FERTILIZER MANAGEMENT TRIAL FOR THE RICE VARIETY MASHURI DURING MUNDAKAN SEASON

By
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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Fertilizer management trial for the rice variety Mashuri during mundakan season" 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.

Vellayani,
11 July, 1984.

AJITHKUMAR, R.

CERTIFICATE

Certified that this thesis entitled "Fertilizer management trial for the rice variety Mashuri during mundakan season" is a record of research work done independently by Sri.AJITHKUMAR,R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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The author also dedicates this piece of work to his parents.

AJITHKUMAR, R.

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INTRODUCTION

INTRODUCTION

Rice which is the staple food of the people of Kerala is extensively grown in the State occupying an area of 8.07 lakhs hectares. During the past substantial increase in rice production has been achieved by the introduction of a large number of high yielding rice varieties. Most of the high yielding varieties evolved and popularised are of dwarf nature having poor straw yield. More over, most of them are not ideally suited for cultivation in problem areas like water logged soils.

The Malaysian rice variety which was introduced to India as early as 1965 was known as Mashuri in Andhra Pradesh. This variety was evolved by hybridisation between Taichung 65 and Maying Ebos 80/2 in Malaysia. This variety is found to respond well to nitrogen and perform much better in water logged conditions. It is a photoinsensitive variety having good cooking quality. It has the added advantage of a higher straw yield.

Palghat is an important rice growing tract of the State where Mashuri is extensively cultivated and is becoming increasingly popular among the farmers of the tract especially during second crop season. But a correct assessment of the nutritional requirement of this variety has not been worked out in this tract.

The Rice Research Station, Pattambi represents the typical agroclimatic condition of Palghat district. Although Mashuri is a tall variety, studies revealed that it can respond fairly well to higher levels of fertilizers (Sobhana, 1983). However, detailed investigations to ascertain the optimum level of nutrition for the variety are lacking in this tract. More over investigations on the effect of phosphorus and potassium are also to be carried out to get the full expression of the growth and yield. Hence the present study was intended to have a detailed investigation of the effect of nitrogen, phosphorus and potassium nutrition on the rice variety Mashuri grown during the second crop season in this tract.

The timing of nitrogen application is an important aspect of overall nitrogen management in rice crop from the point of view of efficient utilization of this nutrient. Proper time of nitrogen application depends upon the rice variety and environmental condition under which the crop is grown (Hall, 1960). The effect of split application of nitrogen vary a lot due to differences in crop management, soil condition, growth duration and weather condition (Have, 1971). Mashuri being a tall indica variety may be susceptible to lodging by the application of nitrogen in heavy doses. Therefore it is necessary to assess the performance of the crop by the application of nitrogen in split doses, so as to work out the best method of split application of nitrogen.

Hence the present investigation was carried out in the Regional Agricultural Research Station, Pattambi during the second crop season of 1982 with the following objectives.

1. To find out the optimum level of nitrogen, phosphorus and potassium for the rice variety Mashuri under transplanted condition.

2. To assess the growth and yield of rice variety as influenced by the different levels of nitrogen, phosphorus and potassium nutrition and time of application of nitrogen.

3. To assess the quality of grain as affected by nitrogen, phosphorus and potassium nutrition and time of application of nitrogen.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The following review deals with the effects of different levels of nitrogen, phosphorus and potassium, along with the times of application of nitrogen on the growth, yield and quality of grain and the uptake of nutrients by rice.

Effect of Nitrogen

A. Growth characters.

1. Height of the plant

Lenka and Behera (1967) reported that application of nitrogen progressively increased the plant height upto 120 kg per hectare. In pot culture experiment Ahmed and Faiz (1969) found that plant height was increased upto 250 kg nitrogen per hectare. Ramanujam and Rao (1971) observed a positive correlation in plant height at tillering and flowering stages with the levels of applied nitrogen. Sumbali and Gupta (1972) observed increased plant height by the application of 200 kg nitrogen per hectare. Panda and Leeuwrik (1972) also reported increased plant height with 200 kg nitrogen per hectare. Koyama and Niamsrichand (1973) reported that the plant height was increased with nitrogen application upto 93 kg per hectare. However, Eunus and Sadeque (1974) opined that, plant height was unaffected by different levels of nitrogen. Sadayappan *et al.*

(1974) reported that there was an increase in plant height with nitrogen application upto 200 kg per hectare. Lenka _et al_. (1976) showed an increase in plant height with 180 kg nitrogen per hectare. Mengal and Wilson (1981) concluded that in rice plant height was increased with nitrogen application.

2. Tiller number

Lenka and Behera (1967) reported significant increase in tiller per plant with increased nitrogen application. Velly and Latrille (1967) observed increased tillering by increased nitrogen application upto 120 kg nitrogen per hectare. Ahmed and Faiz (1969) noticed an increased number of tillers with higher rates of nitrogen application upto 250 kg per hectare. Lenka (1969) found positive response of nitrogen application on tiller number of plant which progressively increased with incremental dose of nitrogen. According to Shrivastava _et al_. (1970) the increase in tiller number by the application of higher levels of nitrogen is responsible for higher grain yield. In pot experiment conducted by Pande and Narkhede (1972) rice variety Taichung-65 produced higher tiller count with higher nitrogen levels upto 90 kg per hectare. Lenka _et al_. (1976) observed increase in tiller number per plant by incremental doses of nitrogen from 0 to 180 kg per hectare.

Murty and Murty (1978) noticed an enhanced rate of tillering by the application of nitrogen from 60 to 120 kg per hectare. Rice cultivar Jaya grown on a sandy clay loam soil gave significant increase in number of tillers per hill with higher nitrogen levels upto 180 kg per hectare (Raju, 1979). On the basis of several field trials, Chow (1980) concluded that nitrogen application had a significant positive effect on tiller number.

