with nitrogen.

4. <u>Effect of phosphorus on quality of grain.</u>

Thandapani and Rao (1974) reported that increasing phosphorus favourably influenced the protein nitrogen in grain. Kadrekar and Mehta (1975) opined that optimum rate of phosphorus application for satisfactory grain protein content was 40 kg per hectare in rice cultivars <u>TN-1</u> and <u>IR-8</u>. Agarwal (1978) reported that increasing the rate of applied phosphorus from 0 to 120 kg/ha increased the crude protein content of the grain from 9.76 to 10.28 percent. Singh and Prakash (1979) reported that applied phosphorus increased the nitrogen content in the grain.

Ageeb and Yousif (1978) observed a reduction in grain protein percentage from 7.11 to 5.81 by increasing the phosphorus level from 0 to 107 kg P_2O_5/ha, but the total protein yield seemed unaffected. Bhuiya et al. (1979) reported that phosphorus had no significant effect on the crude protein content in grain. Usha (1985) observed no significant difference in the protein content of the grain with different levels of phosphorus.

In general phosphorus improves the quality of grain.

5. Uptake of phosphorus.

Gupta et al. (1975) reported from pot trials on five rice cultivars that uptake of phosphorus increased with higher rates of applied phosphorus. Suseelan et al. (1978) found that there was significant increase in phosphorus uptake with increasing rates of phosphorus fertilizer at all stages of growth.

The influence of nitrogen on phosphorus transformation and subsequent increase in the uptake of phosphorus was stressed by Singh (1967). Sushamakumari (1981) observed significant increase in phosphorus uptake with increasing levels of nitrogen from 45 to 90 kg/ha with rice variety Jaya. Surendran (1985) also reported an increase in phosphorus uptake with increase in the levels of nitrogen from 20 to 80 kg/ha.

Trials by Singh et al. (1976) revealed that phosphorus uptake increased with an increase in the levels of potassium. Singh and Prakash (1979) also reported a similar result.

In general nitrogen, phosphorus and potassium favours the uptake of phosphorus.

POTASSIUM

Nutritional Importance of Potassium

Potassium has a catalystic role in biological reactions. It has been estimated that to produce 1 kg of grain, the quantity of potassium removed by a rice crop is 25 kg.

Potassium promotes photosynthesis, promotes translocation of assimilates, improves grain filling and induces disease resistance. When used in conjunction with nitrogen and phosphorus it increases the yield. According to Roy et al. (1980) potassium stimulates building up and translocation of carbohydrates and grain development. Steineck and Haeder (1980) propounded that nitrogen utilization by the rice plant is determined by the potassium supply. The potential of nitrogen to increase yield and dry matter is only fully realised when the necessary amount of potassium is also supplied. Inadequate supply of potassium results in stunted plants with short droopy and dark green leaves (De Datta and Surjith, 1981).

1. Influence of potassium on growth characters.

a. Height of plants.

Ramankutty (1967) reported a progressive increase in the plant height with an increase in the supply of potassium from 0 to 120 kg/ha in Tainan-3. Results of field experiments involving two winter rice varieties and four levels of potassium viz., 0, 60, 120 and 180 lbs per acre (0, 67, 134, 201 kg/ha) along with different levels of nitrogen, revealed that the height of plants was progressively increased with potassium increments at 34 kg nitrogen per hectare (Mukherji et al. (1968)). Vijayan and Sreedharan (1972) reported significant increase in plant height with increase in the level of potassium from 20 to 80 kg/ha in IR-8 variety of rice. Based on the field trials on the response of rice plants to potassium, Xu et al. (1984) reported significant increase in plant height.

on the other hand, Kalyanikutty and Morachan (1974) observed that potash application did not markedly affect plant height. Rao et al. (1974) found no significant increase in plant height by the application of potassium up to 80 kg K_2O/ha.

In general, potassium at higher levels influenced the plant height.

b. Tiller count.

Usha (1966) noticed a beneficial influence of potassium in paddy by way of promoting tillering capacity. Investigations undertaken by Kulkarni et al. (1975) showed that the effect of potash was significant on the total number of tillers. Singh and Singh (1979) obtained increased tillering with application of potash up to 60 kg/ha in two split dressing.

Contrary to these above mentioned reports, Ramankutty (1967) observed that potassium had no significant effect on the number of tillers. Mukherji et al. (1968) pointed out that potassium application had no noticeable effect on tillering. Response of high yielding cultivars to the application of nitrogen, phosphorus and potassium were determined in long term trials by Uexkull (1976) and it was found that the applied potassium slightly decreased tillering in the absence of phosphorus, but increased them in the presence of phosphorus.

2. Influence of potassium on yield attributes.

a. Number of productive tillers and panicles.

Trials on the response of paddy to fertilizers in Shimoga district by Kulkarni et al. (1975) showed that the effect of potassium was significant on the number of effective tillers. Padmaja (1976) observed that the number of productive tillers and consequently panicle production has been favourably influenced by application of potassium. Sahu and Ray (1976) found an increase in the number of effective tillers when tall indicas were supplied with potassium.

However, Rao et al. (1974) reported that the number of productive tillers was not significantly influenced by the application of potash even up to 80 kg K_2O/ha.

In general, the review points out that productive tiller number is favourably influenced by increase in the levels of potassium.

b. Length of panicle.

Summarising the results of trials with rice cv. Jaya Singh and Singh (1979) concluded that application of 60 kg K_2O/ha in split dressing increased panicle length. But Vijayan and Sreedharan (1972) and Rao et al. (1974) reported that application of potassium upto 80 kg K_2O/ha did not have any marked influence on the length of panicle.

In general higher doses of potassium is not necessary for increasing the length of panicle.

c. Weight of panicle.

Potty (1964) failed to record any increase in the weight of panicle with increased levels of potassium. Ramankutty (1967) reported that potassium application up to 120 kg/ha had no significant effect on the weight of panicle in Tainan-3 and TN-1 variety of rice.

In general the weight of panicle is not favourably increased due to increase in the levels of potassium.

d. Number of grains per panicle.

Krishnan (1968) observed that higher levels of potassium increased the number of grains per panicle. Vijayan and Sreedharan (1972) reported increase in the percentage of filled grains with increase in the level of potassium from 20 to 80 kg K_2O/ha. Uexkull (1982) also reported that number of grains per panicle increased with potassium application.

Kalyanikutty and Morachan (1974) observed no significant effect on the number of grains per panicle by supplying potassium. According to Rao et al. (1974) application of potash even upto 80 kg K_2O/ha did not influence the number of filled grains and chaff per panicle.

In general potassium favours the production of more grains per panicle.

e. Thousand grain weight.

Singh and Singh (1979) after detailed study concluded that application of 60 kg K_2O/ha increased the thousand grain weight in rice cv. Jaya. Sreekumaran (1981) reported increase in thousand grain weight due to potassium application upto 70 kg K_2O/ha.

Research findings of Kalyanikutty and Morachan (1974) and Rao et al. (1974) however, showed that potassium application had no effect on the weight of thousand grains.

In general potassium increases the size and weight of grains.

3. Effect of potassium on yield.

a. Grain yield.

Vijayan and Sreedharan (1972) reported that rice cv. IR-8 yielded 3.18 t grains/ha without potassium and 3.45, 3.60, 3.62 and 3.63 t/ha with 20, 40, 60 and 80 kg K_2O/ha respectively. On the basis of trials with rice grown on meadow chernozem soil and given various rates of nitrogen, phosphorus and potassium it was concluded by

Rymar (1973) that the optimum rate of potassium was 90 kg K_2O/ha. Similarly Velly (1973) reported that 90 kg K_2O/ha should be applied to each crop of rice to get higher yields. Experiments conducted by Singh and Dubey (1975) revealed that yields were increased from 3.52 to 4.14 t/ha with increasing potassium rates from 0 to 60 kg K_2O/ha and that 120 kg K_2O/ha gave no additional yield in rice cv. Jaya.

Average paddy yields increased from 2.06 to 2.28 and 2.61 t/ha when potassium rates were increased from 0 to 22.5 and 45 kg K_2O/ha respectively (Sahu and Ray, 1976). Response of high yielding rice cultivars to the application of nitrogen, phosphorus and potassium were studied by Uexkull (1976) and it was found that applied potassium slightly decreased yields in the absence of phosphorus and increased in its presence. The response was 5.40 kg paddy in the dry season and 8.3 to 11.7 kg paddy in the wet season per kg of applied K_2O. Trials conducted by Halm and Dartey (1977) revealed that grain yields increased from 2.33 t/ha with no potash to 2.69 t/ha with the application of 37.20 kg K_2O/ha.

Robinson and Rajagopalan (1977) observed that application of potassium increased the grain yield significantly and the highest grain yield of 4.04 t/ha was recorded at 150 kg K_2O/ha which was 14.10 per cent more than the unfertilized control. Singh and Prakash (1979) reported a significant increase in grain yield with the addition of 60 kg K_2O/ha in rice cv. Saket-4. Agarwal (1980) recorded significant increase in grain yield with potassium upto 60 kg K_2O/ha. Mahapatra et al. (1980) could get significant increase in rice yield by the application of K_2O at 80 kg/ha. Gurmani et al. (1984) reported a significant increase in grain yield with increase in the level of potassium from 0 to 83 kg/ha.

Contrary to the results referred above, Shukla (1969) reported that potassium application had no significant effect on the grain yield of paddy. Summarising the results from trials conducted in cultivators fields under the All India Co-ordinated Agronomic Experiment Scheme, Mahapatra and Prasad (1970) concluded that the locally improved tall-indicas did not respond well to potassium when compared to high yielding varieties. Pandey and Das (1973) reported that potassium application had no significant effect on the grain yield. Ageeb and Yousif (1978) reported that different doses of potassium either alone or in combination with phosphorus had no response.

Potassium helps in increasing the grain yield especially in the presence of nitrogen and phosphorus.

b. Straw yield.

Usha (1966) reported that potassium application in paddy enhanced straw yield. Esakkimuthu et al. (1975) recorded an increase in straw yield to different levels of potassium. Singh et al. (1976) observed that application of 120 kg potassium per hectare gave the highest straw yield. Singh and Prakash (1979) also reported an increase in straw yield with increase in the level of potassium from 0 to 60 kg K_2O/ha.

In general, the straw yield increases with increase in the level of potassium.

c. Grain protein.

Chavan and Magar (1971) reported increase in protein content with increased application of potassium from 20 to 40 kg K_2O/ha. Agarwal (1978) also observed an increase in the crude protein content of grain with increase in the level of potassium from 0 to 120 kg K_2O/ha.

On the other hand, Bhuiya et al. (1979) reported that potassium had no significant effect on grain protein content.

In general potassium helps in improving the quality of grain.

4. Uptake of potassium.

Sadanandan et al. (1969) found that the uptake of potassium significantly increased with higher doses of potassium. Singh et al. (1976) stated that potash uptake and translocation were highest with 160 kg K_2O/ha. Agarwal (1978) recorded increase in the potash uptake of the plant with increase in the level of potassium applied up to 60 kg K_2O/ha. Singh and Prakash (1979) reported that the application of potassium increased its uptake significantly.

Field trials by Singh and Modgal (1978) revealed that an increase in the dose of nitrogen applied from 30 to 120 kg/ha increased the uptake of potassium by the crop at harvest. Sushama kumari (1981) and Sobhana (1983) reported an increase in potassium uptake with increase in the levels of NPK fertilizers.

In general the uptake of potassium is favourably influenced by the levels of nitrogen, phosphorus and potassium.

Time of Application of Nitrogen

Time of application of nitrogen to rice had been the subject of investigation of quite a number of workers in the past.

Yamaguchi et al. (1960) and Matushima and Maneka (1961) emphasised the importance of top dressing at panicle initiation stage. Tanaka (1961) reported that an early burst in vegetative growth later led to over crowding and reduced photosynthetic rate due to mutual shading and suggested split application of nitrogen for rice crop. Bouldin et al. (1980) reported that a reduced yield potential is set by low early season nitrogen, and higher nitrogen at later dates will not overcome an early season deficit.

Urs and Havanagi (1969) suggested split applications at transplanting, tillering and floral initiation stages. The results of trials carried out at Rice Research Station, Pattambi (Anon, 1971) were also in agreement with that of Urs and Havanagi (1969). Moreover, workers like Kumar and George (1972), Nair (1972), Kulkarni et al. (1975), Bhaumik and Ghosh (1977), Deo (1979), Ajitkumar (1984) and Surendran (1985) also suggested three split applications of nitrogen at transplanting, tillering and panicle initiation stages.

But Houng and Liu (1979), Youssef et al. (1980) favoured four split dressings of nitrogen at transplanting, tillering, panicle initiation and before reduction division and/or heading.

1. Influence of time of application on growth characters.

a. Height of plants.

In an investigation with Jaya variety Mathew (1971) could not observe any significant difference in the height of plants due to time of application of nitrogen at active tillering and booting stages. Meerasahib (1972) reported that time of application of nitrogen did not influence plant height, even though split application registered slight increase over basal application, With I.R.8 variety. Panicker (1975) also reported a similar result. Ajitkumar (1984) noticed that application of 25% nitrogen as basal followed by top dressing 50% nitrogen at active tillering and 25% at panicle initiation produced significant increase in plant height only at maximum tillering stage. Surendran (1985) observed that application of nitrogen either in three splits or in two splits did not influence the height of plants.

In general the review points out that time of application of nitrogen did not influence the height of plants.

b. Tiller number/m^2

Ramanujam and Rao (1971) observed that the number of tillers were increased with increased doses of nitrogen applied in three equal splits. Meerasahib (1972) reported that the time of application of nitrogen has very little influence in determining the number of tillers where as Panicker (1975) observed the highest number of tillers at harvest when 50% of nitrogen was given as basal and 25% each given at active tillering and panicle initiation stages. Ajitkumar (1984) observed a significantly higher number of tillers both at active tillering and panicle initiation stages when 50% nitrogen was given as basal and 25% each were given at active tillering and panicle initiation stages. Surendran (1985) reported that application of nitrogen in equal splits, at active tillering and panicle initiation stages recorded a higher tiller number at panicle initiation and flowering stages.

However Mathew (1971) did not observe any significant difference in tiller production due to time of application of nitrogen at any of the growth stages. Nair (1976) also reported similar trend in tiller count with direct sown Triveni.

In general split application favours the production of tillers.

c. Dry matter production.

In an experiment with direct sown Triveni, Nair (1976) obtained highest dry matter production when nitrogen was given in two equal splits at active tillering and panicle initiation stages and lowest when given ¾ at sowing and ¼ at active tillering stage. He also stated that the difference in dry matter production was significant. Nagre and Mahajan (1981) reported that dry matter accumulation with nitrogen application in equal splits at transplanting and 40 days after transplanting was higher than a single application at transplanting or two splits at other proportions. Ajitkumar (1984) observed significant influence in dry matter production due to split application of nitrogen in Mashuri variety. Surendran (1985) reported that time of application of nitrogen did not affect the dry matter yield at active tillering, panicle initiation and flowering stages. He also reported that nitrogen given in three split doses, 50% basal, 25% each at active tillering and panicle initiation stages produced the highest dry matter yield at harvest.

Split application of nitrogen is more beneficial for increasing dry matter production than single application.

2. Influence of time of application on yield attributes.

a. Productive tillers and panicle.

Urs and Havanagi (1969) reported increased number of panicle with nitrogen applications at transplanting, tillering and floral initiation stages. Panda and Leeuwrik (1972) observed that the number of fertile tillers were increased with increase in the level of nitrogen applied two-third at transplanting and the rest top dressed at boot stage. Varma and Sreevastava (1972) reported that application of nitrogen in three splits with ½ at transplanting, ¼ each at tillering and boot stage significantly influenced the number of fertile tillers per clump. Kumar and George (1972) opined that top dressing of nitrogen at tillering stage in IR-8 is associated with highest number of productive tillers. Rao and Murty (1975) reported that number of panicle bearing tillers increased with application of nitrogen at the rate of 40 kg at thinning + 30 kg before maximum tillering + 30 kg at booting stage per ha. Ghobrial (1980) observed that top dressing nitrogen at maximum tillering and panicle initiation stages significantly improved the nitrogen use efficiency by promoting production of more panicles per unit area. Rodriquez et al. (1980) reported that 180 kg nitrogen applied in three or four splits was found to increase the panicle number per square metre. De Datta and Surjith (1981) reported that rice plant requires a large amount of nitrogen at the early and mid tillering stages to maximise the number of panicles.

Ajitkumar (1984) did not observe any significant increase in the number of productive tillers with split application of nitrogen in <u>Mashuri</u> variety of rice. Surendran (1985) found that application of nitrogen in three split doses as well as given at active tillering and panicle initiation stages produced more or less the same number of panicles.

In general, application of nitrogen at the important growth stages helps in increasing the number of panicles/m^2.

b. Length of panicle.

Chang and Yang (1966) reported that split application of nitrogen significantly influenced the length of panicle. Mikoshiba and Takase (1966) found an increase in the length of panicle due to time of application of nitrogen and the increase in length was more in indica than in japonica variety. Patnaik (1969) opined that 75 to 80% of the total amount of nitrogen should be applied at transplanting and the remaining quantity top dressed some time between internode elongation to the emergence of the boot leaf stage, for the full development of panicles. Panda and Leeuwrik (1972) reported that nitrogen application increased panicle length when two-third dose was applied at transplanting and the rest top dressed at boot stage.

Contrary to the above, Ajitkumar (1984) observed that the time of application of nitrogen did not influence the panicle length in Mashuri variety. With Lekshmi variety Surendran (1985) also reported a similar result.

Split application helps in increasing the panicle length though not significant.

c. Weight of panicle.

Varma and Sreevastava (1972) observed that application of nitrogen in three splits increased the weight of panicles. Wang (1981) reported that nitrogen application at the primordial panicle stage of the plant increased the panicle weight.

However, Ajitkumar (1984) did not observe any significant difference in the weight of panicles due to split application of fertilizers in Mashuri variety. Surendran (1985) reported that the time of nitrogen application did not influence the weight of panicle. He further suggested that top dressing of nitrogen in small amounts at panicle initiation stage will be a better practice for tall indica variety for increasing panicle weight.

In general time of applications of nitrogen did not significantly influence the panicle weight in tall indicas.

d. Number of spikelets per panicle.

According to Panda and Leeuwrik (1972) application of nitrogen increased the number of fertile and sterile spikelets per panicle when two-third nitrogen was applied at transplanting and the remainder top dressed at boot stage. Sakai et al. (1972) observed highest number of spikelets per unit area with application of nitrogen 5-6 days before panicle initiation, where as Furuyama and Minami (1974) reported increase in the number of spikelets with top dressing of nitrogen at early panicle formation stage.

Nair (1976) could not notice any significant effect due to split application of nitrogen on the number of spikelets per panicle in the case of direct sown Triveni variety of rice. According to Surendran (1985) time of nitrogen application did not affect the production of spikelets in Lekshmi variety.

e. Number of filled grain per panicle.

Kumar and George (1972) obtained highest number of filled grains per panicle when nitrogen was top dressed at panicle initiation stage. Varma and Sreevastava (1972) observed that application of nitrogen in three splits with half applied at transplanting, one fourth at tillering and the remainder at boot stage increased the number of filled grains per panicle. Bhaumik and Ghosh (1977) reported that nitrogen applied in three splits at planting, before tillering and flowering, directly influenced the production of filled grains per panicle.

Ajitkumar (1984) could not obtain significant increase in number of filled grains per panicle due to split application of nitrogen. According to Surendran (1985) the time of nitrogen application did not have any influence in filled grain production.

In general the review points out that split application of nitrogen helps in increasing the number of filled grain/ panicle in rice.

f. Percentage of unfilled grains.

Nair (1976) reported that time of application of nitrogen did not influence the percentage of unfilled grain in Triveni variety of rice.

In an investigation with Mashuri variety, Ajitkumar (1984) reported that highest number of unfilled grains per panicle was obtained when 25 per cent nitrogen was given each at planting and 20 days after transplanting. Surendran (1985) observed that time of application of nitrogen did not influence the percentage of unfilled grains in Lekshmi variety.

In general, the review points out that the percentage of unfilled grains is not influenced by the time of application of nitrogen.

g. Thousand grain weight.