B. Yield attributes.

1. Productive tiller count and number of panicles per hill

Bredero (1965) reported increased number of panicle bearing tillers with the application of nitrogen. Gupta *et al.* (1970) observed an increase in the number of fertile tillers per plant with nitrogen fertilization of 135 kg per hectare. Ramanujam and Rao (1971) could observe an increase in the number of panicles per hill with nitrogen levels above 90 kg per hectare. 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 nitrogen per hectare. Sumbali and Gupta (1972) could notice an increase in the number of effective tillers per hill with increased levels of nitrogen application upto 200 kg per hectare. Panda and Leeuwrik (1972) showed increased number of fertile tillers with increased rate of nitrogen application. Subramanian and Kolandaiswamy (1973) could notice an increased number of productive tillers per square metre with an increase in nitrogen level upto 240 kg per hectare. Rethinam (1974) observed increase in productive tillers with every increase in the dose of nitrogen upto 160 kg per hectare. Rethinam (1974) also reported a decrease in productive tiller number at an application of 200 kg nitrogen per hectare. Subbiah and Morachan (1974) obtained significant increase in panicle number as the nitrogen levels increased. Gowda and Panikar (1977) obtained higher number of productive tillers per hill with increased nitrogen levels upto 160 kg per hectare. Dixit and Singh (1979) observed a higher number of ear bearing tillers with 60 kg nitrogen per hectare as compared to 0 and 40 kg nitrogen per hectare.

2. Panicle length and panicle weight

Lenka (1969) reported an increase in length of panicle with 0, 40, 80 and 120 kg nitrogen per hectare. Ramanujam and Rao (1971) noticed an increase in panicle length with applied nitrogen upto 180 kg per hectare. Similar results were reported by Singh (1971). He reported an increase in panicle length with incremental doses of nitrogen from 0 to 160 kg per hectare. Panda and Leeuwrik (1972) also observed an increase in panicle length with higher rates of nitrogen application. Sadayappan et al. (1974) found that though panicle length was influenced by nitrogen application treatments with 50, 100, 150 and 200 kg per hectare were all on par. Subbiah and Morachan (1974) reported decrease in panicle weight with increase in the rate of nitrogen application and they attributed this to lodging of these varieties under higher levels of nitrogen application. Raj et al. (1974) obtained the highest panicle length with 200 and 250 kg nitrogen per hectare. Padmaja (1976) reported that panicle weight increased upto 60 ppm nitrogen. Reddy and Prasad (1977) obtained linear response to applied nitrogen upto 100 kg per hectare. He also found that medium duration varieties produced heavier panicles than short duration varieties. Chang and Su (1977) and Subbiah et al. (1977) could find that, length and weight of panicles increased with increasing rates of nitrogen upto 200 kg per hectare. Raju (1979) reported an increase in panicle length with graded doses of nitrogen upto 100 kg per hectare. Similarly Singh et al. (1979a) noticed that panicle length increased with nitrogen rates upto 120 kg per hectare.

3. Number of grains per panicle

Ahmed and Faiz (1969) found that number of grains per panicle increased with increase in nitrogen upto 150 kg per hectare. Gupta *et al.* (1970) observed that increasing the rates of applied nitrogen from 0 to 135 kg per hectare enhanced the number of grains per ear. Shrivastava *et al.* (1970) observed significant reduction in number of grains per panicle with increased nitrogen application. According to Panda and Leeuwrik (1972) nitrogen increased the number of fertile and sterile spikelets per panicle. Koyama and Niamsrichand (1973) reported that spikelet number per panicle increased with higher rates of nitrogen application upto 94 kg per hectare. Prasad and Sharma (1973) analysed the effects of levels of nitrogen and concluded that higher nitrogen level of 225 kg per hectare has more than doubled the total number of spikelet per panicle as against the control with no nitrogen. Natarajan *et al.* (1974) could find no significant increase in number of grains per panicle with incremental doses of nitrogen application. Results obtained by Purushothaman and Morachan (1974) and Sadayappan *et al.* (1974) showed that number of grains per panicle increased with increased nitrogen application. According to Subbiah *et al.* (1975) grain number per panicle was increased with increasing the nitrogen doses from 0 to 100 kg per hectare. Lenka *et al.* (1976) could notice reduction in number of grains per panicle with increased nitrogen application. Bhaumik and Ghosh (1977) showed that filled grains per panicle directly influenced grain yield and that correlation value increased at higher rates of nitrogen application. Dixit and Singh (1979) on the basis of experiments conducted, observed a significant increase in the number of grains per panicle with 80 kg nitrogen per hectare as compared to absolute control.

4. Thousand grain weight

Tsui and Yen (1964) reported reduction in thousand grain weight by higher levels of nitrogen application. Velly and Latrille (1967) also obtained a decreased thousand grain weight with increased application of nitrogen. Lenka (1969) observed that the thousand grain weight increased with higher levels of nitrogen application but the rate of increase was lesser at higher levels of nitrogen. Shrivastava et al. (1970) and Ramanujam and Rao (1971) also reported negative response of nitrogen in the yield attributes. Several workers reported that thousand grain weight was unaffected by nitrogen application (Muthuswamy et al., 1972; Natarajan et al., 1974; Lenka et al., 1976).

According to Panda and Leeuwrik (1972) nitrogen increased thousand grain weight considerably. Rethinam (1974) found that in respect of this yield attribute maximum response was obtained at 160 kg of nitrogen per hectare and there was reduction in grain weight at 200 kg dose. Though

Sadayappan et al. (1974) could observe increase in the weight of thousand grains by nitrogen application, the treatments from 50 to 200 kg nitrogen per hectare were on par in this respect. Padmaja (1976) reported that increase in thousand grain weight with graded doses of nitrogen application was noted upto 200 ppm. Gowda and Panikar (1977) also observed an increase in thousand grain weight due to nitrogen application. Similarly, Raju (1977) could notice a significant increase in thousand grain weight by nitrogen application.

C. Yield.

1. Grain yield

Ramanujam and Rao (1971) reported that paddy yields were decreased when nitrogen was applied more than 90 kg per hectare. Pillai and George (1973) showed that nitrogen supply over 80 kg per hectare could not increase the yield significantly. Nair and George (1973) reported that the levels of nitrogen had no significant effect in increasing the grain yield. Rethinam et al. (1975) could observe an increase in yield due to graded levels of nitrogen application and maximum yield was obtained with 160 kg nitrogen per hectare in both tall and dwarf indica rice varieties. Sahu and Murty (1975) observed grain yield increases with nitrogen levels upto 160 kg per hectare. Pillai et al.

(1975) revealed that there was significant response in grain yield upto 80 kg nitrogen per hectare. Sharma and De (1976) reported that increasing the nitrogen rates from 0 to 150 kg per hectare increased average yield from 3.76 to 5.56t per hectarewhere as a further increase in nitrogen rates gave no additional yield. Satyanarayanan and Sharma (1976) observed that increase in nitrogen rates from 0 to 120 kg per hectare, increased average paddy yield in six early maturing rice cultivars. Singh and Singh (1976) observed that average grain yield increased from 1.44 to 2.0 t per hectare by an increase in nitrogen application from 30 to 90 kg per hectare. Venkatachari *et al.* (1976) observed that highest yield of rice could be obtained at 150 kg nitrogen per hectare where as the response per kg of applied nitrogen was the highest at 50 kg per hectare.

According to Gowda and Panikar (1977) yield response to nitrogen was linear in varieties such as Jaya, IR-8 and IR-5. Raju (1977) reported that the highest yield of 4.99 t per hectare was obtained in the variety Mashuri with 100 kg nitrogen per hectare. Rao (1977) obtained linear increase of paddy yield with increasing nitrogen rates. He also reported that the economic optimum rate of nitrogen was 100 kg per hectare.

An investigation by Dargan and Chillar (1978) to study the effect of nitrogen on rice yields showed that significant increase in grain yield was obtained with 100 kg nitrogen per hectare over control. Murty and Murty (1978) obtained increased rice yields with nitrogen rates upto 120 kg per hectare. Poulose et al. (1978) reported that rice variety IR-8 gave highest grain yield with 80 kg nitrogen per hectare where as Ptb-9 gave the highest yield with 40 kg nitrogen per hectare. Venkateswarlu(1978) revealed that application of 250 kg nitrogen per hectare increased the grain yield significantly over nitrogen rates of 50, 100, 150 and 200 kg per hectare tried. Cabello (1979) showed that cultivar IR-8 gave the highest grain yield with highest nitrogen rates in both seasons. Dixit and Singh (1979) observed that grain yields increased from 2.18 t with no nitrogen to 4.19 t per hectare with 80 kg nitrogen per hectare. According to Panda and Das (1979) increasing the rates of applied nitrogen from 0 to 200 kg per hectare increased the average paddy yield from 6.13 to 8.96 t per hectare in seven dwarf rice cultivars tried. Raju (1979) could observe increase in grain yield with nitrogen doses upto 180 kg per hectare. Dixit and Singh (1980) in a field experiment with nitrogen application at 30, 60 or 90 kg per hectare showed that grain yield increased with increasing rates of nitrogen application. Kumar and

Sharma (1980) observed that average yield of three rice cultivars increased with 40 kg nitrogen per hectare. Further increases in yield with 60 to 80 kg nitrogen per hectare were not significant. He also reported that response of applied nitrogen was of quadratic nature and the most profitable nitrogen rate for the three cultivars namely Saket, Ratna and CR 44-1 was 52.2, 68.5 and 37.6 kg per hectare respectively. Patel et al. (1980) observed that increasing nitrogen rates from 0 to 160 kg per hectare applied to 5 rice cultivars increased the average paddy yields from 1.42 to 6.52 t per hectare. Rao and Rao (1980) from a field trial observed yield reduction with increased levels of nitrogen application above 30 kg per hectare.

According to Fagi and Datta (1981), for maximum grain yields nitrogen doses of more than 120 kg per hectare are required at high solar radiation levels. The varieties used were IR-26 and IR-28. Mengel and Wilson (1981) also reported that grain yield increased with higher levels of nitrogen application. Matin and Bhuiya (1981) reported that grain yield increased from 3.25 to 4.68 t with 0 to 120 kg nitrogen per hectare. Bhatti et al. (1982) revealed that the grain yield increased from 3.59 to 7.32 t by enhancing the dose of nitrogen from 0 to 120 kg per hectare in a rice cultivar.

Heeran and Lewin (1982) reported that grain yields were not affected by an increase in nitrogen application from 100 to 200 kg per hectare which they have attributed as fewer filled florets despite an increase in panicle number.

In a trial with six rice cultivars Peeran and Anandan (1982) showed that the cultivar TKM-9 had low response to nitrogen fertilizers and average yield of all cultivars were increased from 3.1 t with no nitrogen to 5 t with 160 kg nitrogen per hectare. Peeran and Anandan (1982) showed that yield of rice cultivars Ponni and IR-20 were higher at 20 x 20 cm spacing regardless of nitrogen levels applied at 0 to 30 kg per hectare.

2. Straw yield

Daniel (1970) reported that straw yields were found unaffected by nitrogen application in rice variety Ptb-9. Ramanujam and Rao (1971) reported that straw yield increased when nitrogen dose was increased upto 180 kg per hectare. Muthuswamy et al. (1972) observed a significant increase in straw yield upto 120 kg nitrogen per hectare. Panda and Leeuwrik (1972) could observe increased yields of straw upto 200 kg nitrogen per hectare. According to Sumbali and Gupta (1972) straw yield was found to increase upto 200 kg nitrogen per hectare. Sadayappan et al. (1974) also found a positive influence of nitrogen on straw yields. Rethinam et al. (1975) reported that straw yield in rice varieties was influenced by increased dose of nitrogen. Venkateswarlu (1978) noticed an enhanced straw yield upto 200 kg nitrogen per hectare. Dargan and Chillar (1978) also observed similar response. Matin and Bhuiya (1981) reported that straw yield increased from 3.5 to 6.11 t with no nitrogen to 120 kg nitrogen per hectare. Bhatti et al. (1982) revealed that the straw yield increased from 5.72 to 12.77 t per hectare with increased dose of nitrogen from 0 to 120 kg per hectare.

D. Quality of grain.

Ghosh et al. (1971) reported that increase in nitrogen rates was accompanied by linear increase in grain protein content. Kulkarni (1973) observed increased grain protein content in six tall indica and semi dwarf rice cultivars by increased rate of applied nitrogen. Muthuswami et al. (1973a) reported that different levels of nitrogen had no effect in the crude protein content of grain. Abraham et al. (1974) reported that maximum protein content of grain was obtained with 120 kg nitrogen per hectare applied after flowering. Kumar and George (1974b) noticed an increase in grain protein content by higher levels of nitrogen nutrition.