Bhaumik and Ghosh (1977) noticed direct influence of thousand grain weight with equal split applications of nitrogen at planting, tillering and flowering. Nair et al. (1979) obtained maximum weight for thousand grains when half of the nitrogen was applied at panicle initiation stage. Ghobrial (1980) observed that top dressing nitrogen at maximum tillering and panicle initiation stages improved the nitrogen use efficiency by increasing the grain weight. Youssef et al. (1980) reported that nitrogen applied in four equal split doses, at fifteen days after transplanting, necknode differentiation, active reduction division and fifteen days after heading resulted in an increased thousand grain weight over one to three application. Ajitkumar (1984) recorded the highest thousand grain weight when 25% nitrogen each was given at planting and 20 days after planting and 50% given 40 days after planting but not significant.

On the other hand Surendran (1985) reported that time of nitrogen application did not influence thousand grain weight in Lekshmi variety.

In general thousand grain weight increases with split application of nitrogen.

3. Effect of time of application on yield.

a. Grain yield.

Urs and Havanagi (1969) obtained higher grain yields with three split doses of nitrogen at transplanting, tillering and floral initiation. Prasad et al. (1970) observed maximum grain yield with nitrogen application half at transplanting and one third given each at panicle initiation and booting stages. In an investigation at Regional Rice Research Station, Pattambi, nitrogen applied at planting, tillering and panicle initiation stages recorded increase in grain yield over single application at planting (Anon; 1971). But in another trial at Regional Research Station, Moncompu, IR-8 produced higher yields with equal applications of nitrogen at tillering, panicle initiation and booting stages (Anon; 1971). In trials at the International Rice Research Institute, Philippines, significant higher yields were obtained when nitrogen was given in equal splits at sowing, maximum tillering and panicle initiation stages (Anon; 1973) Kulkarni et al. (1975) recorded highest grain yields with three split dressings at transplanting, 20-25 days after transplanting and at panicle initiation stages. In field trials Bhaumik and Ghosh (1977) noticed that application of nitrogen 35 per cent as basal, 33 per cent before tillering and remainder before flowering gave the highest grain yield. Panda et al. (1977) found that application of 50 kg nitrogen/ha in three split dressings (25% at transplanting, 50% at tillering and 25% at panicle initiation) gave higher grain yields compared to two equal split dressings or single application. Deo (1979) in trials on clay loam soil recorded increase in grain yield with increasing levels of nitrogen when given 50% at transplanting and the balance 50% in two equal applications at four and seven weeks after transplanting.

Mishra and Singh (1980) observed that the paddy yields were highest when nitrogen was given in 2 to 3 split dressings at transplanting and tillering, panicle initiation and/or booting stages compared to one at transplanting or four applications at other stages. Ajitkumar (1984) recorded the highest grain yield when 25% nitrogen, each were given at planting and 20 days after planting and 50% given 40 days after planting. Application of 50% nitrogen as basal and 25% each given at 40 and 50 days after planting recorded the highest yield (Anon; 1984 a). In another field experiment highest grain yield was obtained when 50% nitrogen applied at planting and 25% each at tillering and panicle initiation st[illegible] al. (1984) reported that grain yields were highest in Kranti variety of rice when half the nitrogen was applied at intercultivation and the remainder in equal splits at tillering and panicle initiation. Surendran (1985) obtained the highest grain yield when nitrogen was given in three split doses at transplanting (50%) active tillering (25%) and panicle initiation stages (25%) and was on par with one-third nitrogen each given at the above stages.

On the other hand, Rao and Ragaiah (1978) did not observe any significant increase in grain yield due to split applications.

In general nitrogen given in three splits at transplanting, active tillering and panicle initiation stages is found to be better for increasing the grain yield in rice.

b. Straw yield.

Narasaiah et al. (1967) reported that the time of application of nitrogen did not show any marked effect on straw yield. Meerasahib (1972) also obtained a similar result. Panicker (1975) reported significant increase in straw yield when 75% of the nitrogen was given as basal and 25% given as top dressing at active tillering stage.

with direct sown Triveni crop of paddy. Nair (1976) did not observe any significant difference in straw yield due to split application of nitrogen. Hoque et al. (1977) reported considerable increase, though not significant in the straw yield of rice when nitrogen was applied in three splits. Ajitkumar (1984) obtained maximum straw yield when nitrogen was given in three split applications, 25% as basal followed by two top dressings of 50% at active tillering and 25% at panicle initiation stages. Surendran (1985) also recorded highest straw yield with three split applications of nitrogen ie., 50% nitrogen at transplanting and 25% each at tillering and panicle initiation stages.

In general straw yield is more with split application of nitrogen than with application of nitrogen in a single dose at planting.

c. Grain protein and quality of rice.

Patrick et al. (1974) observed that grain protein content was highest when the entire nitrogen was given at sowing or half given at sowing and the balance given when panicles were 2 mm long. According to Pisharady et al. (1976) application of a part of the nitrogen as top dressing at the panicle initiation and booting stages increased grain protein content compared with application of nitrogen in a single dose at sowing. Subramaniam and Morachan (1979) found that nitrogen application at transplanting, tillering and floral initiation stages resulted in highest grain protein content.

Youssef et al. (1980) reported that application of nitrogen in four equal splits increased the grain protein content than 1-3 applications in other proportions. Mahajan and Nagre (1981) obtained high increase in grain protein and protein yields of rice with equal nitrogen applications at transplanting and 40 days later than one application at planting or two splits at other rates. Ajitkumar (1984) did not observe any significant difference in grain protein content with time of application. In the investigation with Lekshmi variety, Surendran (1985) reported that the time of nitrogen application did not influence the protein content of grains.

In general protein content is favourably influenced by split - application of nitrogen especially with top dressing of nitrogen at later stages of growth.

4. Uptake of nitrogen.

Thenabadu et al. (1970) noticed that the uptake of nitrogen from fertilizers was greater from early application than from late application. Koyama et al. (1973) in their investigation with ^{15}N tracertechnique found that application of 37.5 kg nitrogen per hectare each as basal dressing and as top dressing at panicle initiation stage resulted in the uptake of 83 kg nitrogen per hectare, 36% from the fertilizer and 64% from the soil. Of the fertilizer nitrogen absorbed, 33.3% was from basal application and 66.6% from the top dressing. The recovery rate of top dressed nitrogen was 54% and that of basal nitrogen was 27%.Koyama and Niamsrichand (1973) observed that the nitrogen content of plants at harvest consistently increased when 75% nitrogen was given as basal and 25% given as topdressing 30 days before flowering. Furuyama and Minami (1974) reported that top dressing of nitrogen at early panicle formation is positively correlated with increased nitrogen uptake. Korikanthimath (1977) observed that the relative efficiency of nitrogen was higher at the active tillering stage than at transplanting and it reached it's peak at panicle initiation and beyond that the efficiency decreased. Allen and Terman (1978) noticed that the time of application of nitrogen and uptake were highly rectilinear with rates. Houng and Liu (1979) based on pot trials with ^{15}N enriched ammonium sulphate observed 20% recovery from basal applications, 40% from top dressing at tillering, 60-90% from top dressing at young panicle stage and 40-60% from application after heading stage.

However Ajitkumar (1984) did not observe any significant difference in plant nitrogen content with time of application. He observed highest nitrogen uptake when nitrogen was given 25% at planting, 50% 20 days after planting and 25% 40 days after planting. Surendran (1985) reported that the time of application of nitrogen influenced its uptake only at the active tillering stage.

In general nitrogen uptake is more with split application of nitrogen especially with split application at the important stages of growth.

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MATERIALS AND METHODS

III MATERIALS AND METHODS

An experiment was conducted to evolve a suitable fertilizer schedule for rice variety, Cheradi, under the prevailing agroclimatic conditions of the Cheradi growing tracts, viz, Trivandrum and Quilon Districts of Kerala. The various methods employed in carrying out the experiment and also the materials used are described here under.

1. Experimental site.

The field experiment was laid out in the wetlands of the State Seed Farm, Kottarakara, Quilon District. This station is located between 8°, 58' and 8°, 59' North latitudes and between 76°, 46' and 76°, 47' East longitudes.

The experimental field was in a typical ribbon valley situated in between slopy laterite dry land. Irrigation facilities were available all round the year.

a. Soil.

The soil of the experimental site is very deep, ill drained, yellowish brown to very dark greyish brown loamy soils of 'Pooyappally' series, developed from alluvial and colluvial deposits under warm humid tropical climate.

This soil is a member of the coarse loamy mixed isohyperthermic family of Fluventic Eutropepts. (Soil survey report of Kottarakara Taluk, Unpublished). The soil type in the experimental plot is silt loam. The physicochemical properties of the soil are presented in Table 1.

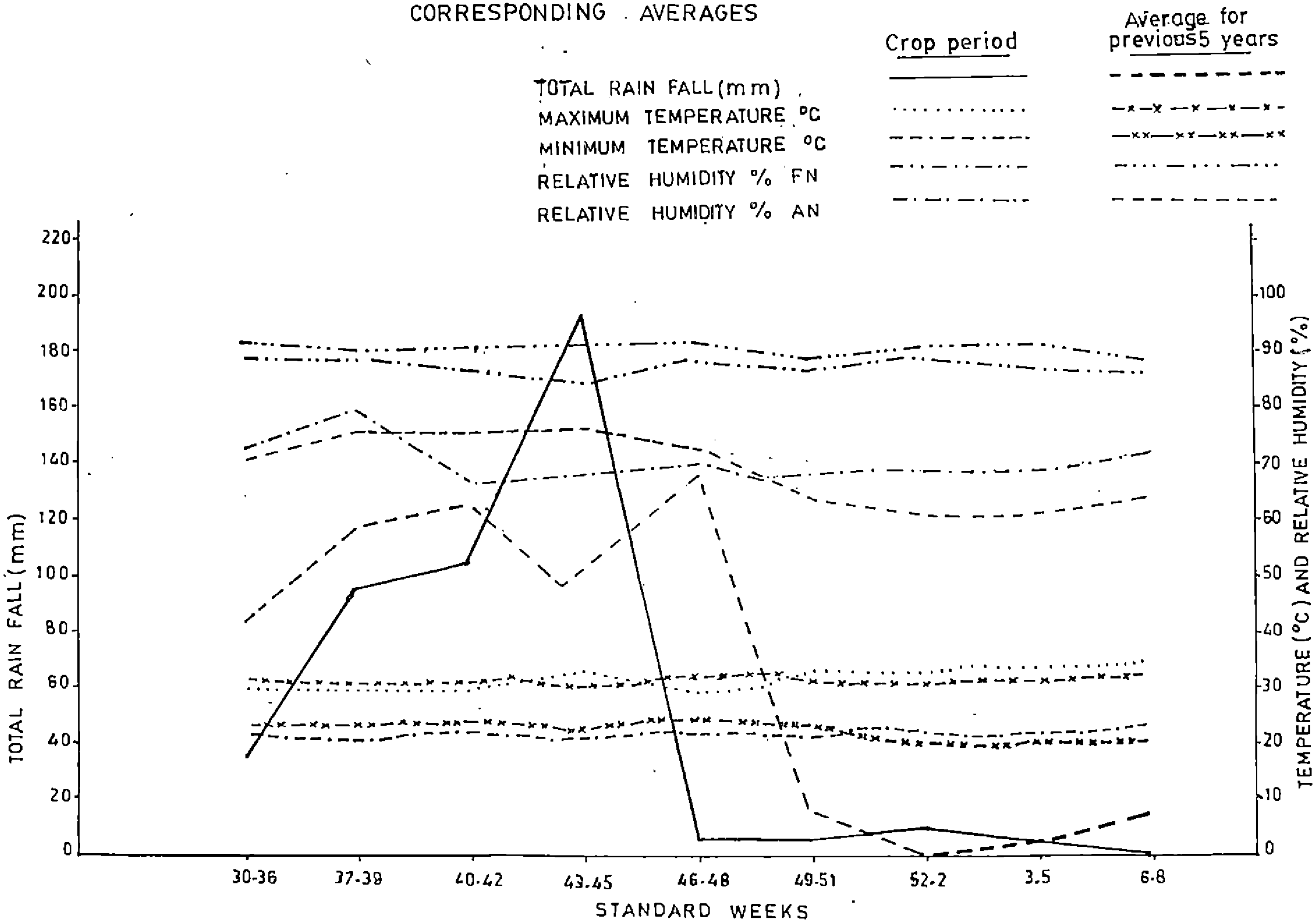
2. Climate

The experimental area enjoys a warm humid tropical climate. The rainfall data was collected from the Taluk Office, Kottarakara. The other climatological data were not available at Kottarakara and hence the data regarding temperature and relative humidity were collected from the nearest meteorological station at Punalur. All the data along with the averages of the same parameters for the corresponding previous five years are presented in Appendix I and graphically represented in Fig.1. The maximum and minimum temperature of the cropping period range from 29°C to 34.3°C and from 20.2°C to 24.6°C respectively. The crop received a total rainfall of 443.5 mm spread over a period of 172 days. Though the amount of rainfall received during the reproductive phase was meagre the crop requirement was supplemented with irrigation and as such the crop did not suffer. A perusal of the data reveal that the weather conditions observed during the cropping period in general did not differ much from the mean weather data recorded in the past five years.

Table 1. Physical and chemical properties of the soil of the experimental field.

A. Physical properties:			
a. Mechanical composition			
Coarse sand	...	...	13.8%
Fine sand	...	...	29.3%
Silt	...	...	32.5%
Clay	...	...	23.3%
B. Chemical properties:			
pH	...	...	5.6
C.E.C.	...	...	4.480 me/100g
Available nitrogen	...	...	0.020%
Total nitrogen	...	...	0.081%
Available phosphorus	...	...	19.2 kg/ha
Available potassium	...	...	82 kg/ha

Fig. 1 WEATHER PARAMETERS FOR THE CROP PERIOD 1984-85 AND THEIR CORRESPONDING AVERAGES



3. Cropping Season.

The experiment was conducted during the mundakan season (second crop) of 1984-85 ie., from August 1984 to February, 1985. The date of sowing, transplanting and harversting were 25th August 1984, 5th October 1984 and 12th February 1985 respectively.

4. Cropping history.

The experimental area was under bulk crop of rice during the past several years.

5. Seeds.

The variety used for the investigation was Cheradi, a traditional local variety grown by the farmers of Trivandrum and Quilon Districts. This is a tall, photosensitive long duration (165-185 days) variety well suited to ill drained deep soils for the second crop season.

6. Manures.

Cattle manure having the following analysis were used for the experiment.

N	- 0.45 %
P_2O_5	- 0.25 %
K_2O	- 0.30 %

7. Fertilizers.

Urea, Superphosphate and Muriate of potash containing 46% N, 16% water soluble P_2O_5 and 60% K_2O, respectively were used.

8. Treatments.

a. Fertilizer levels

		N		P_2O_5		K_2O	
M_1	-	40	:	20	:	20	kg/ha
M_2	-	50	:	25	:	25	kg/ha
M_3	-	60	:	30	:	30	kg/ha
M_4	-	70	:	35	:	35	kg/ha

b. Time of application of Nitrogen.

		Top dressing at		
	Basal	Active tillering stage	Panicle initiation stage	Booting stage
T_1	½	½	Nil	Nil
T_2	½	Nil	½	Nil
T_3	½	¼	¼	Nil
T_4	¼	¼	¼	¼

c. Treatment combinations.

1. M_1T_1	5. M_2T_1	9. M_3T_1	13. M_4T_1
2. M_1T_2	6. M_2T_2	10. M_3T_2	14. M_4T_2
3. M_1T_3	7. M_2T_3	11. M_3T_3	15. M_4T_3
4. M_1T_4	8. M_2T_4	12. M_3T_4	16. M_4T_4

9. Design and layout.

The experiment was laid out as a 4 x 4 Factorial experiment in Randomised Block design. There were sixteen treatment combinations and three replications. The layout plan is given in Fig.2.

a. Plot size and spacing.

Gross plot size	-	5.0 x 4.5 m ($22.5\ m^2$)
Net plot size	-	4.2 x 3.6 m ($15.12\ m^2$)
Spacing	-	20 x 15 cm

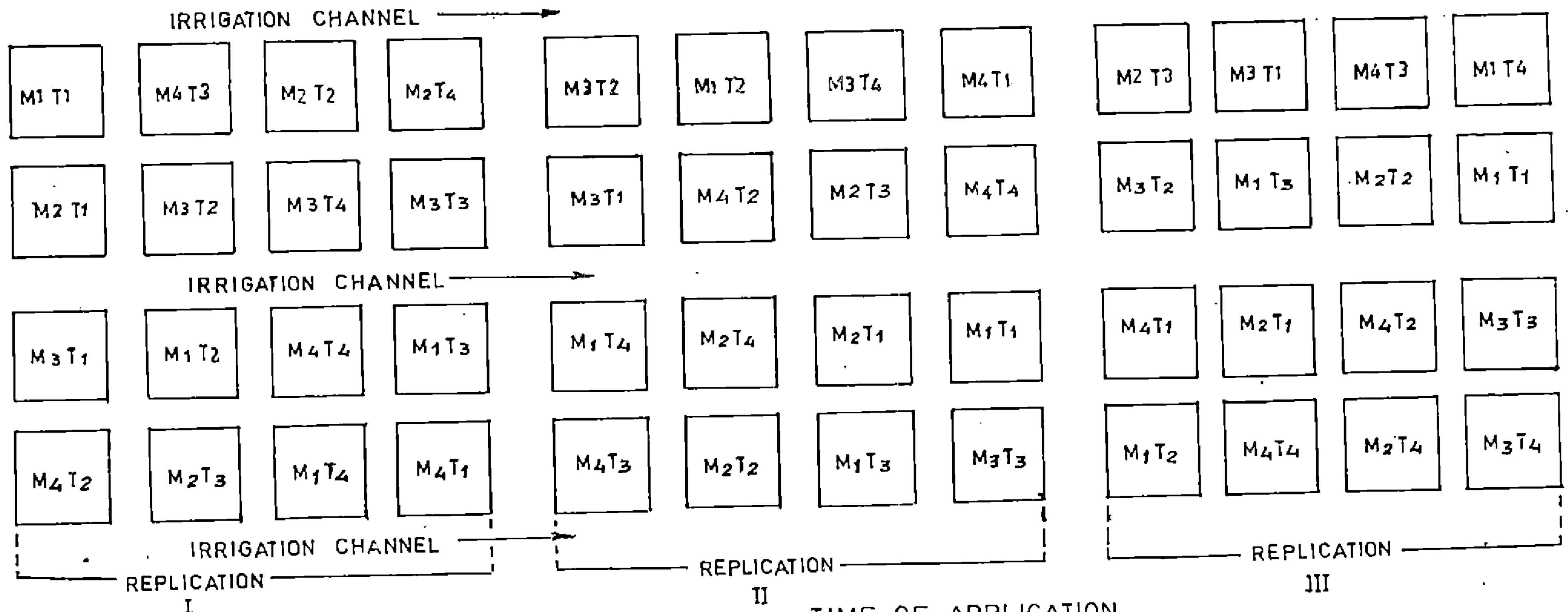
b. Border rows.

Two rows of plants were left as border rows all around the plot. A destructive row was left on the breadth-wise side to facilitate sampling of the plants. An additional row was left next to the sampling row to avoid the possible effect of sampling on the net area.

Fig. 2 LAYOUT PLAN OF THE EXPERIMENT

N

Plot size
Gross - 5.0 x 4.5m
Net - 4.2 x 3.6m



TREATMENTS

LEVELS OF FERTILIZERS

M1 - 40 : 20 : 20 kg/ha NPK
M2 - 50 : 25 : 25 kg/ha NPK
M3 - 60 : 30 : 30 kg/ha NPK
M4 - 70 : 35 : 35 kg/ha NPK

TIME OF APPLICATION

	BASAL	ACTIVE TILLERING STAGE	PANICLE INITIATION STAGE	BOOTING STAGE
T1	1/2	1/2	NIL	NIL
T2	1/2	NIL	1/2	NIL
T3	1/2	1/4	1/4	NIL
T4	1/4	1/4	1/4	1/4

10. Details of field cultivation.

a. Nursery.