Srivastava and Verma (1974) could obtain an enhanced grain protein content with progresssive increase in nitrogen levels upto the highest rate of 200 kg per hectare. Subramanian et al. (1974) reported that levels of nitrogen had no effect on crude protein content of grain. Uptake of nitrogen increased linearly with increased rates of applied nitrogen (Gopalaswamy and Raj, 1977). According to Nagarajan et al. (1975) and Rabindra et al. (1977) grain protein was considerably increased in paddy with nitrogen application. Dutta and Barua (1978) observed that protein, non-protein nitrogen, crude fibre, lipid, phosphorus and iron contents of grain were increased progressively by nitrogen application from 0 to 80 kg per hectare. Raju (1979) also observed increased protein content with applied nitrogen.

E. Uptake of nutrients.

Ramanujam and Rao (1970) observed an increase in the total nitrogen content with increased nitrogen levels. Koyama and Niamsrichand (1973) reported that the nitrogen content of plants at harvest consistantly increased with higher rates of nitrogen. Prasad and Jha (1973) noticed that uptake of nitrogen increased with increasing level of nitrogen. Similarly Ramaswami and Raj (1974) also could observe an increased nitrogen uptake with enhanced nitrogen application. Nagarajan et al. (1975) concluded that although nitrogen application at flag leaf and heading stages resulted in high nitrogen uptake by plants it did not bring about substantial increase in grain yield; but resulted in an enhanced grain protein content. Agarwal (1978) reported that application of nitrogen upto 120 kg per hectare increased the uptake of nitrogen. Singh and Modgal (1978a) and Raju (1978) also reported similar results. According to reports by Reddy et al. (1978) maximum nitrogen uptake was seen at harvest compared to maximum tillering and panicle initiation stages. According to Singh and Modgal (1979) nitrogen concentration in plants due to nitrogen nutrition was the greatest at the panicle initiation stage and thereafter found decreasing.

Loganathan and Raj (1972) reported that the uptake of phosphorus by grain of paddy was not influenced by nitrogen application. He also reported that nitrogen level had little effect upon phosphorus absorption by straw. Pathak et al. (1972) observed a higher concentration of phosphorus in plants at high fertility level. They also reported that grain was richer in phosphorus in comparison to straw. Singh and Bhardwaj (1973b) noticed that smaller amount of nitrogen application proved instrumental in enhancing the phosphorus absorption by rice plant. Sadayappan and Kolandaiswamy (1974) revealed that phosphorus content of the plant was increased with increased nitrogen application. Agarwal (1978) reported that grain phosphorus content was decreased with nitrogen application. Raju (1978) reported increased phosphorus content of straw with increased nitrogen application from 0 to 180 kg per hectare. Singh et al. (1979) found that increasing the rate of nitrogen from 80 to 160 kg per hectare increased the grain phosphorus content. Iruthayaraj and Morachan (1980) could notice that the uptake of phosphorus was more with 240 kg per hectare than with lower levels.

Loganathan and Raj (1972) could notice that the uptake of potassium was little affected by the different combination of phosphorus and nitrogen. Sadayappan and Kolandaiswamy (1974) noticed an increase in the potassium content with increase in nitrogen level upto 100 kg per hectare. Esakkimuthu et al. (1975) observed that potassium uptake was increased with applied nitrogen. Agarwal (1978) reported that potassium uptake was increased by the application of nitrogen upto 120 kg per hectare. Singh and Modgal (1978b) observed that uptake of potassium was enhanced by the application of nitrogen upto 120 kg per hectare.

Effect of Phosphorus

A. Growth characters.

1. Height of the plant

Place et al. (1970) reported that increased application of phosphorus from 0 to 56 kg per hectare decreased the plant height. Aaron et al. (1971) reported that increased application of phosphorus increased plant height. Nair et al. (1972) observed that plant height was unaffected by phosphorus application. In trials with rice cultivar IR-5, Rao et al. (1974) noted that, plant height was not significantly influenced by phosphorus application upto 80 kg per hectare. Alexander et al. (1974a) reported that plant height was unaffected by phosphorus application. Kalyanikutty and Morachan (1974) showed that phosphorus did not have any marked effect on plant height. Bharadwaj et al. (1974) reported that there was no significant difference between the rates of phosphorus application in influencing the plant height.

2. Tiller number

Terman and Allen (1970) observed that tillering increased markedly with amount of applied phosphorus on the low phosphorus content of soil and slightly on the medium phosphorus content of soil and there was no response on the high phosphorus content of soil. Nair et al. (1972)

noticed that, tillering was markedly influenced by phosphorus application. Bharadwaj et al. (1974) from his data showed that the number of tillers per plant increased with increasing rates of phosphorus application. According to Kalyanikutty and Morachan (1974) the number of tillers per plant was not influenced by the phosphorus application. Bhattacharya and Chatterjee (1978) reported that application of phosphorus aided early tillering in fields having soils with inadequate level of phosphorus. In field experiment with rice cultivar IR-8 and given 0,50,100 or 150 kg phosphorus per hectare. Suseelan (1978) noticed that phosphorus application did not significantly affect tiller production. Fageria et al. (1982) observed that, number of tillers per square metre was increased with applied phosphorus from 0 to 66 kg per hectare.

B. Yield attributes

1. Productive tiller count and number of panicles per hill

In field trials, with increasing the rate of applied phosphorus from 0 to 90 kg per hectare, Place et al. (1970) reported that the number of panicles was increased with increase in the levels of phosphorus. Majumdar (1971) observed that phosphorus nutrition effected a significant increase in the number of productive tillers by an application of 59.7 kg phosphorus per hectare. Nair et al. (1972)

reported that number of productive tillers per hill was highly influenced by the phosphorus application.

On contrary to this, Alexander _et al._ (1974a) could not obtain any influence of phosphorus on the number of fertile tillers. Sadanandan and Sasidhar (1976) noticed that increasing rate of applied phosphorus hold no significant effect on the number of productive tillers. Bhattacharya and Chatterjee (1978) reported that production of early tillers was increased with phosphorus application which resulted in more number of productive tiller per hill.

2. Panicle length and panicle weight

According to Place _et al._ (1970) graded levels of phosphorus from 0 to 56 kg per hectare increased panicle weight. Majumdar (1971) reported that panicle length was significantly enhanced with higher levels of phosphorus application upto 59.7 kg per hectare. Singh and Varma (1971) reported that length of panicle was not influenced by phosphorus nutrition at 60 or 90 kg per hectare. Alexander _et al._ (1974a) obtained no difference in panicle length by phosphorus application.

3. Number of grains per panicle

Aaron _et al._ (1971) reported that the number of grains per panicle was increased with increase in phosphorus application. Majumdar (1971) revealed that number of grains per panicle was significantly increased by application of 59.7 kg phosphorus per hectare. Singh and Varma (1971) reported increase in the number of grains per panicle with higher rates of phosphorus application. He reported that application of 60 and 90 kg phosphorus per hectare brought about distinct increase in number of grains per panicle over 30 kg phosphorus per hectare. Alexandar et al. (1974a) observed that the number of grains per panicle was unaffected by the phosphorus application. Sadanandan and Sasidhar (1976) could not find any effect of phosphorus on number of grains per panicle. Bhattacharya and Chatterjee (1978) opined that phosphorus application induced early tillering which in turn gave more number of filled spikelets per panicle. Suseelan et al. (1978) found that the number of filled grains per panicle was unaffected by the rate of phosphorus application.

4. Thousand grain weight

Place et al. (1970) recorded decrease in thousand grain weight with increase in levels of phosphorus applied from 0 to 56 kg per hectare. Majumdar (1971) noticed that thousand grain weight was increased with increase in phosphorus application. Singh and Varma (1971) could observe distinct increase in the thousand grain weight with the application of 60 and 90 kg phosphorus over 30 kg phosphorus per hectare.

Alexandar *et al.* (1974a) noticed that phosphate application did not affect thousand grain weight. Thandapani and Rao (1976) could observe that the thousand grain weight was increased with increasing levels of phosphorus upto 45 kg per hectare.

C. Yield

1. Grain yield

Moolani and Sood (1966) observed yield reduction with increased rates of application of phosphorus. Shukla (1969) noticed that paddy yield was unaffected by phosphorus application. According to Dev *et al.* (1970), in a trial with three rice cultivars grown in Kharif at two sites of Karnal district, Haryana, increases in the rate of applied phosphorus from 30 to 90 kg per hectare were accompanied by linear increase in the average paddy yields from 3 to 4.32 t per hectare at Ramba where available soil phosphorus was 9 kg per hectare and 4.44 to 6.1 t per hectare at Gharaunda where the available soil phosphorus was 3 kg per hectare. The paddy yield response per kg of applied phosphorus varied between soils depending on available phosphorus content. Khatua and Sahu (1970) reported that application of 40 kg phosphorus per hectare resulted in increased paddy yield as compared to no phosphorus application. Nair and Pisharody (1970) reported that paddy yields were not increased with

22.4 to 56 kg phosphorus per hectare applied alone or with various rates of nitrogen of potassium. Aaron _et al_. (1971) could notice increased paddy yields with increased phosphorus application. Majumdar (1971) also noticed increase in paddy yields with incremental dose of phosphorus application. Increase in grain yields with phosphorus application were also reported by Kalyanikutty and Morachan (1974). According to Gopalakrishnan _et al_. (1975) grain yield was influenced by phosphorus application. Dixit and Singh (1977) reported that grain yield was increased from 2.4 to 2.7 t per hectare when the rate of phosphorus application was ranged from 0 to 40 kg per hectare. Agarwal (1978) observed that grain yield was increased from 4.54 to 4.94 t when the application rate of phosphorus ranged from 0 to 120 kg per hectare. Ageeb and Yousif (1978) reported that phosphorus application influenced paddy yield significantly. Rabindra (1978) revealed that, grain yield was increased from 2.86 to 3.26 t per hectare with 0 to 100 kg phosphorus per hectare. Jones _et al_. (1979) reported that increases in paddy yield over control were highest with application of 22.5 kg phosphorus per hectare as Morocco rock phosphate or single super phosphate broadcast at 10 days after sowing and with application of basic slag at 45 kg per hectare broadcast in equal split dressing at 10 days after sowing and 14 days after transplanting. Rao _et al_

(1974) reported that paddy yields obtained with 80 kg phosphorus per hectare was not significantly superior to that obtained at 40 kg phosphorus per hectare. Samui and Bhattacharya (1976) observed that paddy yields were not increased with increasing rates of phosphorus from 0 to 90 kg per hectare. Similarly Robinson and Raja gopalan (1977) reported that paddy yields were not influenced by phosphorus application. Singh _et al_. (1979b) noticed that grain yield was increased with phosphorus application. Singh and Jaiprakash (1979) also obtained similar results. Agarwal (1980) reported that grain yield was increased by the application of 180 kg phosphorus per hectare. Fageria (1980) reported that under normal conditions yield increased significantly by the application of phosphorus upto 150 kg per hectare. Chhabra and Abrol (1981) noticed that application of 50 kg phosphorus per hectare had no effect on the yield of rice in untreated barren sodic soils. Machado _et al_. (1981) reported that phosphorus had no effect on grain yield of rice. But Varma _et al_. (1981) noticed that in a sandy clay loam soil with 10 kg available phosphorus per hectare, grain yield of rice cultivar Cauvery was not affected by phosphorus application in the first year but was increased in subsequent years to give average yields of 1.6, 2.0, 2.2

and 2.4 t per hectare with 0,9,18 and 27 kg phosphorus per hectare respectively. Bora and Goswami (1983) found enhanced grain yields with progressive increase in the rate of phosphorus application.

2. Straw yield

Patel (1967) in a field experiment given 20,40 and 60 kg phosphorus per hectare reported that plant height and therefore straw yield increase with increasing fertility. Place *et al.* (1970) observed that increasing phosphorus application increased straw yield but decreased plant height. Gupta *et al.* (1975) obtained highest straw yield with 60 ppm phosphorus. Prabha *et al.* (1975) in a pot trial given 0,20,40, 60 and 100 kg phosphorus per hectare reported that application of phosphorus increased straw yield. However, Sadanandan and Sasidhar (1976) found that increasing rate of applied phosphorus had no significant effect on yield of straw and grain.