The seeds for raising the nursery were procured from a progressive farmer and the seedlings were raised in a wet nursery following the package of practices recommendations (Anon; 1982).

b. Main field.

All the field operations were carried out according to the package of practices recommendations except for the treatments tried. The plots of 5.0 x 4.5 m size were laid out with bunds of 30 cm width. The block bunds were given 50 cm width. Main and sub irrigation channels were provided to irrigate the individual plots. Each of the plots were dug, puddled and perfectly levelled. Forty two days old seedlings were used for transplanting. Two seedlings were planted per hill at a depth of 3 to 4 cm. Gap - filling was done on the seventh day after planting. The crop was hand weeded twice at 20 days interval after transplanting. A continuous 5 cm submergence, except the occasional draining during the tillering stage and at the time of top dressing, was given from seventh day after planting. Water was drained from the plots ten days prior to harvest.

c. Application of fertilizers.

Nitrogen was given in split doses as per the treatments. The entire dose of phosphorus and half the dose of potash were applied as basal dressing. The remaining dose of potash was given as top dressing at panicle initiation stage in all the plots.

d. Plant protection.

Pest surveillance was made in the farm using light trap and two sprayings with Ekalux and Bavistin were given against stem borer, rice bug and leaf diseases, first at 20 days after planting and thereafter 90 days of planting as a prophylactic measure.

e. Harvest.

The crop was harvested on the 130th day of transplanting. All the border row plants including the plants in the destructive rows and the row next to it were harvested and removed first. There after the net area of individual plots were harvested and threshed separately. The per plot dry weight of cleaned grains and dry weight of straw were then recorded individually.

Observations

1. Biometric observations.

Three sample units of 2 hills x 2 hills were randomly selected in each plot as suggested by Gomez (1972) and the following periodical observations recorded.

a. Height of plants.

Height of plants was measured from the ground level to top of the tallest leaf at active tillering, panicle initiation and booting stages. At harvest, the height was recorded from the base of the plant to the tip of the tallest panicle and the mean height was computed and expressed in cm.

b. Number of tillers/m^2.

The total number of tillers from all the 12 hills at one week interval were counted and the maximum number of tillers/m^2 when observed was recorded.

2. Growth analysis.

a. Leaf area index.

Leaf area index was computed at active tillering stage, panicle initiation and booting stages. Two sample hills were randomly selected in each plot and the number of tillers was counted in each hill. The length and maximum width of leaves in the middle tiller of all the sample hills were measured separately and leaf area was computed based on length-width method.

Leaf area = K x lxw, where

K is the adjustment factor (0.75), 'l' is the length and 'w' is the width. Thereafter the leaf area per hill and leaf area index were calculated using the following formulae.

Leaf area/hill = Total leaf area of middle tiller x Total number of tillers.

$$\text{Leaf area index} = \frac{\text{Sum of leaf area per hill of n sample hill } (cm^2)}{\text{Area of land covered by n hills } (cm^2)}$$

b. Crop growth rate.

Crop growth rate between stages were worked out by using the following formulae as explained by Hunt (1978).

$$\text{Crop growth rate } (g/m^2/day) = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{P}$$

where W_2 = Dry matter production at time T_2

W_1 = Dry matter production at time T_1

P = Ground area

c. Relative growth rate.

Relative growth rate between stages were worked out by using the following formula suggested by Hunt (1978)

$$\text{Relative growth rate (g/kg/day)} = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1}$$

Where W_2 = Dry matter production at time T_2

W_1 = Dry matter production at time T_1

3. Dry matter production.

Dry matter production was estimated at the active tillering, panicle initiation, booting and harvest stages of the crop. Five sample hills were randomly selected and uprooted from the sampling row and the soil from the roots was thoroughly washed off. Thereafter the samples were first dried in the Sun and then oven dried at a temperature of 80 ± 5°C to constant weight. Dry matter production was computed and expressed in t/ha at active tillering, panicle initiation and booting stages. At harvest the sum total yield of grain and straw was taken as the dry matter production.

Post Harvest Observations

1. Yield attributes.

The following yield attributes were computed using the method suggested by Gomez (1972).

a. Number of panicles/m^2.

The total number of panicles (P) from the 12 hills selected were counted and the number of panicles/m^2 computed.

b. Length of panicle.

The length of the middle panicle of each hill was measured and mean length computed.

c. Weight of panicle.

All the panicles from the 12 hills were weighed and mean weight computed.

d. Number of spikelets per panicle.

The number of spikelets in all the panicles from 12 hills were counted and the mean number of spikelets per panicle was computed.

e. Number of filled grains per panicle.

The main culm panicles from all the 12 hills were separated based on the height of individual panicles and were threshed and number of filled grains (f), number of unfilled grains (u) and weight of filled grains (w) determined.

The rest of the panicles from all the 12 hills were also threshed and number of unfilled grains (U) and weight of filled grains (W) assessed.

From the above data, the number of filled grains per panicle was computed using the following formula (Gomez, 1972)

Number of filled grains/panicle = $\frac{f}{w} \times \frac{W+w}{P}$

Where P is the total number of panicles from all the 12 hills.

f. Percentage of unfilled grains.

The percentage of unfilled grains were worked out using the formula given below:

$$\text{Percentage of unfilled grains} = \frac{U + u}{f(W+w)/W+U+u} \times 100$$

g. Thousand grain weight.

Thousand grain weight was calculated and adjusted to 14% moisture using the formula given below:

$$\text{Thousand grain weight} = \frac{100 - M}{86} \times \frac{W}{f} \times 1000$$

Where M is the moisture content of filled grains.

2. <u>Yield</u>.

a. Grain yield.

Yield of grain from the net area harvested was recorded and adjusted to 14% moisture using the adjustment co-efficient given by Gomez (1972) and expressed in t/ha

Adjusted grain weight = A x W, where A, is the adjustment co-efficient and W, is the dry weight of grain.

b. Straw yield.

Straw obtained from the net area was uniformly dried, weighed and yield of straw expressed in t/ha.

c. Harvest index.

Harvest index was worked out by dividing the weight of grains per ha. (economic yield) with the weight of the sum total yield of grain and straw (biological yield) per ha.

3. Economics of rice production.

a. Net return.

Net return was worked out and expressed in '000 rupees per ha. Cost of inputs including the labour charges and the extra treatment costs were taken together as the expenditure. Values of paddy and straw were worked out at current market rate and were taken as the total receipts for computing net returns.

b. Cost : benefit ratio.

This was worked out by dividing the gross return obtained with the total expenditure incurred on a per hectare basis.

Chemical Analysis

1. Plant analysis.

a. Uptake of nitrogen.

Nitrogen content of plant samples at active tillering, panicle initiation and booting stages and that of grain and straw at harvest were determined by modified Micro-kjeldahl digestion method as suggested by Jackson (1967).

The nitrogen concentrations thus obtained was multiplied with the dry matter yield at the respective stages and uptake of nitrogen computed and expressed in kg/ha.

b. Uptake of phosphorus.

Phosphorus concentrations of the plant samples at active tillering, panicle initiation and booting stages and that of grain and straw at harvest was determined from the triple acid extract (9 : 2 : 1 = HNO_3: H_2SO_4: $HClo_4$) and thereafter estimating colorimetrically by employing the Vanadomolybdo Phosphoric yellow colour method in Nitric acid system. The yellow colour was read in spectronic 2000 spectrophotometre at a wave length of 470 nm (Jackson, 1967).

The value of total phosphorus uptake at active tillering, panicle initiation, booting and harvest stages were obtained as a product of the content of this nutrient in the plant and the weight of dry matter. The values were expressed in kg/ha.

c. Uptake of potassium.

Potassium concentrations of the plant samples at active tillering, panicle initiation, booting and that of grain and straw at harvest were determined from the triple acid extract of the plant using an EEL - Flame photometer (Jackson, 1973).

From the above, uptake of potassium was calculated as in the case of nitrogen and expressed in kg/ha.

2. Grain protein content.

The nitrogen concentration of grain was estimated and the protein content was computed by multiplying the nitrogen concentration by a factor 6.25 (Simpson et al. 1965).

3. Soil Analysis.

Representative soil samples were collected from the individual plots prior to planting and immediately after harvest, air dried, powdered with a wooden mallet, Sieved through a 2 mm sieve and were stored for chemical analysis.

a. Total nitrogen.

Total nitrogen was estimated using modified Micro-kjeldahl digestion method as suggested by Jackson (1967).

b. Available nitrogen.

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

c. Available phosphorus.

Available phosphorus was estimated by extracting with bray No.1 solution and thereafter developing the chlorostannous reduced phosphomolybdic blue colour in Hcl system and the colour was read in a klett-Summerson Photoelectric colorimeter using a red filter. (Bray and Kurtz,1945)

d. Available potassium.

Available potassium was extracted with Normal neutral ammonium acetate solution and estimated in an E E L - Flame photometer (Jackson, 1973).

4. <u>Statistical analysis</u>.

The data relating to different observations were statistically analysed applying the technique of analysis of variance for factorial experiment in R.B.D. The significance was tested by 'F' test (Cochran and Cox, 1965). Important correlations were worked out and the cause and effect relationship (by Path analysis technique) was established. (Nageswara Rao, 1983).

RESULTS

IV RESULTS

The observations recorded were statistically analysed. Results obtained are presented below with mean values in Tables 2 to 14 and the analysis of variance in Appendices II to VI . Mean values for interaction between main effects have been given, only in those cases where there is significance.

Biometric Characters

1. Growth characters.

a. Height of plants.

The data on mean height of plants recorded at active tillering, panicle initiation, booting and at harvest stages are presented in Table 2 and the analysis of variance in Appendix II.

The data showed that mean height of plants at active tillering was significantly influenced by the graded doses of fertilizers. Height of plants with treatment M_3 and M_4 were on par, but both were significantly superior to M_2 and M_1. Minimum height was recorded with M_1 which was significantly inferior to all other treatments.

The time of application of nitrogen had no effect on the height of plants at this stage.

At panicle initiation stage also, higher levels of fertilizers significantly influenced the plant height. Successive addition of fertilizers progressively increased the height of the plants and the rate of increase was significant at all levels.

At this stage also the height of plants was not significantly affected by the time of application of nitrogen.

As in the case of panicle initiation stage, an increase in the rate of fertilizers produced a progressive and significant increase in the plant height at booting stage. Maximum plant height was recorded by M_4, which was significantly superior to other treatments. Minimum plant height was observed with the lowest level of fertilizer (M_1) and was significantly inferior to other treatments.

The time of nitrogen application had no pronounced effect on plant height at booting stage too.

At harvest stage, higher levels of fertilizers increased the plant height and the increase was significant at all levels.

Table 2. Height of plants at different growth stages and maximum number of tillers/m^2.

Treatments	Height of plants (cm) stages				Number of tillers/m^2 at PIS
	ATS	PIS	Booting	Harvest	
M_1	51.6	78.1	118.8	128.5	331.6
M_2	53.3	80.7	124.4	134.3	354.3
M_3	55.6	82.7	138.7	144.7	375.5
M_4	56.4	84.5	144.7	148.7	385.7
CD (0.05) M	1.39	1.07	0.67	1.08	2.64
T_1	54.9	82.2	131.3	138.6	364.9
T_2	53.9	80.9	131.4	138.7	361.0
T_3	54.4	81.5	131.8	138.8	362.0
T_4	53.6	81.9	132.1	139.0	359.20
SE	0.97	0.74	0.47	0.75	1.83
CD (0.05) T	NS	NS	NS	NS	2.64

ATS - Active tillering stage

PIS - Panicle initiation stage

The observations taken at harvest showed that the time of nitrogen application had no significant influence on the height of plants as was observed in earlier stages.

b. Tiller Count/m^2.

The data on mean tiller count/m^2 at panicle initiation stage is given in Table 2 and the analysis of variance in Appendix II.

The mean values show that the level of fertilizers and the time of application of nitrogen significantly influenced the tiller production. With an increase in the levels of fertilizers from M_1 to M_4 there was significant increase in the number of tillers.

Regarding the time of application of nitrogen, T_1 recorded the highest tiller number which was superior to the other treatments. Further, the treatment T_2 was found to be superior to T_4. However T_2 and T_3 were on par. The tiller count was the lowest with treatment T_4.

The combination effect between the levels of fertilizers and the time of nitrogen application was also significant. (Table 10). The tiller production was significantly higher in the combinations M_4T_4, M_4T_3, M_4T_2, M_4T_1 and M_3T_1, which were on par among themselves. The lowest tiller number was observed with M_1T_4 which was on par with M_1T_2 and inferior in tiller production to other treatment combinations.

2. <u>Growth analysis</u>.

a. Leaf area index.

The mean values of LAI at active tillering, panicle initiation and booting stages are presented in Table 3 and analysis of variance in Appendix II.

Significant and progressive increase in LAI was observed with graded levels of fertilizers at the active tillering stage. The time of application of nitrogen also influenced the LAI at this stage. Highest LAI was observed when nitrogen was given as in T_3 which was on par with T_2 and T_1.

The treatment T_4 was inferior to all the other treatments. Combination effect of the levels of fertilizers and the time of application of nitrogen was also found significant (Table 13). Highest LAI was recorded with M_4T_3 which was on par with M_4T_1 and significantly superior to the LAI recorded by all the other treatment combinations. The lowest LAI recorded by M_1T_4 was on par with M_1T_1, M_1T_2, M_1T_3, M_2T_2 and M_2T_3 and significantly inferior to all the other treatment combinations.

Table 3. Leaf area index at different growth stages.

Treatments	Active tillering stage	Panicle initiation stage	Booting stage
M_1	0.868	2.479	2.791
M_2	0.906	2.646	3.125
M_3	1.257	3.137	3.461
M_4	1.455	3.543	3.604
CD (0.05) M	0.0395	0.124	0.1315
T_1	1.138	3.136	3.139
T_2	1.141	2.864	3.278
T_3	1.144	3.004	3.312
T_4	1.064	2.801	3.253
SE	0.027	0.09	0.09
CD (0.05) T	0.0395	0.124	NS

An increase in LAI was observed with an increase in the level of fertilizers at panicle initiation stage. Highest LAI was recorded with M_4, which was significantly superior to all the other treatments. The treatment M_3 was significantly superior to M_2.M_1 recorded the least LAI which was significantly the lowest to all the other treatments. The time of application of nitrogen also influenced the LAI at this stage. Highest LAI was observed when nitrogen was given as in T_1 which was significantly superior to the other treatments. The treatment T_3 was significantly superior to T_2 and T_4 which were on par. The lowest LAI was recorded with T_4 treatment.

Significant and progressive increase in LAI was observed with higher doses of fertilizers at the booting stage. The highest LAI of 3.604 was observed when the plants were fertilized with the dosage of 70:35:35 kg NPK/ha, where as the LAI was lowest (2.791) with the dosage of 40:20:20 kg NPK/ha.

The time of application of nitrogen did not influence the LAI at booting stage.

b. Crop growth rate.

The data on mean values of crop growth rate between active tillering and panicle initiation stages and panicle

Table 4. Crop growth rate and relative growth rate between different growth stages.

Treatments	Crop growth rate ($g/m^2/day$) between		Relative growth rate (g/kg/day) between	
	ATS and PIS	PIS and booting stage	ATS and PIS	PIS and booting stage
M_1	6.893	10.68	53.58	34.50
M_2	7.612	12.49	52.36	36.14
M_3	9.577	14.77	57.61	35.56
M_4	9.862	17.61	55.33	39.21
CD (0.05) M	0.371	1.188	1.927	2.56
T_1	8.867	13.26	56.05	34.43
T_2	8.282	14.77	53.84	38.66
T_3	8.602	14.09	55.12	36.30
T_4	8.193	13.43	53.87	36.02
SE	0.257	0.823	1.335	1.773
CD (0.05) T	0.371	NS	NS	2.56

ATS - Active tillering stage

PIS - Panicle initiation stage

initiation and booting stages are presented in Table 4 and analysis of variance in Appendix III.

Crop growth rate worked out between the active tillering and the panicle initiation stages, was influenced by the graded doses of fertilizers. CGR with M_3 and M_4 were on par and both were significantly superior to the other levels. M_1 recorded the lowest CGR and was significantly inferior to other levels.

The time of application of nitrogen also influenced the CGR. The highest CGR worked out with T_1 was on par with T_3 and significantly superior to the other times of application of nitrogen. No significant difference in CGR was seen with T_3 and T_2 and T_2 and T_4.

The crop growth rate observed between panicle initiation and booting stages was affected by the graded levels of fertilizers only. The CGR values increased with increase in the level of fertilizers upto M_4 level and the rate of increase was significant at all levels.

c. Relative growth rate.

The analysis of the data showed that the relative growth rate was affected by the graded doses of fertilizers between active tillering and panicle initiation stages.

Highest RGR observed with M_3 was significantly superior to other levels. No significant difference in RGR was observed between M_2 and M_1 and M_1 and M_4 treatments.

The time of application of nitrogen did not influence the RGR between the active tillering and panicle initiation stages.

The relative growth rate observed between panicle initiation and booting stages, was influenced by the graded levels of fertilizers and the time of application of nitrogen. The highest RGR observed with M_4 was significantly superior to M_1, M_2 and M_3 levels. The RGR observed with M_1, M_2 and M_3 treatments were on par.

With respect to the time of application of nitrogen, the highest RGR was observed with T_2 which was on par with T_3 and significantly superior to the other times of application of nitrogen. The RGR worked out with T_3, T_4 and T_1 were found to be on par.

3. Dry matter production.

The data on mean dry matter production at active tillering, panicle initiation, booting and harvest stages are presented in Table 5 and analysis of variance in Appendix II.

It could be seen from the data that progressive increase in dry matter production was observed with increase in levels of fertilizers at active tillering stage. Dry matter yield with the treatment M_4 was significantly superior to the other treatments. The lowest dry matter yield was obtained with M_1, which was significantly inferior to other treatments. The time of application of nitrogen did not influence the dry matter production.

At panicle initiation stage also, M_4 treatment recorded significant increase in the dry matter production over the other treatments. The dry matter yield observed with M_3 was significantly superior to M_2 and M_1 and M_2 inturn was superior to M_1. The time of nitrogen application did not influence the dry matter production.

At booting, the dry matter production was profoundly influenced by the graded levels of fertilizers. M_4 treatment recorded significant increase in the dry matter production over the other treatments. The dry matter yield observed with M_3 was significantly superior to M_2 and M_1, and M_2 inturn was significantly superior to M_1. The time of application of nitrogen did not influence the dry matter production.

The trend of increasing the dry matter production with increased fertilizer dose as seen in all the other stages, was maintained at the harvest stage also. With regard to the time of application of nitrogen, no pronounced effect was noticed.

Table 5. Dry matter production at different growth stages (t/ha).

Treatments	Active tillering stage	Panicle initiation stage	Booting stage	Harvest
M_1	0.613	2.335	3.928	8.983
M_2	0.703	2.607	4.480	9.684
M_3	0.745	3.143	5.358	10.706
M_4	0.826	3.291	5.933	11.438
CD (0.05) M	0.0307	0.091	0.209	0.279
T_1	0.721	2.938	4.927	10.065
T_2	0.725	2.795	5.012	10.215
T_3	0.724	2.878	4.988	10.358
T_4	0.716	2.765	4.775	10.173
SE	0.0213	0.063	0.145	0.193
CD (0.05) T	NS	NS	NS	NS

Post Harvest Observations

1. Yield attributes.

The data on mean values of number of panicles/m^2, length of panicle, weight of panicle, number of spikelets per panicle, number of filled grains per panicle, percentage of unfilled grains and thousand grain weight are presented in Table 6 and analysis of variance in Appendix III.

a. Number of panicles/m^2.

It was observed from the results that the graded doses of fertilizers produced progressive increase in the number of panicles/m^2 and the increase was significant at all the levels. The time of application of nitrogen did not affect the number of panicles/m^2.

b. Length of panicle.

It could be seen from the results that the treatments which received higher doses of fertilizers gave appreciable increase in panicle length. The panicle length observed with M_4 and M_3 were on par, and both of them were significantly superior to M_2 and M_1. The treatment M_1 recorded the least value for length of panicle which was significantly inferior to the other treatments.

The time of application of nitrogen did not have any influence on the panicle length.

c. Weight of panicle.