D. Quality of grain.

Karim *et al.* (1968) noticed a decreased crude protein content of the husked grain with increased levels of phosphorus application from 0 to 120 kg per hectare. Verkhotin (1974) reported that grain protein content decreased with applied phosphorus. Kadrekar and Mehta (1975) opined that optimum rate of phosphorus application for satisfactory grain content was 40 kg per hectare in the case of all cultivars. Agarwal (1978) reported that increasing the rate of applied phosphorus from 0 to 120 kg per hectare increased the crude protein content of grain from 9.76 to 10.28 per cent. Ageeb and Yousif (1978) reported a decreased grain protein from 7.11 to 5.81 per cent by increased phosphorus level from 0 to 107 kg per hectare but the total protein yield seemed unaffected.

E. Uptake of nutrients.

Pande and Tilak (1970) revealed that phosphorus fertilization increased phosphorus content of the upland rice crop. Varma (1971) in trial with high yielding rice reported that nitrogen uptake in grain and straw increased with rates of applied phosphorus. Loganathan and Raj (1972) in a pot experiment found that nitrogen uptake by rice grain was the highest in plants receiving 80 kg phosphorus per hectare and did not vary with different nitrogen levels. Thandapani and Rao (1974) observed that increase in rates of applied phosphorus from 0 to 75 kg per hectare were accompanied by linear increase in nitrogen content in roots, shoots and grains. Reddy *et al.* (1978) reported that nitrogen uptake increased with increase in rates of nitrogen + phosphorus + potassium from 100 + 50 + 50 to 200 + 100 + 100 kg per hectare. Agarwal (1980) recorded an increase in the uptake of nitrogen from 34.2 to 51.8 kg from 0 to 180 kg doses of phosphorus application upto the tillering stage. He also reported that the increase from the extreme doses varied from 43.5 to 89. 4 kg during flowering stage and from 72.5 to 147.6 kg during maturity stage.

Naphede (1969) reported that the rate of phosphorus absorption was much higher at 40 and 90 days after transplanting than at other periods and increased with increase in phosphorus supply. Muthuswamy et al. (1973b) observed that more than half of the total requirement of phosphorus was absorbed between the stages of panicle initiation and flowering. Ali and Morachan (1973) reported that the uptake of phosphorus was higher in the early stages and decreased with crop growth. Iruthayaraj and Morachan (1980) found that the uptake of phosphorus was high at harvest stage.

Oommen et al. (1972) revealed that the percentage of total phosphorus in the plant increased with an increased dose of phosphorus from 25.75 to 51.5 kg per hectare. Alexander et al. (1974b) revealed that various rates of phosphorus had no significant effect on the uptake of phosphorus. Krishnaswamy et al. (1974) showed that application of 180 kg phosphorus per hectare gave the highest grain phosphorus content. Gupta et al. (1975) reported that uptake of phosphorus increased from 75.62 mg without applied phosphorus to 189.1 mg with 100 ppm applied phosphorus in a pot culture experiment. Agarwal (1978) revealed that grain phosphorus content was increased with phosphorus application upto 120 kg per hectare. Studies on the uptake of phosphorus by rice under graded levels of phosphorus revealed that there was a significant increase in phosphorus absorption with increasing rates of phosphorus fertilizer at all stages of growth (Suseelan et al., 1978). Bora and Goswamy (1980) reported that phosphorus uptake increased with increasing rates of phosphorus application. In a pot trial with three cultivars grown in a vertisol, Rastogi et al. (1981) showed that increasing levels of applied phosphorus increased the total phosphorus uptake and fertilizer phosphorus uptake but decreased available phosphorus uptake and utilization percentage of the applied phosphorus at tillering, flowering and maturation stages. Bora and Goswamy (1983) showed that when rice plant was supplied with 0, 26.4 or 52.8 kg per hectare of phosphorus, its concentration in rice grain was increased with increase in the rate of phosphorus in submerged soils.

Loganathan and Raj (1972) reported that levels of phosphorus did not influence potassium uptake by grains. Krishnaswamy et al. (1974) suggested that application of potassium in combination with phosphorus slightly increased the potassium content of grain. Ramaswami and Raj (1974) observed that nitrogen and phosphorus increased potassium uptake. Thandapani and Rao (1974) found that applied phosphorus had no effect on potassium content in plants and grains Kothandaraman et al. (1975) reported that maximum grain content of potassium was given by 180 kg phosphorus per hectare. Lal and Mahapatra (1975) observed that potassium content was generally high with fertilizer high in water soluble phosphorus. Agarwal (1980) reported that increase in the potassium uptake was from 35.5 to 129.9 kg due to phosphorus application though the increase was rather small.

Effect of potassium

A. Growth characters.

1. Height of the plant

Bavappa and Rao (1956) reported an increase in height of plants with an increase in potassium. Results of field experiments revealed that the height of plant was progressively increased with potassium increments (Mukherji et al., 1968). Kalyanikutty and Morachan (1974) reported that potassium application did not have any influence on plant height. Rao et al. (1974) observed that height of plant was not significantly influenced by the application of potassiu upto 80 kg per hectare.

2. Tiller number

Noguchi and Sugawara (1952) observed lesser number of tillers in plots that received no potassium. Bavappa and Rao (1956) recorded an increase in number of tillers when potassium was applied. Mukherji *et al.* (1968) pointed out that potassium application had no noticeable effect on tillering. Usha (1966) noticed a beneficial influence of potassium in paddy by way of prombting tillering capacity. Ramankutty (1967) observed that potassium level had no significant effect on the number of tillers. Kalyanikutty and Morachan (1974) reported no influence of potash on increasing tiller number. According to Kulkarni *et al.* (1975) effect of potash was significant on the total number of tillers. Uexkull (1976) reported that applied potassium slightly decreased tillering. Chamura and Mizusawa (1979) noticed that the number of tillers was increased with increasing uptake of potash. Singh and Singh (1979) recorded increased tillering with graded doses of application of potash upto 60 kg per hectare.

B. Yield attributes.

1. Productive tiller count

Rao *et al.* (1974) observed that the number of productive tillers was not significantly influenced by the application of potash even upto 80 kg per hectare. Kulkarni *et al.* (1975)

reported 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 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. Uexkull (1982) found that the number of panicle per hill was decreased by potassium application. Rhee et al. (1979) reported that potassium deficiency decreased the number of panicles per hill.

2. Panicle length

Singh and Singh (1979) observed that panicle length was increased with incremental doses of potassium.

Rao et al. (1974) reported that application of potassium even upto 80 kg per hectare did not have any marked effect on the length of panicle. Singh and Singh (1979) found that application of potassium increased panicle length.

3. Number of grains per panicle

Bavappa and Rao (1956) reported that number of grains per panicle was increased with potassium application. Krishnan (1968) observed that higher levels of potassium increased the number of grains per earhead.

Kalyanikutty and Morachan (1974) reported that the number of grains per panicle was not affected by the rates of application of potassium. Rao *et al.* (1974) noticed that application of potash even upto 80 kg per hectare did not influence the number of filled grains and chaff per panicle. Uexkull (1982) reported that number of grains per panicle increased with potassium application.

4. Thousand grain weight

Bavappa and Rao (1956) recorded an increase in the thousand grain weight when potash was applied. Kalyanikutty and Morachan (1974) reported that the weight of thousand grains was not influenced by potassium application. Rao *et al.* (1974) also could not observe any effect of potassium on thousand grain weight. Singh and Singh (1979) found increase in thousand grain weight with the application of 60 kg potassium per hectare.

C. Yield.

1. Grain yield

Shukla (1969) could not get any significant effect of potassium on the grain yield of rice. Vijayan and Sreedharan (1972) noticed that grain yield was increased with higher levels of potash application. He obtained a yield of 3.63 t per hectare with 80 kg potassium per hectare and 3.18 t with no potassium. Pande and Das (1973) could not get any response of potassium to rice yields. Rao *et al.* (1974)

obtained better results with application of 40 kg potassium per hectare. Singh and Dubey (1975) reported yield increases with increasing levels of potassium application upto 60 kg per hectare and they could not get any additional yield by increasing further the level of application to 120 kg per hectare. Mamadaliev _et al_. (1976) also got the highest grain yield by the application of 120 kg potassium per hectare. Sahu and Ray (1976) reported that by increasing the potassium rates from 0 to 22.5 and 45 kg per hectare, average paddy yield increases were 2.06 t to 2.28 t and 2.61 t per hectare respectively. Singh _et al_. (1976) reported that application of 120 kg potassium per hectare gave the highest yield of grain. Uexkull (1976) reported that applied potassium slightly decreased grain yields at certain locations in the absence of phosphorus but increased in the presence of phosphorus. Halm and Dartey (1977) found that grain yields were increased from 2.33 t per hectare with no potash to 2.69 t per hectare with the application of 37.20 kg potash per hectare. Ageeb and Yousif (1978) reported that different doses of potassium either alone or with phosphorus as super phosphate gave no response. Agarwal (1980) observed significant increase in grain yield with potassium upto 60 kg per hectare. Mahapatra et al. (1980) could get significant yield increase in rice only by the application of 80 kg potassium per hectare as compared to untreated control. Ma and Du (1982) reported that yield increased by the application of both nitrogen and potassium was 19.8 to 80.1 per cent than with nitrogen alone.

2. Straw yield

Noguchi and Sugawara (1952) observed a decrease in straw yield with incremental doses of potash. Usha (1966) reported that potassium application in paddy enhanced straw yield . Esakkimuthu et al. (1975) reported that application of potassium in the presence of 150 kg nitrogen per hectare significantly increase straw yield. Singh et al. (1976) observed that application of 120 kg potassium per hectare gave the highest straw yield.

D. Quality of grain.

The application of large amount of muriate of potash to the soil reduced absorption of nitrogen, phosphorus and sulphur which resulted in reduction of protein synthesis, (Rehaja, 1966). Karim et al. (1968) showed that grain protein decreased with higher ratios of application of potassium. According to Chavan and Magar (1971) 40 kg potassium per hectare increased the protein content of five rice varieties on upland and lowland sites as compared with 20 kg potassium per hectare. Agarwal (1978) reported that by increasing potassium rate from 0 to 120 kg, the crude protein content of grain was increased from 9.62 to 10.17 per cent. Bhuiya *et al.* (1979) reported that potassium had no significant effect upon grain crdue protein content.

E. Uptake of nutrients.

Mohanty and Pathaik (1974) reported that lack of applied fertilizer decreased uptake of all nutrients and in soils deficient in phosphorus and potassium, application of phosphorus and potassium increased uptake of nitrogen, phosphorus and potassium. Muthuswamy *et al.* (1974) showed that increasing the rate of nitrogen, phosphorus and potassium increased their uptake. Esakkimuthu *et al.* (1975) observed that nitrogen uptake was increased with applied potassium. Mengel *et al.* (1976) reported that uptake of nitrogen of the shoot increased by the higher potassium supply. Singh *et al.* (1976) noticed that nitrogen uptake and translocation were highest with application of 160 kg potassium per hectare. Agarwal (1978) revealed that the increases in uptake of nitrogen were the highest with applied pôtassium. Reddy *et al.* (1978) found that nitrogen uptake increased with increase in rate of potassium from 50 to 100 kg per hectare.

Krishnan (1968) reported that different levels of potassium exerted no significant influence in the phosphorus content of grain and straw. Sadanandan et al. (1969) reported that uptake of phosphorus was significantly correlated with potassium uptake. Loganathan and Raj (1972) noticed that the uptake of phosphorus in the variety Co 32 was enhanced by the application of potassium at 40 and 80 kg per hectare. Mohanty and Patnaik (1974) observed that potassium application has increased the phosphorus uptake. Singh et al. (1976) opined that phosphorus uptake and translocation were the highest with the application of 160 kg potassium per hectare. Krishnamoorthy et al. (1977) reported that addition of 60 kg potassium per hectare had no effect on yield, but increased the utilization and uptake of fertilizer phosphorus. Agarwal (1978) also noticed that phosphorus content of grain was increased with increased potassium application.