The data on the weight of panicle revealed that there was no significant difference in the weight of panicles due to different doses of fertilizers and due to the time of application of nitrogen.

d. Number of spikelets per panicle.

The levels of fertilizers significantly influenced the number of spikelets per panicle. The highest number of spikelets was observed with M_3 which was on par with M_4 and both of them were significantly superior to M_1 and M_2. M_1 recorded the lowest number of spikelets per panicle which was significantly inferior to M_2 too.

The time of application of nitrogen also influenced the number of spikelets per panicle with a maximum at T_3 which was significantly superior to other treatments. Treatments T_4, T_2 and T_1 were on par.

e. Number of filled grains per panicle.

An increasing trend was evident in the number of filled grains per panicle with increasing fertilizer levels upto M_3 which was on par with M_4, but both of them were significantly superior to M_2 and M_1 levels. The number of filled grains per panicle obtained with M_1 was significantly inferior to the other treatments. The time of application of nitrogen also had significant influence on this character. The treatment T_3 recorded the highest number of filled grains per panicle which was on par with T_4 and both of them were significantly superior to T_2 and T_1. T_1 recorded the lowest number of filled grains per panicle which was significantly inferior to the other treatments.

There was significant influence on this character by the various treatment combinations (Table 14). The highest number of filled grains per panicle obtained with M_3 T_3 was on par with M_3 T_4, M_4T_2, M_4T_3, M_4T_1 and M_3 T_2 and significantly superior to other treatment combinations. The lowest number of filled grains per panicle obtained with M_1 T_1 was significantly inferior to all the other treatment combinations.

f. Percentage of unfilled grains.

Significant and progressive decrease in the percentage of unfilled grains was observed with increased level of fertilizers from M_1 to M_2 and M_2 to M_3, but at M_4 there was significant increase in percentage of unfilled grains

Table 6. Yield attributes.

Treatments	Number of panicles per m^2	Length of panicle (cm)	Weight of panicle (g)	Number of spikelets per panicle	Number of filled grains per panicle	Percentage of unfilled grains	Thousand grain weight (g)
M_1	275.2	21.9	2.32	102.2	80.6	23.6	25.69
M_2	305.9	22.8	2.48	105.1	85.8	23.3	25.98
M_3	332.6	23.8	2.52	108.9	93.3	22.2	26.96
M_4	343.6	24.1	2.48	108.8	93.2	22.5	27.11
CD (0.05) M	6.82	0.436	NS	0.60	0.90	0.13	0.18
T_1	311.6	23.0	2.43	105.9	86.4	23.1	26.37
T_2	311.9	22.9	2.46	106.2	88.1	22.9	26.41
T_3	317.5	23.4	2.45	106.9	89.4	22.8	26.48
T_4	316.2	23.1	2.44	106.1	89.1	22.8	26.48
SE	1.51	0.30	0.165	0.42	0.62	0.09	0.13
CD (0.05) T	NS	NS	NS	0.60	0.90	0.13	NS

when compared to M_3.

With regard to the time of application of nitrogen the lowest value for percentage of unfilled grains was obtained when nitrogen was given as in T_3 and T_4 which was on par with T_2 treatment. The highest value for percentage of unfilled grains was observed with T_1 which differed significantly from all the other treatments.

g. Thousand grain weight.

The data show that thousand grain weight was affected only by the levels of fertilizers. There was significant increase in thousand grain weight resulting from increased fertilizer levels upto M_3 level. No significant difference in thousand grain weight was observed between M_3 and M_4 levels of fertilizers.

2. <u>Yield</u>.

The data on mean values of grain and straw yields and harvest indices are presented in Table 7 and analysis of variance in Appendix IV.

a. Grain yield.

Significant increase in grain yield was observed with increased levels of fertilizers. The highest grain yield, recorded at M_4 was significantly superior to all the other treatments. The treatment M_3 was significantly superior to M_2 and M_1. The lowest grain yield was obtained with M_1 which was significantly inferior to the other treatments.

The time of nitrogen application did not influence the grain yield significantly.

b. Straw yield.

It was observed from the data that the straw yield also increased with increase in the level of fertilizer and the rate of increase was significant at all levels.

No significant difference in straw yield was observed due to the different times of application of nitrogen.

c. Harvest index.

The statistical analysis of the data showed that the harvest index was influenced by the graded levels of fertilizers. M_1 recorded the lowest harvest index when compared to the other treatments. M_3 recorded the highest index which was on par with M_4 and M_2.

The time of application of nitrogen did not influence the harvest index.

Table 7. Grain and straw yields, harvest index and protein content of grain.

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	Protein content of grain (%)
M_1	3.016	5.97	0.335	5.73
M_2	3.417	6.27	0.353	6.74
M_3	3.879	6.83	0.363	7.30
M_4	4.128	7.31	0.358	8.24
CD (0.05) M	0.203	0.189	0.0136	0.50
T_1	3.566	6.50	0.353	6.68
T_2	3.592	6.63	0.350	7.05
T_3	3.683	6.68	0.354	7.04
T_4	3.599	6.57	0.352	7.24
SE	0.140	0.131	0.0094	0.347
CD (0.05) T	NS	NS	NS	NS

Chemical Studies

1. Protein content of grain.

The data on mean protein content of grain is given in Table 7 and the analysis of variance in Appendix IV.

An increase in protein content was observed with increase in level of fertilizers and the rate of increase was significant at all levels. The time of application of nitrogen did not influence the protein content of grains.

2. Uptake of nitrogen, phosphorus and potassium at different stages of growth.

The data on mean uptake of nitrogen, phosphorus and potassium at active tillering, panicle initiation and booting stages are presented in Table 8 and the analysis of variance in Appendix V.

a. Nitrogen.

It is seen from the data that the uptake of nitrogen at active tillering was affected by various levels of fertilizers. The uptake was found to increase with an increase in the level of fertilizer and the rate of increase was significant at all levels.

The time of nitrogen application did not influence the nitrogen uptake at active tillering stage.

At panicle initiation stage there was progressive increase in nitrogen uptake when the level of fertilizer was enhanced from M_1 to M_4 and the rate of increase was significant at all the levels. The nitrogen uptake at panicle initiation stage was not influenced by the different times of application of nitrogen.

At booting stage also there was profound increase in the nitrogen uptake with increased level of fertilizer and this increase was significant at all levels.

The time of nitrogen application did not influence the nitrogen uptake at this stage.

b. Phosphorus.

There was a progressive increase in the phosphorus uptake with increased application of fertilizer at active tillering and this increase was significant at all levels.

The time of application of nitrogen did not influence the uptake of phosphorus at this stage.

At panicle initiation stage, the phosphorus uptake increased with increased level of fertilizers. All the treatments differed significantly and the superiority was in the order of $M_4 > M_3 > M_2 > M_1$.

The time of nitrogen application did not affect the phosphorus uptake at panicle initiation stage.

The phosphorus uptake at booting was also influenced by the levels of fertilizers only. The highest phosphorus uptake was recorded with M_4 which was significantly superior to the other treatments. Similar significant differences were noted with regard to M_3 and M_2 levels over their respective lower levels.

c. Potassium.

The potassium uptake at active tillering stage differed significantly with levels of fertilizers. The treatments M_4 and M_3 were on par and both were significantly superior to M_2 and M_1 and M_2 was significant over M_1.

The time of application of nitrogen did not influence the potassium uptake at this stage.

The levels of fertilizers significantly influenced the potassium uptake at panicle initiation stage. The highest potassium uptake recorded with M_4 was on par with M_3. Both M_3 and M_4 were significantly superior to M_1 and M_2. M_1 was inferior to the other treatments.

Table 8. Uptake of Nitrogen, Phosphorus and Potassium at different growth stages (kg/ha).

Treatments	N			P			K		
	ATS	PIS	Booting	ATS	PIS	Booting	ATS	PIS	Booting
M_1	10.34	28.14	34.46	1.75	7.54	12.26	7.78	29.81	53.82
M_2	12.82	34.64	40.23	2.11	8.20	15.70	9.30	33.33	63.22
M_3	16.01	42.48	52.40	2.42	9.43	16.95	10.35	42.63	72.68
M_4	18.45	46.49	64.34	2.68	9.96	19.43	10.60	43.53	82.26
CD (0.05) M	0.51	1.604	2.5	0.14	0.29	0.53	0,92	1.69	1.26
T_1	14.43	37.83	47.18	2.13	8.59	16.18	9.20	36.78	67.53
T_2	14.60	37.83	48.16	2.24	8.73	16.47	9.65	37.41	69.13
T_3	14.56	37.91	47.90	2.27	8.68	15.83	9.83	37.39	68.29
T_4	14.03	37.79	48.19	2.31	8.93	15.88	9.50	37.77	69.02
SE	0.35	1.111	1.73	0.09	0.20	0.37	0.64	1.17	1.26
CD (0.05) T	NS	NS	NS	NS	NS	NS	NS	NS	NS

ATS - Active tillering stage

PIS - Panicle initiation stage

The time of nitrogen application did not influence the potassium uptake at panicle initiation stage.

At booting, there was increase in the potassium uptake with increase in the levels of fertilizers.

The potassium uptake at booting was not affected by the time of nitrogen application.

3. <u>Uptake of nitrogen, phosphorus and potassium at harvest</u>.

The data on mean uptake of nitrogen, phosphorus and potassium at harvest are presented in Table 9 and the analysis of variance in Appendix V.

a. Nitrogen.

There was highly significant and progressive increase in nitrogen uptake with increase in the levels of fertilizers.

The time of application of nitrogen also influenced the plant uptake of nitrogen. Treatments T_3, T_4 and T_2 were on par and superior to T_1.

b. Phosphorus.

The uptake of phosphorus was influenced only by the levels of fertilizers. The uptake of phosphorus was high at M_4 level which was on par with M_3 and significantly

Table 9. Uptake of nitrogen, phosphorus and potassium at harvest (kg/ha).

Treatments	Nitrogen	Phosphorus	Potassium
M_1	38.41	14.11	64.63
M_2	41.80	16.61	72.97
M_3	58.28	19.12	80.20
M_4	69.66	20.09	88.93
CD (0.05) M	1.34	1.131	2.86
T_1	50.64	17.17	75.42
T_2	52.25	17.53	77.05
T_3	53.10	17.69	76.65
T_4	52.26	17.52	77.61
SE	0.93	0.78	1.98
CD (0.05) T	1.34	NS	NS

Table 10. Number of tillers/m^2 (M x T interaction)

	T_1	T_2	T_3	T_4	Mean
M_1	334.3	330.3	384.0	327.8	331.6
M_2	352.2	355.7	356.4	352.9	354.3
M_3	386.3	373.7	373.0	368.9	375.5
M_4	386.7	384.2	384.6	387.2	385.7
Mean	364.9	361.0	362.0	359.2	

CD for M x T combinations = 5.29

superior to M_2 and M_1 levels. M_3 was significantly higher to M_2 which inturn was significantly superior to M_1.

c. Potassium.

The graded levels of fertilizers positively influenced the potassium uptake and the differences were significant at all the levels.

The time of nitrogen application did not show any influence on potassium uptake.

4. Soil analysis after cropping.

The data on mean values of total nitrogen, available nitrogen, available phosphorus and exchangeable potassium are presented in Table 11 and analysis of variance in Appendix VI.

a. Total nitrogen.

The total nitrogen content of the soil did not differ significantly after cropping either with the fertilizer levels or with the time of applications.

b. Available nitrogen.

It is seen from the data that available nitrogen content was not influenced by the graded levels of fertilizers and the time of application of nitrogen.

Table 11. Soil analysis after cropping.

Treatments	Total nitrogen (%)	Available nitrogen (%)	Available phosphorus (ppm)	Exchangeable potassium (ppm)
M_1	0.083	0.024	10.007	38.062
M_2	0.093	0.025	10.008	38.458
M_3	0.101	0.025	10.091	38.502
M_4	0.086	0.025	10.007	38.330
CD (0.05) M	NS	NS	NS	NS
T_1	0.088	0.025	10.007	38.349
T_2	0.091	0.025	10.008	38.292
T_3	0.088	0.025	10.009	38.478
T_4	0.096	0.025	10.007	38.321
SE	0.0679	0.0010	0.0022	0.59
CD (0.05) T	NS	NS	NS	NS

c. Available phosphorus.

There was no significant difference in the available phosphorus content either due to levels of fertilizers or by time of application of nitrogen.

d. Exchangeable potassium.

The soil exchangeable potassium after cropping was neither influenced by the levels of fertilizers nor by the time of application of nitrogen.

5. Economics of rice production.

The data on net return and cost : benefit ratio at harvest are presented in Table 12 and analysis of variance in Appendix IV.

a. Net return.

The net return per hectare increased with increase in the level of fertilizers and the rate of increase was significant at all levels, the order of superiority being $M_4 > M_3 > M_2 > M_1$.

The time of nitrogen application did not affect the net return.

Table 12. Economics of Rice Production ('000 rupees/ha).

Treatments	Cost of production excluding treatments	Extra treatment cost	Total Expenditure	Total income	Net return	Cost: benefit ratio
M_1	4.250	0.501	4.751	8.114	3.36	1.71
M_2	4.250	0.593	4.843	9.021	4.18	1.86
M_3	4.250	0.685	4.935	10.055	5.12	2.04
M_4	4.250	0.778	5.020	10.800	5.78	2.15
CD (0.05) M	--	--	--	--	0.425	0.085
T_1	4.250	0.603	4.853	9.385	4.53	1.93
T_2	4.250	0.603	4.853	9.413	4.56	1.94
T_3	4.250	0.651	4.901	9.700	4.80	1.98
T_4	4.250	0.699	4.949	9.489	4.54	1.91
SE	--	--	--	--	0.290	0.059
CD (0.05) T	--	--	--	--	NS	NS

Cost of inputs

1. Nitrogen Rs.5.40/kg
2. Phosphorus Rs.5.63/kg
3. Potassium Rs.2.17/kg

Price of paddy Rs.2.00/kg

Price of straw Rs.0.35/kg

Labour charges

Men Rs.25.00/day

Women Rs.23.00/day

Table 13. LAI at active tillering stage (MxT interaction).

	T_1	T_2	T_3	T_4	Mean
M_1	0.873	0.864	0.865	0.857	0.865
M_2	0.939	0.883	0.903	0.938	0.916
M_3	1.197	1.254	1.246	1.089	1.197
M_4	1.497	1.334	1.540	1.344	1.429
Mean	1.127	1.084	1.139	1.057	

CD for MxT interaction = 0.08

Table 14. Number of filled grains per panicle (MxT interaction).

	T_1	T_2	T_3	T_4	Mean
M_1	75.67	79.47	82.77	84.40	80.6
M_2	84.3	85.73	87.10	86.17	85.8
M_3	91.73	93.40	93.97	93.96	93.3
M_4	93.80	93.87	93.67	91.57	93.2
Mean	86.4	88.1	89.4	89.0	

CD for MxT interaction = 1.80

b. Cost : benefit ratio.

The cost : benefit ratio was influenced by the levels of fertilizers. It increased with increase in the level of fertilizer and the rate of increase was significant at all levels.

The time of nitrogen application did not influence the cost : benefit ratio.

Statistical analysis with path analysis and Correlation Studies.

1. Direct and indirect effects of yield attributes on yield.

The direct and indirect influence of the number of panicles/m^2 (X_1), the number of spikelets/panicle (X_2), thousand grain weight (X_3), the number of filled grains/ panicle (X_4), the weight of panicle (X_5), the LAI at active tillering (X_6), the LAI at panicle initiation (X_7) and the LAI at booting stage (X_8) on yield were investigated (Table 17). All the above characters were found to be highly correlated with the yield by 69 to 87 per cent.

The maximum direct effect was observed for X_3 (76 per cent) while it's correlation with yield was 87 per cent. Though, this character has got positive indirect effect via X_1 by 45 per cent, it has about an equal negative indirect effect via X_4 by 44 per cent. The positive indirect effects through X_2 was 7 per cent, X_7 was 11 per cent and X_8 was 18 per cent and negative indirect effects through X_5 was 11 per cent and X_6 was 15 per cent.

The correlation between X_1 and yield was 86 per cent, of which 47 per cent was the direct effect of X_1. It's indirect effect via X_3 was high (72 per cent). X_1 was positively and indirectly influenced by X_2 (7 per cent), X_7 (11 per cent) and X_8 (17 per cent) and negatively influenced by X_4 (43 per cent), X_5 (10 per cent) and X_6 (15 per cent). Though the correlation between X_2 and yield was high (86 per cent), it's direct effect was only small (7 per cent). This correlation is mainly the resultant of it's indirect effect via X_3 (73 per cent) and X_1 (43 per cent). The high negative indirect effect for X_2 was observed for X_4 (41 per cent). The characters X_7 and X_8 positively and indirectly influenced by 11 and 18 per cent respectively while X_5 (9 per cent) and X_6 (15 per cent) negatively influenced X_1.

The Correlation between X_4 and yield was positive and high (81 per cent) but it's direct effect was negative (46 per cent). This high Correlation is mainly due to it's indirect effects via X_3 (73 per cent) and X_1 (44 per cent).

Similarly the Correlationsbetween X_5 and yield (69 per cent) and X_6 and yield (77 per cent) werehighly significant while they have negative direct influence (13 per cent and 17 per cent respectively). Here also the positive indirect effects via X_3 (62 and 65 per cent respectively) and X_1 (38 and 40 per cent respectively) helped to get the high Correlation. The characters X_7 and X_8 though influenced the yield directly and positively their contribution was less (13 per cent and 21 per cent respectively). While their correlation with yield was high (78 and 79 per cent respectively). This high Correlation is mainly due to their indirect effects via X_3 (64 and 63 per cent respectively) and X_1 (39 and 38 per cent respectively).

The characters X_5 and X_6 were found to have negative influence on yield both directly and indirectly. However their contributions were less ranging from 8 to 13 per cent and 10 to 17 per cent respectively.

2. Direct and indirect effects of nitrogen, phosphorus and potassium.uptake at harvest on dry matter production.

Ninety seven to ninety eight per cent Correlation was observed between nitrogen, phosphorus and potassium uptake with dry matter production (Table 18). The Correlation between nitrogen uptake and dry matter yield was

Table 15. Simple correlation between grain yield and yield attributes.

Number of Panicle/m^2	Number of spikelets/ panicle	Thousand grain weight	Number of filled grains/ panicle	Weight of panicle	LAI at active tillering stage	LAI at panicle initiation stage	LAI at booting stage
0.8603	0.8555	0.8729	0.8071	0.6905	0.7711	0.7784	0.7868
	0.9098	0.9507	0.9344	0.8087	0.8446	0.8380	0.8087
		0.9515	0.9005	0.7238	0.8401	0.8337	0.8247
			0.9546	0.8123	0.8464	0.8408	0.8308
				0.8026	0.8213	0.8396	0.8090
					0.5967	0.6673	0.7243
						0.9146	0.8390
							0.8718

All the correlation values are significant at 1% level.

Table 16. Simple correlation between dry matter yield and Nitrogen, Phosphorus and Potassium uptake at harvest.

Nitrogen	Phosphorus	Potassium
0.9790	0.9762	0.9713
	0.9336	0.9567
		0.9518

All the correlation values are significant at 1% level.

Table 17. Direct and indirect effects of yield contributing characters on yield.

X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	Total Corre-lation (r)
0.4683	0.0674	0.7249	-0.4269	-0.1046	-0.1469	0.1057	0.1724	0.8603
0.4260	0.0741	0.7256	-0.4115	-0.0936	-0.1462	0.1052	0.1759	0.8555
0.4452	0.0705	0.7625	-0.4362	-0.1051	-0.1473	0.1061	0.1772	0.8729
0.4376	0.0667	0.7279	-0.4570	-0.1039	-0.1429	0.1060	0.1727	0.8071
0.3787	0.0536	0.6195	-0.3668	-0.1294	-0.1038	0.0842	0.1545	0.6905
0.3955	0.0623	0.6454	-0.3753	-0.0772	-0.1740	0.1154	0.1789	0.7710
0.3925	0.0618	0.6411	-0.3837	-0.0863	-0.1592	0.1262	0.1860	0.7784
0.3787	0.0611	0.6335	-0.3701	-0.0937	-0.1460	0.1100	0.2133	0.7868

X_1 - No. of panicles/m^2
X_2 - No. of spikelets/panicle
X_3 - Thousand grain weight
X_4 - No. of filled grains/panicle
X_5 - Weight of panicle
X_6 - LAI at active tillering stage
X_7 - LAI at panicle initiation stage
X_8 - LAI at booting stage

The underlined figures denote the direct effects.

Table 18. Direct and indirect effects of nitrogen, phosphorus and potassium uptake at harvest on dry matter production.

Nitrogen	Phosphorus	Potassium	Total correlation (r)
0.4679	0.4064	0.1047	0.9790
0.4368	0.4353	0.1041	0.9762
0.4476	0.4143	0.1094	0.9713

The underlined figures denote the direct effects.

98 per cent which is the sum total effect of nitrogen directly by 47 per cent and indirectly via phosphorus (41 per cent) and potassium (10 per cent). The Correlation of phosphorus uptake with the dry matter yield was 98 per cent which is the sum total effect of phosphorus directly by 44 per cent and indirectly via nitrogen (44 per cent) and potassium (10 per cent). The Correlation between potassium uptake and dry matter production was 97 per cent though the direct contribution of potassium was only 11 per cent. The high indirect effects through nitrogen (45 per cent) and phosphorus (41 per cent) are responsible for the high correlation of potassium with dry matter production.

DISCUSSION

V DISCUSSION

The present experiment was conducted in the State Seed Farm, Kottarakara, Quilon District to bring out a suitable fertilizer management schedule for the rice variety Cheradi under the prevailing agro-climatic conditions of Quilon and Trivandrum districts. The treatments included were four graded levels of fertilizers such as 40:20:20, 50:25:25, 60:30:30 and 70:35:35 NPK/ha and four times of nitrogen application. The results obtained are discussed below.

1. Growth characters.

a. Height of plants.

The results presented in Table 2 revealed that application of fertilizers at higher doses significantly influenced the height of plants at active tillering, panicle initiation, booting and harvest stages. Application of 70:35:35 kg NPK/ha gave the maximum height and 40:20:20 kg NPK/ha gave the minimum height at all stages of growth. In general an increase in fertilizer levels produced progressive increase in height of plants at all the stages of growth. This positive influence of nitrogen, phosphorus and potassium in increasing the height of plants might be due to their combined influence in cell division and cell elongation. An adequate supply of nitrogen is associated with a vigorous vegetative growth (Tisdale and Nelson, 1985). It is reported that supply of nitrogen increases height and a deficiency results in stunted growth of rice plant (Roy et al. 1980). Significant influence of nutrients especially nitrogen in enhancing the vegetative growth of rice plant is a well established fact. Increase in height of plants due to nitrogen fertilization has been reported by Lenka and Behera (1967), Koyama and Niamsrichand (1973), Alexander et al. (1974), Sadayappan et al. (1974) Gunasena et al. (1979), Sushamakumari (1981), Sobhana (1983) and Surendran (1985). Increase in the height of plants due to phosphorus fertilization has been reported by Jagadeesh chandran (1968), Aaron et al. (1971) and Chowdhury et al. (1978). Inadequate supply of potassium results in stunted plants with short droopy and dark green leaves (De Datta and Surjith (1981). Ramankutty (1967), Mukherji et al. (1968) and Vijayan and Sreedharan (1972) have reported increase in plant height due to potassium application. The present finding of this experiment is in agreement with the above findings.

Time of nitrogen application did hot influence the height of plants at any of the growth stages. It was observed from the results that application of nitrogen in two, three or four splits do not significantly influence the height of plants. The results of this experiment corroborate the findings of Mathew (1971), Meerasahib (1972), Panicker (1975), Ajitkumar (1984) and Surendran (1985) who also did not find any influence on the height of rice plants due to change in time of nitrogen application.

b. Tiller count/m^2.

The data on mean tiller count/m^2 presented in Table 2 revealed that application of higher levels of fertilizers significantly influenced the tiller production. Application of 70:35:35 kg NPK/ha produced the highest tiller count of 385.7/m^2 while the minimum count of 331.6 was obtained with the lowest level of 40:20:20 kg NPK/ha. Though tiller production is largely a genetic character, it has been well established that application of higher levels of nitrogen, phosphorus and potassium have influence in increasing the number of tillers. According to De Datta and Surjith (1981) nitrogen increases height and tiller number, phosphorus encourages active tillering and stimulates root development and potassium increases phosphorus response and favours tillering in rice. Similarly, Uexkull (1976) propounded that tillering in rice plant is strongly influenced by genetic factors and by nitrogen and phosphorus levels in the soil.

The effect of nitrogen fertilization in enhancing the tiller count has been reported by Lenka and Behera (1967), Sood and Singh (1972), Kalyanikutty and Morachan (1974), Gunasena et al. (1979), Sreekumaran (1981), Sushamakumari (1981), Ajitkumar (1984) and Surendran (1985). Phosphorus was also found to have a favourable influence, as it is the nutrient which encourages root development and more tillering. The results obtained in the investigation regarding the effect of phosphorus on tiller count is in comformity with the findings of Terman and Allen (1970), Nair et al. (1972), Katyal et al. (1975), Chowdhury et al. (1978) and Fageria et al. (1982). Potassium being an element favouring protein production of plants might have exerted some influence on growth and tiller production. Increase in tiller counts with increasing potassium levels have been obtained by Usha (1966), Kulkarni et al. (1975) and Singh and Singh (1979).

Time of nitrogen application significantly influenced tiller production and application of nitrogen in two equal splits (viz., at basal and at active tillering) produced the highest number of tillers at panicle initiation stage. It is evident further that an early supply of nitrogen has a positive effect in increasing the tiller number. In the case of other treatments even though the same quantity of nitrogen was supplied it failed to produce beneficial effect on the tiller production since their applications were untimely.

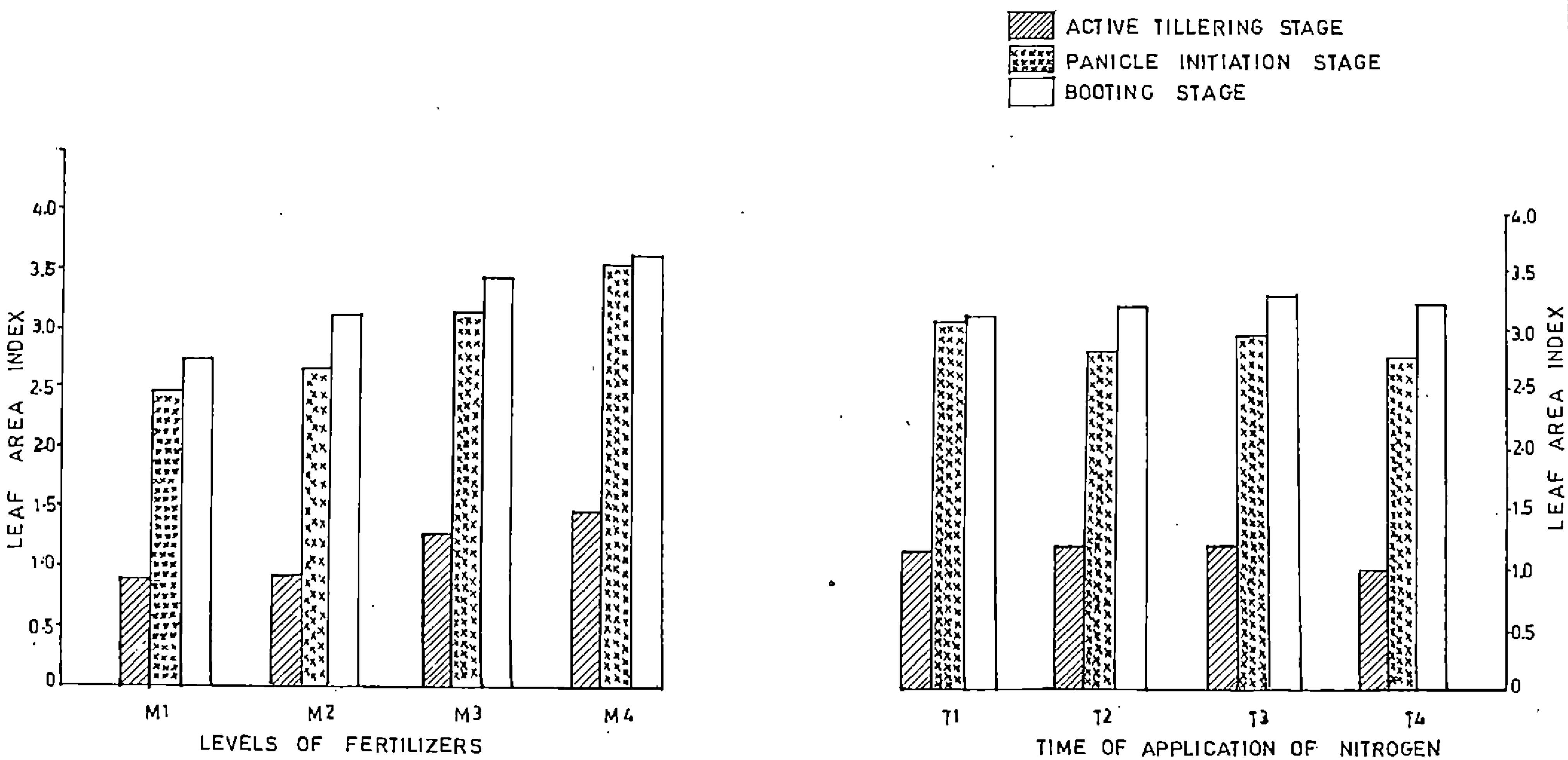
Interaction of fertilizer levels with time of application of nitrogen was also found significant (Table 10). Higher levels of fertilizers in combination with two split applications as basal and at active tillering stage, helped in increasing the tiller count at panicle initiation stage compared to the lower levels.

2. <u>Growth analysis</u>.

a. Leaf area index.

Results presented in Table 3 and Fig.3 revealed that there was an increase in LAI with increase in levels of fertilizers at all stages of growth. The NPK level of 70:35:35 kg/ha gave the highest leaf area indices at active tillering, panicle initiation and booting stages and was superior to other levels, while 40:20:20 kg NPK/ha gave the lowest leaf area indices at all stages. The influence of nitrogen in increasing the LAI is well known. Nitrogen stimulates tillering, formation of new leaves and increases the size of leaves (Uexkull, 1976). Nitrogen application increased the LAI due to its influence on the increment of number of tillers and size of leaves (Stone and Steinmetz, 1979). It is seen from Table 2 that those

Fig. 3. LEAF AREA INDEX AT DIFFERENT GROWTH STAGES AS INFLUENCED BY DIFFERENT FERTILIZER LEVELS AND TIME OF APPLICATION OF NITROGEN



Scale. 1cm.= 0.5

levels of nutrients which produced the highest number of tillers, correspondingly recorded higher leaf area indices. Probably the increase in number of tillers might have contributed to a corresponding increase in the number of leaves which in turn might have influenced in increasing the LAI. The result of this experiment is in confirmity with the findings of Anon (1965), Singh and Pande (1974) Abdul galil et al. (1979) Sreekumaran (1981), Sobhana (1983) and Surendran (1985) who observed that an increase in leaf area index is caused by an increase in the number of tillers and that the LAI increases with increase in the levels of nitrogen.

The time of application of nitrogen significantly influenced the LAI at active tillering and panicle initiation stages only. At active tillering the LAI of all the treatments which received 50% of nitrogen as basal dose were found to be on par. The treatments which received 25% of nitrogen as basal dose recorded the minimum LAI and was found to be significantly inferior to other treatments. At panicle initiation, the treatment which received the full dose of nitrogen was found to be significantly superior to other treatments. The treatment T_3, which received ¾ dose of fertilizer was significantly superior to treatment T_2 and T_4 which received half the dose of fertilizers in one and two splits respectively.

This clearly spells out the role of nitrogen in enhancing the leaf area index, which corroborate the findings of Murthy and Murthy (1981), Sushamakumari (1981) and Surendran (1985).

Though no significant difference in LAI was noticed at booting stage, the highest LAI was observed when half dose of nitrogen was given as basal followed by top dressing with 25% nitrogen each at active tillering and panicle initiation stages. Here the lowest leaf area index was seen in the treatment which received the full dose of nitrogen before panicle initiation stage.

The interaction between levels and times of nitrogen application (Table 13) did not show any definite trend. The interaction is seen erratic and so any definite conclusion cannot be drawn.

b. Crop growth rate.

Successive addition of NPK fertilizers from 40:20:20 kg/ha level to 70:35:35 kg/ha level progressively increased the crop growth rate between active tillering and panicle initiation, and panicle initiation and booting stages. This increase in growth rate might be due to the highest dry matter production observed with this fertilizer level at all the stages of growth (Table 5). Increase in

LAI due to nitrogen application might have also contributed for the increase in CGR. The result of this experiment is in conformity with the findings of Palit et al. (1976) and Surendran (1985).

Time of nitrogen application influenced the crop growth rate between active tillering and panicle initiation stages only, at which the highest CGR resulted when equal doses of nitrogen were given at transplanting and at active tillering. This was on par with nitrogen given half at transplanting, one fourth at active tillering and one fourth at panicle initiation stages. This may be due to the highest dry matter production observed with these treatments at active tillering and panicle initiation stages, consequent on the availability of more nitrogen in the early stages of growth.

c. Relative growth rate.

Although relative growth rate between active tillering and panicle initiation, and panicle initiation and booting stages were influenced by levels of fertilizers; the data presented in Table 4 did not show any definite trend or pattern in these two phases. This may be due to the variation in dry matter production observed with levels of fertilizers between stages of growth. Highest RGR was observed with the fertilizer level of 60:30:30 kg NPK/ha between active tillering and panicle initiation stages where as it was with 70:35:35 kg NPK/ha between panicle initiation and booting stages. This shows the favourable influence of NPK fertilizer elements on RGR. Increase in RGR due to increase in level of nitrogen has been reported by Rao and Ramanujam (1971) and Surendran (1985).

Time of nitrogen application influenced RGR, between panicle initiation and booting stages where in it was the highest when equal doses of nitrogen was given as basal and at panicle initiation stage which was on par with nitrogen given half as basal, one fourth at active tillering and one fourth at panicle initiation stages. This may be due to the highest dry matter production observed with this treatments at the booting stage, consequent on the availability of more nitrogen in the early stages of growth. This result is in agreement with the findings of Rao and Ramanujam (1971) and Surendran (1985).

3. <u>Dry matter production</u>.

The results presented in Table 5 showed that there was an increase in dry matter production in accordance with an increase in the levels of nutrition at active tillering, panicle initiation, booting and at harvest stages. Increased supply of nitrogen in combination with phosphorus and potassium seemed to have improved the overall growth of rice plant resulting in increased dry matter accumulation.

According to Steineck and Haeder (1980) the efficiency of nitrogen utilisation by the plant is determined by the potassium supply. The potential of nitrogen to increase yield and dry matter is only fully realised when the necessary amount of potassium is also supplied. The above observations re-inforce the effect of higher levels of nitrogen coupled with increase in potassium fertilization. The highest nitrogen, phosphorus and potassium levels of 70:35:35 kg/ha produced the highest number of tillers and maximum height of plants. An increase in the height of plants and tiller number was observed with an increase in the level of fertilizer. Correspondingly the dry matter production also maintained the same trend. The nitrogenous compounds contribute significantly to the total dry weight of the plants. Increase in dry matter production with increased application of nitrogen was also reported by workers like Ramanujam and Rao (1971), Singh and Pande (1974), Nair (1976), Gunasena et al. (1979), Nagre and Mahajan (1981), Sushamakumari (1981), Upadhyay and Pathak (1981) and Surendran (1985). Phosphorus and potassium also have influence on dry matter production by way of producing a well developed root system and a betterment, in general, of plant growth which inturn facilitate increased uptake of all nutrients. Increase in dry matter production with increase in phosphorus levels has been reported by Upadhyay and Pathak (1981). Significant and positive correlations (Table 16) were observed between dry matter production and uptake of nitrogen, phosphorus and potassium at harvest

Time of nitrogen application did not significantly affect the dry matter yield at any of the growth stages. Application of 50% nitrogen as basal followed by 25% each at active tillering and panicle initiation stages, produced the highest dry matter at harvest while the highest dry matter accumulation was obtained by the treatment which received equal doses of nitrogen at transplanting and panicle initiation stages. The results obtained were in agreement with the findings of Surendran (1985).

Post Harvest Observations

1. Yield attributes.

a. Number of panicles/m^2.

The results presented in Table 6 showed that the number of panicles/m^2 was influenced by increase in the level of fertilizers. Significant and progressive increase in the production of panicles was observed at all levels. Highest number of panicles/m^2 (344) was recorded with NPK level of 70:35:35 kg/ha and the lowest number was recorded with the fertilizer level of 40:20:20 kg/ha. It is seen from Table 2 that there was an increase in tiller number with an increase in the level of fertilizer. Out of the total number of tillers produced more number have become productive with increased level of fertilizers. Rice plant requires a large amount of nitrogen at the early and mid tillering stages to maximise the number of panicles (De Datta and Surjith, 1981). The role of nitrogen in increasing the panicle number in tall indica had been stressed by Sood and Singh (1972). Similar results were also reported by Nishi and Kaneki (1967), Ramanujam and Rao (1971), Koyama and Niamsrichand (1973), Rethinam (1974), Dixit and Singh (1979), Sushamakumari (1981), Balasubramaniyan (1984) and Surendran (1985). The beneficial effects of phosphorus in increasing the panicle number were reported by Place et al. (1970), Majumdar (1971), Nair et al. (1972), Kuo (1973), Bhattacharya and Chatterjee (1978) and Bhatti et al. (1985). The favourable influence of higher levels of potassium on this attribute has been reported by Kulkarni et al. (1975), Padmaja (1976) and Sahu and Ray (1976). Panicle number positively correlated with grain yield (Table 15).

Time of nitrogen application did not influence the number of panicles/m^2 significantly. But the highest number of panicles (317.5) was obtained when nitrogen was given in three splits (½ basal + ¼ active tillering + ¼ panicle initiation stage) and was more or less the same with nitrogen applied in four equal splits (316.2) at basal, active tillering, panicle initiation and booting stages. This may be due to the better utilisation of nitrogen by the crop since nitrogen was supplied at the important stages of growth. Similar results were also reported by Ajitkumar (1984) and Surendran (1985).

b. Length of panicle.

The results (Table 6) revealed that the length of panicle was significantly influenced by the NPK levels. Maximum panicle length was observed with 70:35:35 kg NPK/ha which was on par with 60:30:30 kg NPK/ha level. Even though panicle length is a genetically controlled character, the positive influence of management practices like NPK fertilization in increasing the panicle length had been reported. Increase in panicle length due to nitrogen fertilization had been reported by (Anon, 1969 a) Ramanujam and Rao (1971), Singh (1971), Dixit and Singh (1979), Sushamakumari (1981) and Surendran (1985). The favourable influence of phosphorus on this yield attribute had been reported by Potty (1964) and Majumdar (1971).

Length of panicle was not influnced by the time of nitrogen application. Ajitkumar (1984) and Surendran (1985) also reported similar results of panicle length due to time of nitrogen application on tall indicas.

c. Weight of panicle.

The results (Table 6) showed that there is an increasing trend in the weight of panicle with increase in the fertilizer level upto 60:30:30 kg level after which it declined. Though not significant it reveals that the weight of panicle in tall indica variety requires an NPK level of 60:30:30 kg/ha.

Time of nitrogen application also did not influence the weight of panicles. This is in confirmity with the findings of Ajitkumar (1984) and Surendran (1985).

d. Number of spikelets per panicle.

It is observed from the results (Table 6) that spikelet number increased upto the fertilizer level of 60:30:30 kg/ha beyond which there was no favourable effect. De Datta and Surjith (1981) has reported that nitrogen increases the number of spikelets per panicle and also the filled spikelet percentage per panicle. Increase in spikelet number due to nitrogen fertilizationhas also been reported by Koyama and Niamsrichand (1973), Prasad and Sharma (1973), Sushamakumari (1981) and Surendran (1985). Favourable influence of phosphorus on number of grains per panicle has been reported by Aaron et al. (1971), Majumdar (1971), Singh and Varma (1971), Sasaki and Wada (1975) and Bhattacharya and Chatterjee (1978). Krishnan (1968), Vijayan and Sreedharan (1972) and Uexkull (1982) reported that number of grains/panicle increased with potassium application.

Application of nitrogen at different times also influenced the number of spikelets per panicle. Highest number was recorded when nitrogen was applied in three split doses viz., 50% as basal, 25% at tillering and 25% at panicle initiation stage. Here it has been very clearly seen that application of a higher dose of fertilizer in the early stages followed by an adequate supply in the active tillering and panicle initiation stages helped in increasing the no. of spikelets/panicle. Bouldin et al. (1980) stated that a reduced yield potential is set by low early season nitrogen, and high nitrogen at later dates will not over come an early season deficit. This statement is well corroborated with the findings of this experiment.

e. Number of filled grains per panicle.

The results presented in Table 6 showed that the filled grains per panicle was significantly influenced by levels of fertilizers. Application of 60:30:30 kg NPK/ha produced the highest number of filled grains (93.3) which was on par with the fertilizer level of 70:35:35 kg NPK/ha (93.2) and both were significantly superior to other levels. Uexkull (1976) propounded that nitrogen increases potential number of grains per panicle and phosphorus increases the percentage of filled grains. Similarly, Roy et al. (1980) reports that potassium stimulates building up and translocation of carbohydrates and grain development. The results of this experiment, however, show that higher levels of fertilizers over the NPK dose of 60:30:30 kg/ha has no influence on <u>Cheradi</u> variety in increasing the number of filled grains per panicle. This observation is in agreement with the findings of Ramanujam and Rao (1971).

The time of nitrogen application also has a significant influence on filled grain production. Three split applications of nitrogen, half at transplanting, one fourth at active tillering and one fourth at panicle initiation stages, were found to produce the highest number of filled grains. This treatment was on par with four equal split applications at transplanting, active tillering, panicle initiation and booting stages. This shows that continuous and more or less uniform supply of nitrogen from transplanting to panicle initiation and/ or booting stages is more beneficial than other times of application in enhancing the number of filled grains per panicle. This result is in conformity with the findings of Varma and Sreevastava (1972) and Bhaumik and Ghosh (1977).

There was significant influence on this aspect by the various treatment combinations. Highest number of filled grains per panicle was observed where 60 kg N/ha was given half as basal, ¼ at active tillering and ¼ at panicle initiation stages which was on par with 60 kg N/ha given in two or four equal splits or 70 kg nitrogen given in two, three or four splits. This shows the favourable effect of split application of higher levels of nitrogen in increasing the filled grain production per panicle.

f. Percentage of unfilled grains.

It is seen from the results presented in Table 6 that an increase in fertilizer dose from 40:20:20 to 60:30:30 level resulted in a significant decrease in the percentage of unfilled grains. But when the fertilizer level was raised from 60:30:30 level to 70:35:35 level, an increase in percentage of unfilled grains was observed. From this result it is quite evident that the effect of NPK fertilizer was beneficial up to 60:30:30 kg/ha and beyond which the effect was retrograded probably due to the effect of excess nitrogen in increasing sterility in cereals. Increase in the percentage of unfilled grains due to enhanced application of nitrogen has been reported by workers like Patel (1967), Kalyanikutty et al. (1968), Enus and Sadique (1978), and Surendran (1985).

Time of application of nitrogen also influenced the percentage of unfilled grains. The percentage of unfilled grains has been significantly reduced in the treatments where a portion of the nitrogen was applied at the panicle initiation stage which has been found to be a critical period with regard to nitrogen application.

g. Thousand grain weight.

The results on thousand grain weight (Table 6) show that it was significantly increased at 60:30:30 kg NPK level compared to the lower levels, while it was on par with 70:35:35 kg NPK level. This shows that for Cheradi a fertilizer level of 60:30:30 NPK is more than sufficient for increasing the thousand grain weight.

According to De Datta and Surjith (1981) nitrogen increases the size of grains and phosphorus gives higher food value in addition to promoting good grain development, and potassium increases the size and weight of grains. Similarly increase in thousand grain weight due to nitrogen fertilization has been reported by Nishi and Kaneki (1967), Kalyanikutty and Morachan (1974), Nair (1976), Raju (1979) Sushamakumari (1981), and Surendran (1985). Increase in thousand grain weight due to phosphorus fertilization has been reported by Halappa et al. (1970), Majumdar (1971), Singh and Varma (1971), Kuo (1973), Thandapani and Rao (1976) and Chowdhury et al. (1978). The beneficial effect of potassium in increasing thousand grain weight has been reported by Singh and Singh (1979) and Sreekumaran (1981). The present finding is in full agreement with the above observations.

Time of nitrogen application did not influence thousand grain weight in Cheradi. Workers like Ajitkumar (1984) and Surendran (1985) have also reported similar results in tall indicas.

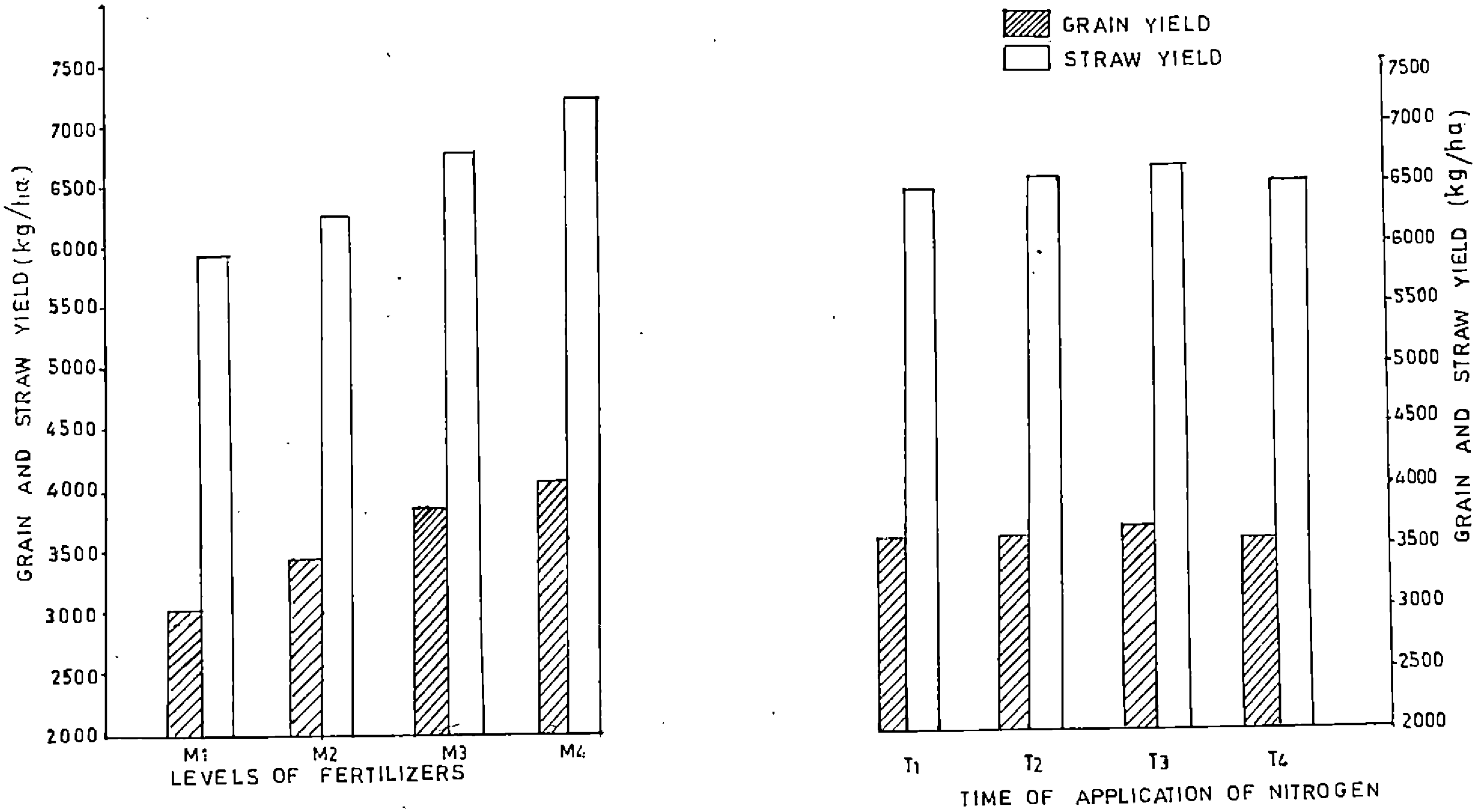
2. Yield.

a. Grain Yield.

The results presented in Table 7 and Fig.4 showed that there was significant increase in grain yield corresponding to an increase in fertilizer level. It is discernible from the result that 70:35:35 kg/ha NP and K resulted in highest grain yield (4.128 t/ha) where as 40:20:20 kg/ha N, P and K produced the minimum grain yield (3.016 t/ha). The data on yield attributes presented in Table 6 showed that important yield attributes such as number of panicles, number of spikelets per panicle and thousand grain weight increased with higher nutrition. Therefore, the increase in panicle number/m^2 and other yield attributes might have contributed to the increased grain yield. The beneficial effect of NPK fertilization in increasing the grain yield on cereals is well established. According to Steineck and Haeder (1980) increasing the potassium supply enhances response to increasing nitrogen supply which indicates that the main function of potassium lies in controlling nitrogen metabolism. Both the nutrients must be supplied in sufficient concentration for the realisation of their optimum effects. The effect of nitrogen on grain yield is more obvious than that of potassium, but the efficiency of nitrogen utilisation is improved by increasing the potassium supply. The beneficial effects of nitrogen, phosphorus and potassium in increasing grain yield with their higher supply might have contributed for this higher yields of grain. The favourable influence of nitrogen upon grain yield in tall indicas has been stressed by several workers like Lenka and Behera (1967), Nishi and Kaneki (1967), Ramanujam and Rao (1971), Sood and Singh (1972), Rathinam (1974), Sharma and De (1976), Bhuiya et al. (1979), Gunasena et al. (1979) and Surendran (1985). The role of phosphorus in increasing grain yield of rice has been established in the works of Naphade (1969), Padmakumari et al. (1969), Dev et al. (1970), Aaron (1971), Majumdar (1971), Kalyanikutty and Morachan (1974), Gopalakrishnan et al. (1975), Katyal et al. (1975), Ageeb and Yousif (1978), Rabindra (1978), Agarwal (1980), Upadhyay and Pathak (1981) and Ghobrial (1982). Favourable influence of potassium on grain yield has been reported by Vijayan and Sreedharan (1972). Velly (1973), Singh and Dubey (1975), Sahu and Ray (1976), Halm and Dartey (1977), Robinson and Rajagopalan (1977), Singh and Prakash (1979), Agarwal (1980), Mahapatra et al. (1980) and Gurmani et al. (1984). Significant and positive correlations were observed between grain yield and weight of panicle, number of spikelets per panicle, number of filled grains per panicle and thousand grain weight. Grain yield was also positively correlated with panicle number per unit area (Table 15).

Though time of application of nitrogen did not influence the grain yield significantly, highest grain

Fig. 4 GRAIN AND STRAW YIELD AS INFLUENCED BY DIFFERENT LEVELS OF FERTILIZERS AND TIME OF APPLICATION OF NITROGEN



Scale. 1cm.=500kg.

yield was recorded when nitrogen was applied in three splits such as half at transplanting, one fourth at active tillering and one fourth at panicle initiation stages. Split applications have been widely recommended to improve the efficiency of nitrogen fertilizer. However, time, quality and frequency of nitrogen topdressing will be governed by soil type, season, degree of water control and variety of rice (Uexkull, 1978). Application of nitrogen in splits up to panicle initiation stage is found to be a better practice for the variety. Urs and Havanagi (1969), Kulkarni et al. (1975), Mishra and Singh (1980), Anon, (1984 a and b) and Surendran (1985) reported higher grain yields with application of nitrogen in three splits upto panicle initiation stages.

b. Straw yield.

The results on straw yield (Table 7) showed significant increase at all levels of fertilizers. The highest fertilizer level of 70:35:35 kg NPK/ha was significantly superior to the lower levels and yielded maximum straw (7.31 t/ha). The enhanced straw yield with higher fertilizer doses may be attributed to the combined effect of plant height, tiller production, dry matter weight etc., which were favourably influenced by enhanced fertilizer doses. Thus a higher contribution of vegetative matter was obtained with higher nutrient levels. In the case of tall indica varieties, nitrogen acts as a vegetative growth stimulator resulting in higher straw production instead of correspondingly increasing the grain yield as in the case of dwarf indicas (Tanaka et al. 1964). The beneficial effect of nitrogen on increasing straw yield has been reported by many workers like Patel (1967), Sahu and Lenka (1967), Sood and Singh (1968), Anon., (1969), Allen and Terman (1978), Sushamakumari (1981), Bhatti et al. (1982) and Surendran (1985). Increase in straw yield with an increase in phosphorus application has been reported by workers like Patel (1967), Place et al. (1970), Prabha et al. (1975), Singh and Prakash (1979) and Rastogi et al. (1981). Usha (1966), Esakkimuthu et al. (1975), Singh et al. (1976) and Singh and Prakash (1979) reported increase in straw yield due to potassium application.

Time of nitrogen application did not given any significant difference in the straw yield. Application of 50 per cent nitrogen at transplanting, 25% each at active tillering and panicle initiation stages produced the highest straw yield (6680 kg/ha). Since dry matter production and LAI at the later stages of growth was not influenced by time of application of nitrogen, the straw yield was also not significantly influenced. Nair (1976) and Hoque et al. (1977) also did not observe any significant difference in straw yield due to split application of nitrogen.

c. Harvest index.

The data presented in Table 7 showed that the harvest index increased with increase in level of fertilizer up to 60:30:30 kg NPK/ha (0.363), and thereafter a decrease in harvest index was observed. It is seen from the same table that application of fertilizers at higher levels resulted in a marked increase in straw yield which in turn brought out a subsequent decrease in harvest index at the higher level of 70:35:35 kg NPK/ha. Eventhough, nitrogen by itself tends to decrease the harvest index, a combination of nitrogen, phosphorus and potassium brings about an increase in grain (Table 7) yield also. So the decrease in harvest index is not significant at the highest level of fertilizer application. Decrease in harvest index with increase in level of nitrogen, has been reported by Prasad (1981), Sreekumaran (1981), Sushamakumari (1981), Son et al. (1983) and Surendran (1985).

Time of nitrogen application did not influence the harvest index since it had no effect on grain and straw yield. This result is in conformity with the findings of Surendran (1985) who observed that the harvest index was not influenced by time of application of nitrogen.

In the present experiment, in general, a positive and significant influence was observed with higher levels of N, P and K in increasing the growth, yield attributes and yield of produces. At the same time there were not much conspicuous effect in many of the observations with the time of application of nitrogen. This phenomenon observed might probably be due to the combined effect of nitrogen, phosphorus and potassium on the growth and yield of rice. Eventhough nitrogen directly influenced the yield, the efficiency with which it is utilised by the plant is determined by potassium supply. (Steineck and Haeder, 1980). Similarly phosphorus allows the use of optimum nitrogen without detriment to straw strength, fertile ears or maturation of grain. The specific weight of the grain depend on the phosphate fertilization to a certain extent (Chaversia, 1980).

Chemical Studies

1. Protein content and quality of rice.

The protein content of grain provided in Table 7 showed that there was significant difference in the protein content of grain with different levels of NPK. The highest protein content (8.24%) was recorded with 70:35:35 kg NPK/ha and the lowest protein content (5.73%) was recorded by 40:20:20 kg NPK/ha. It is known that the major factor controlling the protein content of grain is nitrogen supply. Nitrogen increases the protein content in grain as reported by De Datta and Surjith (1981). Similarly phosphorus improves the quality of grain (Uexkull, 1976). In a general manner, good phosphate and potassium nutrition of the crop allows the optimal rate of nitrogen to be used without risk or upsetting the vegetative cycle or prejudicing the quality of the crop (Chaversia, 1980). Workers like Kulkarni (1973), Sadayappan and Kolandaiswamy (1974), Nagarajan et al. (1975), Rabindra et al. (1977), Singh and Prakash (1979), Mahajan and Nagre (1981), Sreekumaran (1981) and Surendran (1985) reported increase in grain protein content with increased rates of nitrogen. Favourable influence of phosphorus on grain protein content is reported by Thandapani and Rao (1974) and Agarwal (1978), and Singh and Prakash (1979). Increase in protein content with increased application of potassium was reported by Chavan and Magar (1971) and Agarwal (1978). The result in the present experiment is in agreement with the above mentioned findings.

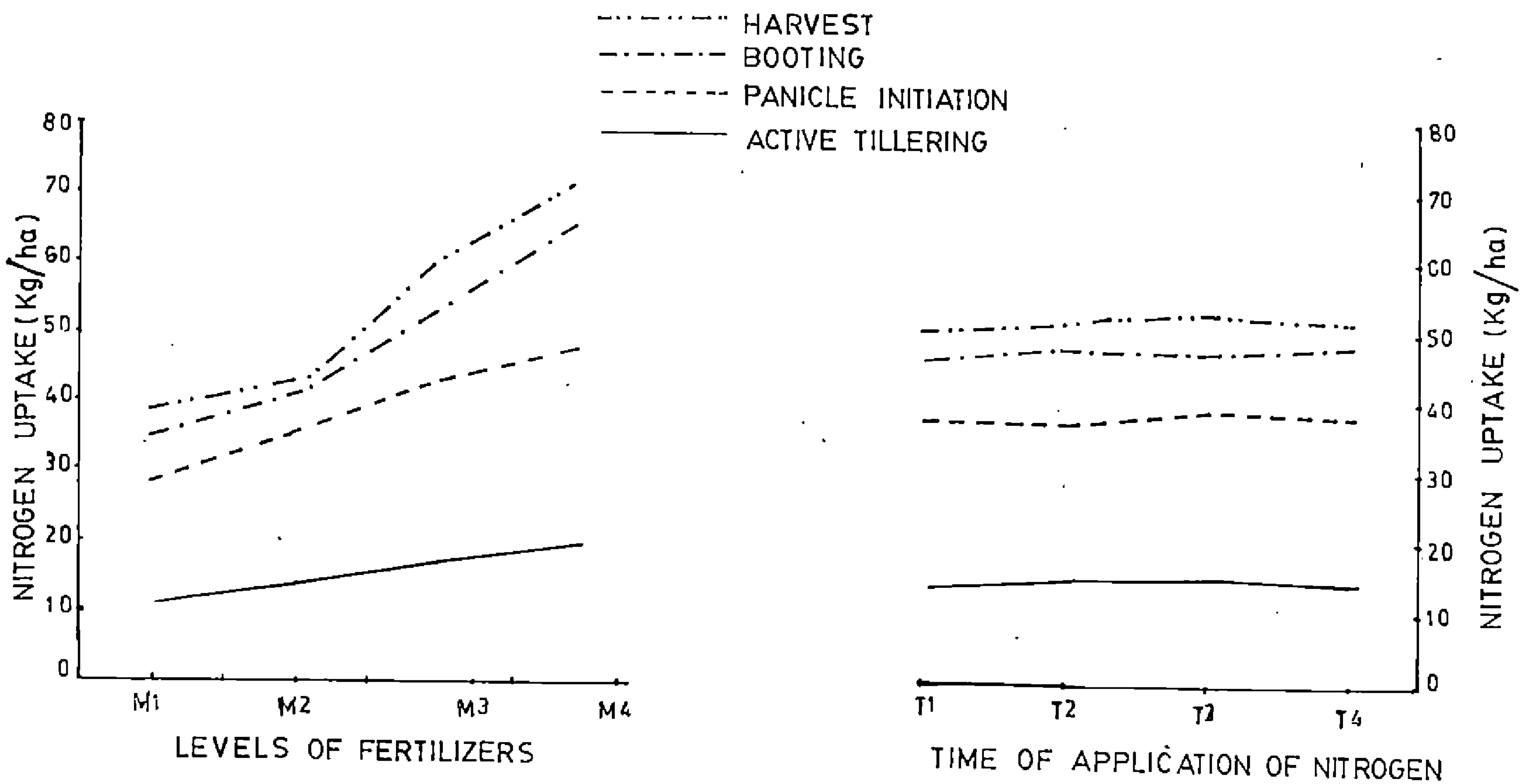
Time of nitrogen application did not influence the protein percentage of grains. This finding corroborates with the results of Ajitkumar (1984) and Surendran (1985).

2. Uptake of nitrogen, phosphorus and potassium at different stages of growth.

a. Nitrogen.

The results on mean uptake of nitrogen (Table 8 and Fig.5) at active tillering, panicle initiation and booting stages showed significant difference between different levels, at all stages of growth. It is seen from the results that increase in fertilizer level from 40:20:20 to 70:35:35 kg/ha of N, P and K gave a correspondingly progressive increase in the uptake of nitrogen at all stages of growth. Application of 70:35:35 kg NPK/ha gave the highest uptake of nitrogen at active tillering (18.45 kg/ha), panicle initiation (46.49 kg/ha) and booting stages (64.34 kg/ha). Nitrogen uptake was minimum at all the stages of growth by the application of the lowest level of 40:20:20 kg NPK/ha. The increase in nitrogen uptake may be due to the increase in the quantity of total dry matter produced and the increase in the content of nitrogen in the plant parts which were resulted by an increased supply of N P and K. Increase in nitrogen uptake

Fig. 5 NITROGEN UPTAKE AT DIFFERENT GROWTH STAGES



Scale. 1cm.=10kg.

with increase in level of nitrogen has been reported by many workers like Sims and Place (1968), Gopalaswamy and Raj (1977), Agarwal (1978), Raju (1978), Singh and Modgal (1978), Rai and Murthy (1979), Sushamakumari (1981), Ajitkumar (1984) and Surendran (1985). Along with nitrogen, the incremental doses of phosphorus and potassium given also might have contributed to the increased uptake of nitrogen. Singh and Prakash (1979) reported increase in nitrogen uptake due to increase in levels of phosphorus and potassium.

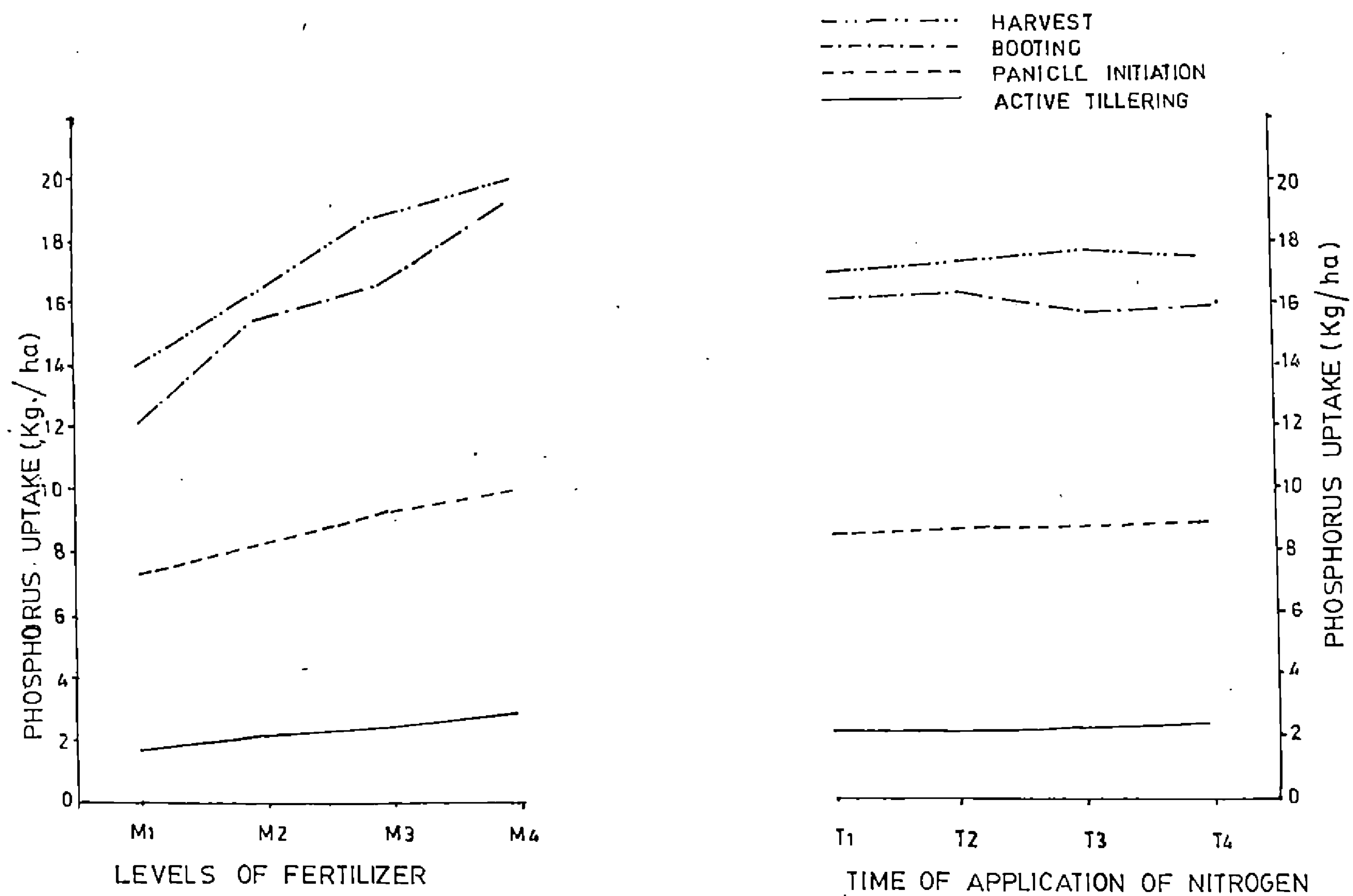
Time of nitrogen application did not influence nitrogen uptake at all stages of growth. This result is in agreement with the findings of Ajitkumar (1984) who did not observe any significant difference in nitrogen uptake due to different times of application of nitrogen.

b. Phosphorus.

The result presented in Table 8 and Fig. 6 showed that in general phosphorus uptake was found to increase with increase in the application of fertilizers at active tillering, panicle initiation and booting stages. Application of 70:35:35 kg NPK/ha recorded the highest uptake, while 40:20:20 kg/ha recorded the lowest uptake, and the same pattern was noticed at all stages of growth.

Fig. 6

PHOSPHORUS UPTAKE AT DIFFERENT GROWTH STAGES



Scale. 1cm.=2kg.

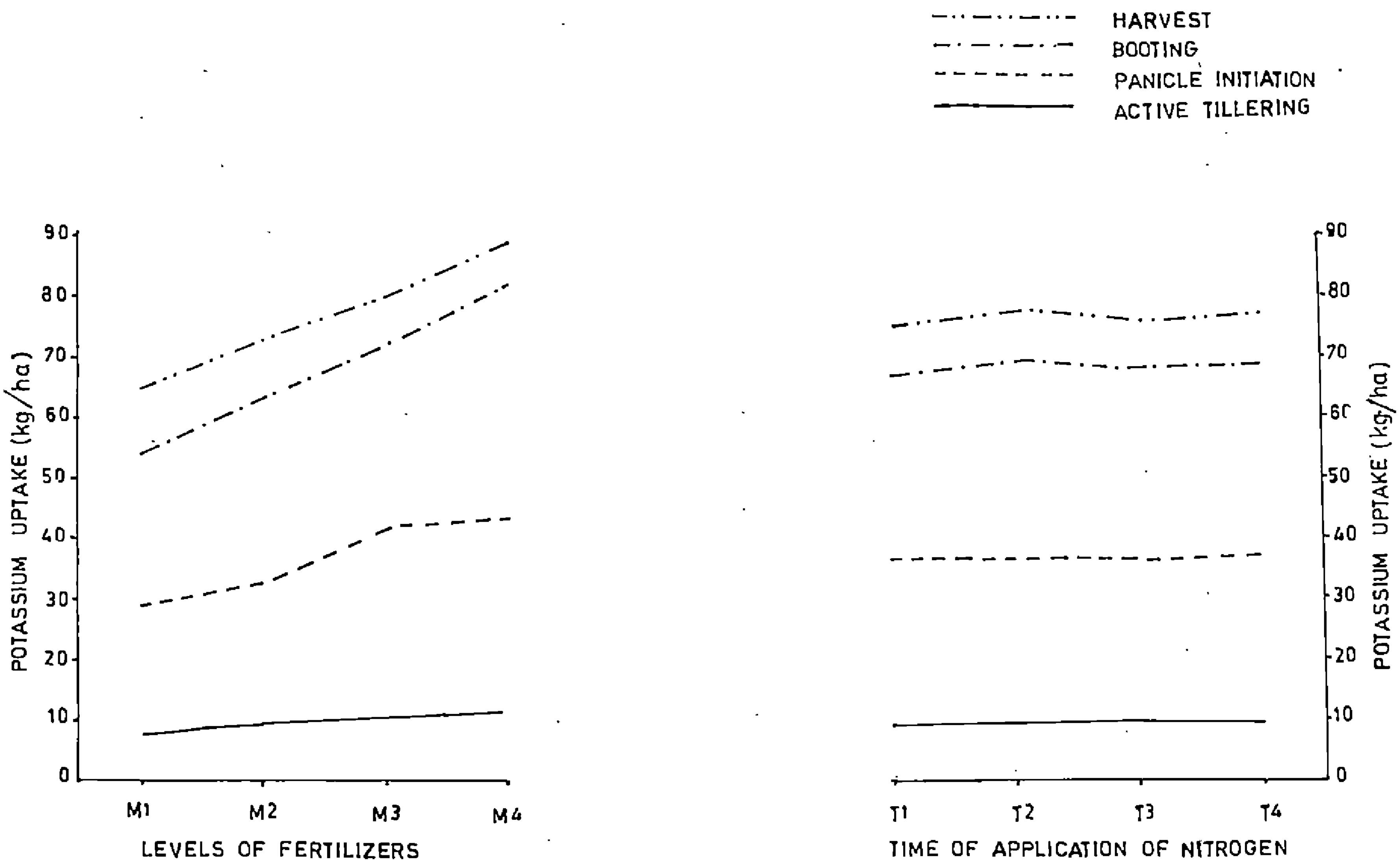
The increase could possibly be due to the increase in dry matter production and higher absorption of nutrients with increase in level of fertilizers at the various growth stages. Increase in uptake of phosphorus with increase in level of nitrogen has been reported by Sushamakumari (1981) and Surendran (1985). Higher level of phosphorus is found to increase the uptake as shown by Gupta et al. (1975). Trials by Singh et al. (1976) revealed that phosphorus uptake and translocation were higher with increase in application of potassium.

Time of nitrogen application did not have any significant influence on phosphorus uptake. Ajitkumar (1984) and Surendran (1985) also observed a similar trend in phosphorus uptake.

c. Potassium.

The data on uptake of potassium presented in Table 8 and Fig.7 showed that levels of fertilizers influenced potassium uptake at active tillering, panicle initiation and booting stages. At all stages of growth an increase in fertilizer levels brought about an increase in the uptake of potassium. At active tillering and panicle initiation stages, the uptake of potassium at 60:30:30 kg/ha and 70:35:35 kg/ha levels were found to be on par. The increase

Fig. 7 POTASSIUM UPTAKE AT DIFFERENT GROWTH STAGES



Scale. 1cm.=10 kg.

in potassium uptake with increase in the level of fertilizer may be due to the combined effect of dry matter production (Table 5) and the increase in the N, P and K content of plant parts. This result corroborates with the findings of Sushamakumari (1981) and Sobhana (1983) who also observed significant increase in potassium uptake with increase in the level of NPK nutrients.

Time of nitrogen application did not influence the uptake of potassium at any of the growth stages. Similar trend in potassium uptake due to time of nitrogen application has also been reported by Ajitkumar (1984) and Surendran (1985).

3. Uptake of nitrogen, phosphorus and potassium at harvest.

a. Nitrogen.

The result on the mean uptake of nitrogen (Table 9) shows significant influence due to levels of fertilizers. Application of higher doses of fertilizers resulted in an increase in the uptake of nutrients. The increase in the uptake of NPK may be due to the combined effect of higher content of the elements in plant parts and the overall increase in dry matter production observed with higher level of fertilizers in the various growth stages of the plant. Similar results have also been reported by many workers like Koyama and Niamsrichand (1973), Gopalaswamy and Raj (1977), Sushamakumari (1981) and Surendran (1985). Increase in the uptake of nitrogen with increase in levels of phosphorus has been reported by many workers like Krishnaswamy et al. (1974), Gupta et al. (1975) and Suseelan et al. (1978).

Time of application of nitrogen also influenced the nitrogen uptake at harvest. The uptake was found to be the minimum in the treatment which received the entire dose by active tillering stage. Other times of application of nitrogen were found to be on par. It can be infered from the results that top dressing of nitrogen is more effective for higher utilization of the element by the Plant. Increase in nitrogen uptake with top dressing given at panicle initiation stage, has been reported by Koyama et al. (1973), Ajitkumar (1984) and Surendran (1985).

b. Phosphorus.

It is seen from the result (Table 9) that application of higher doses of fertilizers resulted in an increase in the uptake of phosphorus at harvest. The highest uptake of phosphorus observed with the higher levels of fertilizer may be due to the combined effect of increased dry matter production with the increase in level of fertilizers (Table 5) and the increase in the composition of the element in plant parts. The influence of nitrogen on phosphorus transformation and subsequent increase in the uptake of phosphorus was stressed by Singh (1967). Suseelan et al. (1978) found that there was significant increase in phosphorus absorption with increasing rate of phosphorus fertilization. Singh and Prakash (1979) reported significant increase in phosphorus uptake with increased application of potassium.

Time of nitrogen application did not influence the uptake of phosphorus. This result is in agreement with the findings of Ajitkumar (1984) and Surendran (1985).

c. Potassium.

The result on potassium uptake presented in Table 9 shows significant increase in potassium uptake with increase in the levels of fertilizer. Highest uptake was observed with the fertilizer level of 70:35:35 kg NPK/ha. This result is in agreement with the findings of Singh and Prakash (1979). Sobhana (1983) also reported increase in uptake of potassium with increased application of N, P and K nutrients.

Time of nitrogen application did not affect the uptake of potassium. Ajitkumar (1984) and Surendran (1985) reported similar findings which are in corroboration with the present results.

4. Soil analysis.

a. Total nitrogen, available nitrogen, available phosphorus and exchangeable potassium.

The soil of the experimental site is rated as medium with respect to nitrogen and phosphorus status and as low with respect to potassium status, (Table 1). The nitrogen, phosphorus and potash content of the soil before and after cropping did not show much variation.

The results presented in Table 11 showed that total nitrogen, available nitrogen, available phosphorus and exchangeable potassium content of the soil after cropping were not influenced by the levels or times of application of nitrogen. This may be because the quantity of fertilizer applied is comparatively negligible to the total weight of the root zone depth of soil.

5. Economics of rice production.

The relative economics of NPK fertilization of Cheradi variety in Quilon district, in terms of grain and straw production, worked out on the basis of expenditure and returns, are presented in Table 12.

a. Net return.

The results showed significant increase in net return when the fertilizer levels were enhanced from 40:20:20 kg to

70:35:35 kg NPK/ha. There was an increase of 24.4 per cent in the net return with an increase in the level from 40:20:20 kg/ha to 50:25:25 kg/ha where as the increase was 22.48 per cent when the dosage was increased from 50:25:25 to 60:30:30 kg/ha. But the percentage increase in net return was reduced to 12.89 per cent when the level was enhanced from 60:30:30 kg/ha to 70:35:35 kg/ha.

Time of application of nitrogen did not influence the net return. The highest net return of Rs.4800/- was obtained when nitrogen was applied in three splits as 50% at transplanting, 25% each at active tillering and panicle initiation stages. The net return for the two splits and four splits were more or less the same (4530-4560) which shows that the three splits are better.

b. Cost : benefit ratio.

The result in Table 12 shows that different levels of fertilizer influenced the cost : benefit ratio, which was the highest at 70:35:35 kg NPK/ha (2.15) and lowest at the level of 40:20:20 kg/ha (1.71).

Time of nitrogen application did not influence the cost : benefit ratio. Application of 50 per cent nitrogen at transplanting followed by top dressing 25 per cent each at active tillering and panicle initiation stages recorded the highest cost : benefit ratio of 1.98, while two splits and four split applications gave a lower cost : benefit ratio varying between 1.91 to 1.94.

Statistical Analysis with path analysis and Correlation Studies.

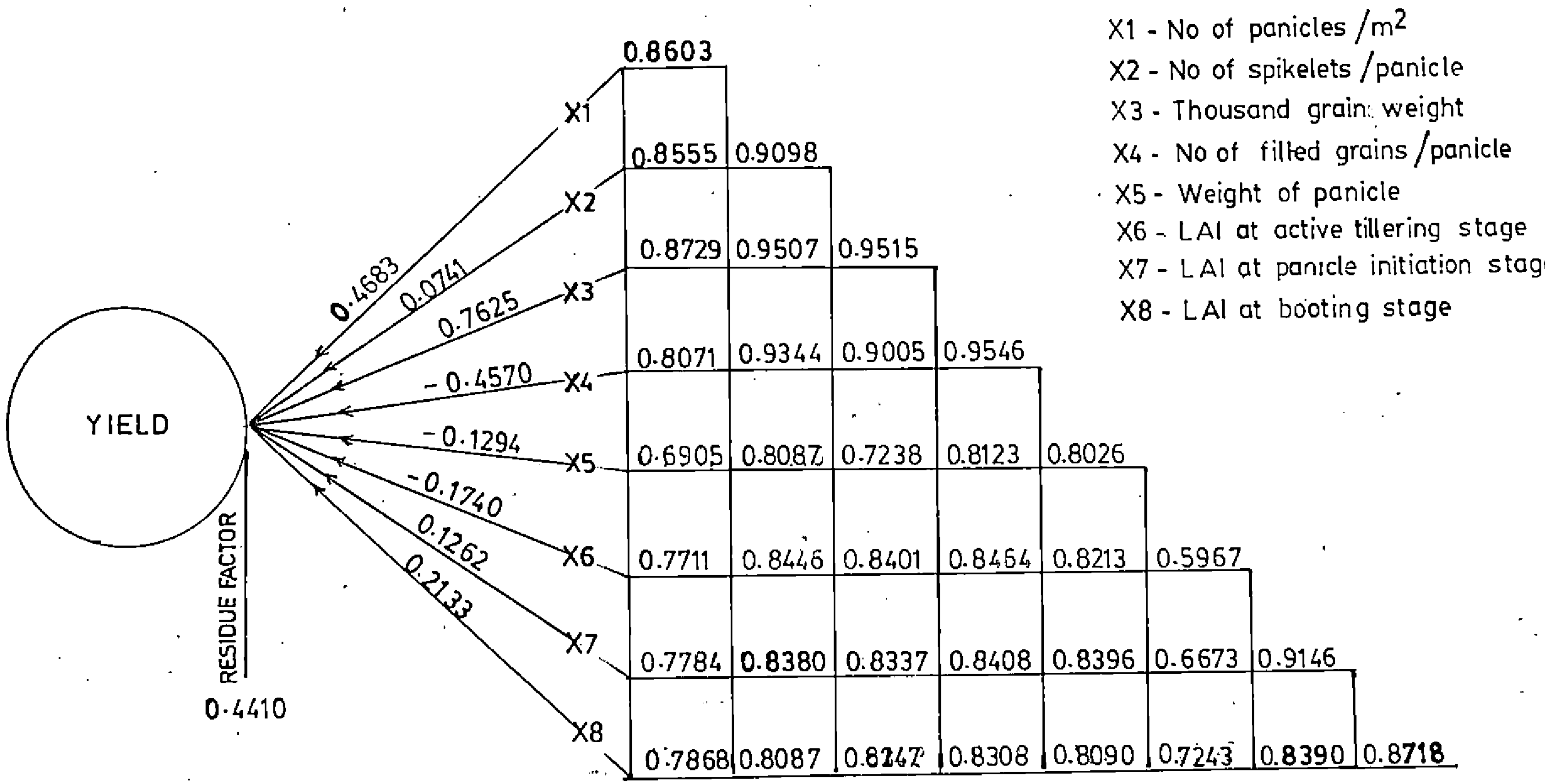
1. Direct and indirect effects of yield attributes on yield.

The Cause and effect relationship of yield with number of panicles/m^2, the number of spikelets/panicle, thousand grain weight, the number of filled grains/panicle, the weight of panicle, the LAI at active tillering stage, the LAI at panicle initiation stage and the LAI at booting stage were investigated by applying path analysis (Table 17 and Figure 8). All the above characters were found to be highly correlated with yield by 69 to 87 per cent; the important characters which contributed for high yield being thousand grain weight and number of panicles/m^2. These characters contributed altogether via direct and indirect effect by 56 per cent. The remaining 44 per cent may be attributed to other factors like soil fertility status, applied nutrients, climate etc.

2. Direct and indirect effects of nitrogen, phosphorus and potassium uptake at harvest on dry matter production.

The cause and effect relationship of dry matter yield with nitrogen, phosphorus and potassium uptake

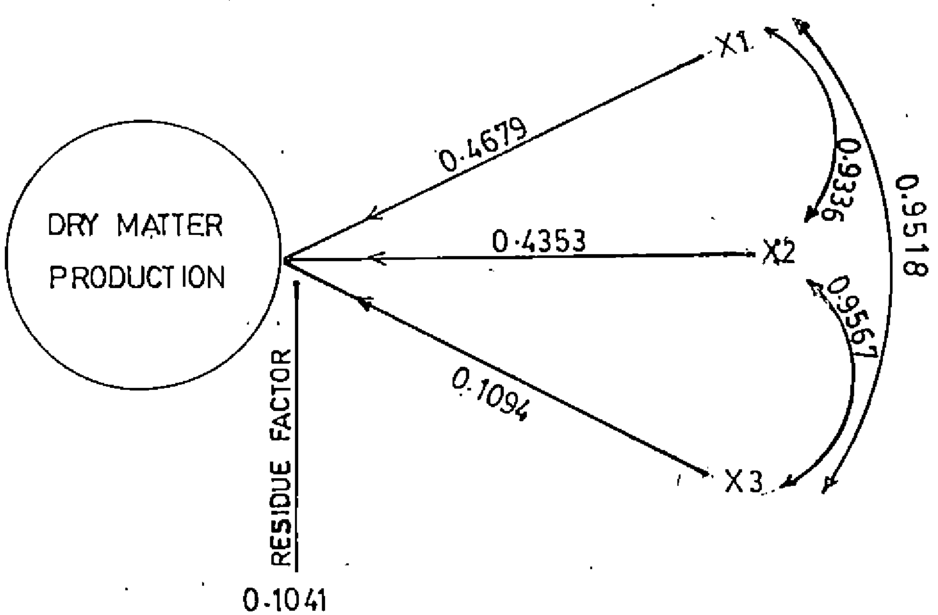
Fig. 8 PATH DIAGRAM SHOWING DIRECT EFFECTS AND INTERRELATIONSHIPS OF YIELD COMPONENTS AND YIELD



DIRECT EFFECTS SHOWN IN THE ARROWS AND CORRELATION COEFFICIENTS SHOWN IN STEPS at harvest were investigated (Table 18 and Figure 9). Dry matter production was mainly influenced by nitrogen and phosphorus uptake both directly and indirectly and their effects were found to be positive. Direct and indirect effect of nitrogen, phosphorus and potassium uptake on dry matter yield was by 90 per cent.

SUMMARY

Fig 9 PATH DIAGRAM SHOWING THE DIRECT EFFECTS AND INTERRELATIONSHIPS OF N, P AND K UPTAKE AND DRY MATTER PRODUCTION



X1 - Nitrogen X2 - Phosphorus X3 - Potassium

DIRECT EFFECTS SHOWN IN ARROWS AND CORRELATION COEFFICIENTS SHOWN IN DOUBLE ARROWS.

SUMMARY

VI SUMMARY

An investigation was undertaken at the State Seed Farm, Kottarakara, Quilon District, during the mundakan season (Second crop) of 1984-85 to evolve a suitable fertilizer management schedule for rice variety Cheradi. The treatments included four graded levels of NPK fertilizers such as 40:20:20, 50:25:25, 60:30:30 and 70:35:35 kg/ha and four times of application of nitrogen. The experiment was laid out as a 4 x 4 factorial experiment in Randomised Block Design with three replications. The findings of the study are summarised below:

1. The different levels of fertilizers significantly influenced the plant height at all stages of growth.

2. The number of tillers per hill increased significantly with increase in levels of fertilizers. Application of nitrogen in equal splits at transplanting and active tillering stage recorded highest tiller number at panicle initiation stage. Higher tiller count was obtained by two, three or four split applications of 70 kg nitrogen.

3. Levels of fertilizers significantly increased the LAI at all stages of growth. Highest LAI was recorded with the highest level of fertilizers. Time of application

of nitrogen influenced the LAI at active tillering and panicle initiation stages. At active tillering stage highest LAI resulted when 50% nitrogen was given at transplanting, 25% each at active tillering and panicle initiation stages. At panicle initiation stage, highest LAI was recorded when nitrogen was given in two splits at transplanting and at active tillering stages. Interaction between levels of fertilizers and time of nitrogen application influenced the LAI only at active tillering stage wherein the highest LAI resulted when 70 kg nitrogen was given in three split doses (50% basals 25% at active tillering and 25% at panicle initiation stage).

4. Application of 70:35:35 kg NPK/ha recorded the highest values for crop growth rate between active tillering and panicle initiation stages and between panicle initiation and booting stages. A two equal split application of nitrogen at transplanting and at active tillering stage, recorded the highest CGR between active tillering and panicle initiation stages.

5. Relative growth rate was significantly affected by graded levels of fertilizers between active tillering and panicle initiation stages and between panicle initiation and booting stages. Between active tillering and panicle initiation stages, highest RGR was recorded with the

fertilizer level of 60:30:30 kg NPK/ha. Between panicle initiation and booting stages the highest value for RGR was obtained with the fertilizer level of 70:35:35 kg NpK/ha. The time of nitrogen application had significantly influenced the RGR between panicle initiation and booting stages where in the highest value was observed when nitrogen was given in two equal splits at transplanting and at active tillering stages.

6. An increase in the level of fertilizer from 40:20:20 kg NPK/ha to 70:35:35 kg/ha gave a progressive and significant increase in dry matter production at all stages of growth. Time of nitrogen application did not influence the dry matter production at any of the growth stages.

7. Yield attributes viz., the number and length of panicle showed progressive increase with enhanced application of fertilizers from 40:20:20 kg level to 70:35:35 kg level of NPK/ha. Half dose of nitrogen as basal followed by two equal splits of the remaining half at active tillering and panicle initiation stages recorded highest values for these attributes.

8. Application of 60:30:30 kg NPK/ha gave highest panicle weight, spikelet number, number of filled grains and minimum percentage of unfilled grains. Nitrogen applied

in three splits (50% as basal, 25% at active tillering and 25% at panicle initiation stages)recorded the highest values for these attributes.

9. Thousand grain weight progressively increased with increase in the fertilizer levels. But the difference between the two higher levels was not significant.

10. An increase in the level of fertilizer from 40:20:20 kg to 70:35:35 kg NPK/ha brought about a progressive increase in grain yield. Application of 70:35:35 kg NPK/ha gave the highest grain yield of 4128 kg/ha. Even though not significant, nitrogen given in three splits, 50% as basal, 25% at active tillering and 25% at panicle initiation stages, recorded the highest grain yield.

11. Successive increment of fertilizers from 40:20:20 kg to 70:35:35 kg NPK/ha brought about a progressive and significant increase in straw yield and was highest at 70:35:35 kg NPK/ha. Regarding the time of nitrogen application, highest straw yield was observed with three split applications (50% as basal, 25% at active tillering and 25% at panicle initiation stages).

12. Highest harvest index was noted with the fertilizer level of 60:30:30 kg NPK/ha beyond which a decrease was observed.

13. The grain protein content significantly increased with increasing levels of fertilizers. Application of nitrogen in four equal splits at transplanting, active tillering, panicle initiation and booting stages recorded highest protein content.

14. Effect of fertilizer levels in increasing the nitrogen, phosphorus and potassium uptake by plants was significant at all stages of growth and the highest uptake was recorded at 70:35:35 kg/ha NPK level. The treatment which received the entire nitrogen by active tillering recorded the minimum uptake of nitrogen at harvest stage.

15. Total nitrogen, available nitrogen, available phosphorus and exchangeable potassium contents of the soil after cropping did not vary with the levels of fertilizers and time of application of nitrogen.

16. With regard to the economics of rice production, highest values for net return (Rs.5780/-) and cost : benefit ratio was observed with 70:35:35 kg level of NPK. Nitrogen given at transplanting (50%) at active tillering (25%) and at panicle initiation stage (25%) gave the highest net return of Rs.4800/- and cost : benefit ratio of 1.98.

Future line of work.

Since rice variety Cheradi belongs to the photosensitive tall indica group, the optimum time of planting suited to different agro-climatic zones of traditional Cheradi growing tracts needs further investigation. Also, plant density in relation to the number of seedlings per hill and spacing and age of seedlings require further investigation.

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VII REFERENCES

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* Originals not seen

APPENDICES

APPENDIX I

Meteorological data for the cropping period (1984-85) and the average values for the corresponding previous five years (1979-1984)

Standard week	Period		Total rainfall (mm)		Mean maximum temperature (°C)		Mean minimum temperature (°C)		Relative humidity Forenoon (%)		Relative humidity Afternoon (%)	
			A	B	A	B	A	B	A	B	A	B
34	August	20-26	2	47.7	29.6	31.3	23.0	23.5	90	94	77	69
35	,,	27-2	31	5.0	29.9	31.9	22.5	23.3	89	91	79	72
36	September	3-9	NIL	30.2	29.0	32.4	22.5	23.5	89	93	63	76
37	,,	10-16	NIL	29.6	30.0	31.5	22.2	23.8	89	92	73	77
38	,,	17-23	12	26.2	30.6	32.0	22.5	22.5	92	92	79	71
39	,,	24-30	81	61.7	29.7	31.5	22.8	24.2	90	90	88	79
40	October	1-7	95	44.5	29.1	31.9	24.6	23.8	85	89	75	72
41	,,	8-14	9	71.2	30.1	30.5	22.9	23.2	87	93	65	78
42	,,	15-21	NIL	9.5	30.9	32.5	20.9	24.0	88	91	62	77
43	,,	22-28	46	29.5	32.8	32.0	22.0	23.6	83	91	68	78
44	,,	29-4	30.5	35.3	33.3	31.5	22.0	22.3	83	92	64	71
45	November	5-11	117.0	32.5	32.9	30.8	22.7	22.3	86	90	69	82
46	,,	12-18	NIL	38.0	30.3	33.5	22.5	22.7	90	93	69	76
47	,,	19.25	45	71.4	30.2	31.5	22.4	23.9	90	91	71	72
48	,,	26-2	NIL	26.4	29.2	30.8	20.7	22.3	86	91	70	71
49	December	3-9	NIL	3.0	32.3	30.5	22.1	22.7	86	92	65	65
50	,,	10-16	1.5	NIL	33.3	31.6	20.4	22.9	89	89	69	61
51	,,	17-23	2.0	11.8	32.7	31.8	20.8	23.1	86	93	71	67
52	,,	24-31	7.0	NIL	34.2	32.0	21.7	19.9	89	91	69	61
1	January	1-7	1.0	NIL	32.1	30.5	22.6	21.6	87	91	71	63
2	,,	8-14	NIL	NIL	32.9	31.8	20.6	20.7	89	91	69	61
3	,,	15-21	NIL	NIL	32.2	32.0	21.9	20.6	89	91	69	63
4	,,	22-28	4	2.0	33.3	31.0	19.9	20.2	87	91	69	61
5	,,	29-4	NIL	NIL	34.3	32.2	21.2	20.0	86	91	70	59
6	February	5-11	NIL	5.0	34.2	33.8	20.2	21.6	86	89	72	64
7	,,	12-18	NIL	5.5	34.2	32.2	21.8	22.0	86	88	72	64
8	,,	19.25	NIL	4.0	33.9	31.0	21.8	22.2	86	91	72	64

A - Cropping period B - Average of previous five years

APPENDIX II

Abstract of ANOVA for Growth characters and Growth analysis.

Table No.	Characters	Mean Square: Block (2)	Main factors: M (3)	Main factors: T (3)	Interaction: M x T (9)	Error (30)
	A. Height of Plants.					
2	1. Active tillering	35.1808**	57.5503**	4.1925	4.3545	2.7953
	2. Panicle initiation	4.6120	85.5700**	3.2313	1.0042	1.6468
	3. Booting	0.1016	1757.7400	1.5170	0.0270	0.6525
	4. Harvest	3.0940	974.1200**	0.3880	0.3670	1.6750
	B. Tiller count.					
	1. Panicle initiation	10.5100	6900.2079**	67.0702**	49.8809**	10.0486
	C. Growth analysis.					
3	a. Leaf area index					
	1. Active tillering	0.0009	142.4690**	2.6600**	0.0109**	0.0023
	2. Panicle initiation	5.3233	2.8012**	2.6938**	0.0306	0.0219
	3. Booting	0.0180	1.5850**	0.0070	0.0227	0.0249
4.	b. Crop growth rate					
	1. Between Active tillering and panicle initiation	0.3379	25.5350**	1.1460**	0.1987	0.1980
	2. Between Panicle initiation and booting	3.49	107.7623**	5.7466	2.7422	2.0316
4	c. Relative growth rate					
	1. Between active tillering and Panicle initiation	4.3800	62.3112**	13.70	7.4580	5.3449
	2. Between panicle initiation and booting.	47.5300	49.1196**	36.5326*	20.4992	9.4307
	D. Dry matter production.					
	1. Active tillering	0.0016	0.0946**	0.0002	0.0026	0.0014
	2. Panicle initiation	0.0266	2.4184**	0.0097	0.0140	0.0119
	3. Booting	0.0675	9.5850**	0.1346	0.04388	0.0631
	4. Harvest	0.3405	14.1343**	0.1769	0.02139	0.1117

Figures in parenthesis indicates degrees of freedom

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX III

Abstract of ANOVA table for yield attributes

Table No.	Characters	Mean Square				
		Block (2)	Main factors M (3)	Main factors T (3)	Interaction M x T (9)	Error (30)
6	<u>Yield attributes</u>					
	1. Number of panicles/m^2	60.8425	11182.5350**	106.9372	81.2848	66.9358
	2. Length of panicle	0.3036	12.1831**	0.3534	0.0959	0.2742
	3. Weight of panicle	0.1004	0.1420	0.0996	0.0808	0.0823
	4. Number of spikelets/panicle	0.2815	128.8158**	2.3503**	0.7119	0.5170
	5. Number of filled grains/ panicle	4.7410*	460.8120**	21.9150**	11.1060**	1.1564
	6. Percentage of unfilled grains	0.2680**	5.3173**	0.2440**	0.0929	0.02326
	7. Thousand-grain weight	0.1050	6.0000**	0.0367	0.0089	0.0493

Figures in parenthesis indicates degrees of freedom

* Significant at 0.05 level.

** Significant at 0.01 level.

APPENDIX IV

Abstract of ANOVA table for grain and straw yields, Harvest index, Protein percentage and Economics of rice production.

Table No.	Characters	Mean Square				
		Block (2)	Main factors M (3)	Main factors T (3)	Interaction M x T (9)	Error (30)
7	A. Yield					
	1. Yield of grain	0.15271	2.92322**	0.03086	0.00695	0.05948
	2. Yield of straw	0.04489	4.26400**	0.06833	0.01903	0.05170
	3. Harvest index	0.00028	0.00176**	0.00004	0.00007	0.00026
	4. Protein percentage	0.12715	13.31867**	0.68193	0.21124	0.35840
	B. Economics of rice Production.					
	1. Net return	0.93000*	13.47330**	0.18410	0.01889	0.25970
	2. Cost:benefit ratio	0.03615*	0.44933**	0.00730	0.00072	0.01060

Figures in parenthesis indicates degrees of freedom

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX V

Abstract of ANOVA Table for uptake of N, P and K at different stages of growth.

Table No.	Characters	Block (2)	Main factors M (3)	Main factors T (3)	Interaction M x T (9)	Error (30)
8	A. Nitrogen uptake.					
	1. Active tillering	1.2250	152.2130**	0.8160	0.0700	0.3760
	2. Panicle initiation	3.5250	809.8100**	0.3600	2.1700	3.7030
	3. Booting	34.3700*	2119.9100**	2.6500	1.0230	9.002
	4. Harvest	7.3300	2553.9527**	12.6747**	2.1271	2.5811
9	B. Phosphorus uptake					
	1. Active tillering	0.0243	1.9113**	0.0669	0.0197	0.02637
	2. Panicle initiation	0.1000	14.7400**	0.2780	0.0330	0.1189
	3. Booting	1.0900	106.5010**	1.0480	0.2360	0.4107
	4. Harvest	1.0746	86.4400**	0.5960	0.4952	1.8266
	C. Potassium uptake					
	1. Active tillering	0.5250	14.0300**	0.8430	2.9000*	1.2200
	2. Panicle initiation	0.6350	556.5300**	1.8050	0.7680	4.099
	3. Booting	0.02781	1582.2900**	6.5830	5.02386	2.294
	4. Harvest	7.6018	1285.521**	10.3824	10.2785417	11.7656

Figures in parenthesis indicates degrees of freedom.

* Significant at 0.05 level.
** Significant at 0.01 level.

APPENDIX VI

Abstract of ANOVA table for Soil analysis after cropping.

Table No.	Characters	Mean Square				
		Block (2)	Main factors M (3)	Main factors T (3)	Interaction M x T (9)	Error (30)
11	1. Total nitrogen	0.0000003	0.0007600	0.0001553	0.0002371	0.0138743
	2. Available nitrogen	0.0000030	0.0000043	0.0000005	0.0000004	0.0000032
	3. Available phosphorus	0.0000250	0.0000080	0.0000100	0.0000024	0.0000141
	4. Exchangeable potassium	0.0589000	0.05780000	0.0813000	0.0430000	1.0453000

Figures in parenthesis indicates degrees of freedom.

* Significant at 0.05 level.

** Significant at 0.01 level.

FERTILIZER MANAGEMENT IN RICE VARIETY CHERADI

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ABSTRACT OF THESIS
submitted in partial fulfilment of the
requirement for the degree
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani, Trivandrum
1986

ABSTRACT

To evolve a suitable fertilizer management schedule for rice variety Cheradi, an experiment was conducted at State Seed Farm, Kottarakka, Quilon District during the second crop season of 1984-85. The treatment consisted of four graded levels of fertilizers (40:20:20, 50:25:25, 60:30:30 and 70:35:35 kg NPK/ha) and four times of application of nitrogen. The experiment was replicated thrice in a Factorial Randomised Block Design.

Growth characters such as plant height, number of tillers/m^2, LAI, CGR and dry matter production were the highest at the level of 70:35:35 kg NPK/ha. Interaction between levels of fertilizers and time of application of nitrogen influenced the LAI at active tillering stage. The LAI was the highest when 70 kg nitrogen was given 50% as basal, 25% each at active tillering and panicle initiation stages.

Application of 70:35:35 kg NPK/ha gave the highest number of panicle/m^2, length of panicle and thousand grain weight. The number of spikelets/panicle, number of filled grains/panicle and weight of panicle were maximum with 60:30:30 kg NPK/ha.

Grain and straw yield and protein content of the grain were the highest with 70:35:35 kg NPK/ha. Nitrogen, 50 per cent at transplanting and 25 per cent each at active tillering and panicle initiation stages produced the highest grain and straw yields. Four equal split applications of nitrogen recorded maximum grain protein content.

N, P and K uptake increased with incremental doses of fertilizers at all growth stages. Three applications recorded the highest N and P uptake at harvest.

Highest value for net return and cost : benefit ratio was observed with 70:35:35 kg level of NPK/ha. Nitrogen given at transplanting (50%) at active tillering (25%) and at panicle initiation stage (25%) gave highest net return and cost : benefit ratio.