According to Sadanandan et al. (1969) potassium uptake was significantly increased with higher dose of potassium and potassium percentage was high at tillering and flowering and thereafter declined towards maturity. Mohamed Ali and Morachan (1973) noticed that uptake of potassium was the highest at harvesting stage. According to Rai and Murty (1976) uptake of potassium was vigorous at early stage, retarded during lag phase and decreased after flowering. Singh *et al.* (1976) noticed the highest rate of uptake and translocation of potassium by the application of 160 kg per hectare. Agarwal (1978) showed that the potassium uptake was increased by higher levels of potassium upto 60 kg per hectare. Singh and Jaiprakash (1979) also reported that potassium application increased potassium uptake in rice.

Effect of Time of Application of Nitrogen

A. Growth characters.

1. Height of the plant

Wells (1970) opined that delaying mid season nitrogen until just after the start of rapid internode elongation decreased plant height. Gopalakrishnan *et al.* (1971) reported that plant height was significantly increased when nitrogen was applied 50 per cent as basal and 50 per cent at panicle initiation. According to Ramanujam and Rao (1971) rice cultivar ADT-27 when grown with a basal dressing of green manure, phosphorus, potassium and 0, 30, 60, 90, 120, 150 or 180 kg nitrogen per hectare in three equal split dressings was found to increase plant height. Panda and Leeuwrik (1972) reported that application of nitrogen, two-third at transplanting and the remainder top-dressed at the booting stage increased plant height.

Koyama and Niamsrichand (1973) observed increase in plant height by the application of two-third of nitrogen as basal dressing and one-third as top-dressing 30 days before flowering. Jakhro (1982) noticed that plant height was increased when 50 per cent of the nitrogen was applied at panicle initiation.

2. Tiller number

Patnaik (1969) opined that 75 to 80 per cent of the nitrogen applied at transplanting will increase the tillering capacity of the plant and the rest should be applied during the period from internode elongation to the emergence of the boot leaf stage. Takur and Saxena (1970) reported that split application of fertilizer nitrogen half at transplanting and half one month after, produced maximum number of tillers per hill. Alenshin and Tur (1971) showed that highest tillering occured in plants when nitrogen was given at the two leaf stage. Ramanujam and Rao (1971) observed that number of tillers were increased with increased nitrogen dose applied in three equal splits at transplanting, 30 and 40 days after transplanting. Pande and Narkhede (1972) reported that tillering increased with increasing nitrogen rates and it was higher when the nitrogen was applied in two instalments than when applied in single dose.

In greenhouse experiment, Thenababu (1972) observed that adequate nitrogen during the vegetative growth phase encouraged tillering. Koyama and Niamsrichand (1973) found that tiller number was closely related to nitrogen rate during the early stage of growth.

Rice cultivar IET 1991 when given 120 kg each of nitrogen and phosphorus applied in various splits as (a) 50 per cent at planting + 50 per cent at panicle initiation (b) 50 per cent at planting + 25 per cent at 21 days after planting (c) 50 per cent at planting + 25 per cent at panicle initiation + 25 per cent as foliar application 4 to 6 weeks after planting, Rao et al. (1973) reported that number of tillers per hill was lower with (b) and (c) than with (a). Rao and Murty (1975a) concluded that application of nitrogen at the maximum tillering stage increased the tiller survival. Bhuiyan (1981) reported that increase in tiller number at maximum tillering was associated with increase in inorganic nitrogen at transplanting in some soils.

B. Yield attributes.

1. Productive tiller number and number of panicles per hill

Halappa et al. (1970) reported that nitrogen applied at 120, 160 or 200 kg per hectare in 2 to 3 split dressings resulted in the highest number of ear bearing tillers per hill. Muraleedharan *et al.* (1972) reported that there was no significant effect on number of panicle per square metre with time of nitrogen application. Ramanujam and Rao (1971) reported that number of panicles per hill increased with increase in nitrogen when applied in 3 equal split dressings at transplanting and at 30 and 40 days after transplanting. Panda and Leeuwrik (1972) observed that number of fertile tillers were increased with increase in level of nitrogen applied two-third at transplanting and the rest top-dressed at the boot stage. Varma and Srivastava (1972) observed that application of nitrogen in 3 splits with half at transplanting, one-fourth at tillering and one-fourth at boot stage significantly influenced the number of fertile tillers per clump. Koyama and Niamsrichand (1973) noticed that panicle number per hill increased with increasing rate of nitrogen upto 112.5 kg per hectare applied, two-third as basal and one-third at 30 days before flowering. Kumar and George (1974) showed that the variety IR-8 requires two top dressings, one at the active tillering stage to increase the number of productive tillers and another at ear primordial initiation stage. Rao and Murty (1975a) reported that number of panicle bearing tillers increased with application of 40 kg nitrogen at thinning + 30 kg nitrogen before maximum tillering + 30 kg nitrogen at booting stage.

Rao and Murty (1975b) observed that 3 split dressing at (a) the thinning stage 25 days after sowing (40 kg N), (b) the maximum tillering stage (30 kgN) and (c) the booting stage (30 kgN) gave 525 panicles per square metre compared with 485 panicles per square metre in rice given 70 kg nitrogen per hectare at (a) and 30 kg nitrogen per hectare at (c). Thasanasongchan et al. (1976) reported that, fertilizer applied in 2 to 3 split application at 30 days after emergence and at panicle emergence increased the number of panicles. Bhaumik and Ghosh (1977) noted that neither the level of fertilizers, nor the time of application of nitrogen had effect on number of tillers per hill.

Hub et al. (1979) noticed that application of 180 to 200 kg nitrogen per hectare 24 days before heading in rice increased the number of panicles per hill. Nair et al. (1979) suggested that the treatment receiving half nitrogen at active tillering and the other half at panicle initiation stage, recorded the maximum number of panicle per square metre. Ghobrial (1980) reported that top dressing nitrogen at maximum tillering and panicle initiation stages significantly improved nitrogen use efficiency by promoting production of more panicles per unit area. Rodriguez et al. (1980) reported that 180 kg nitrogen applied in 2,3 or 4 doses, found to increase the panicle numberper square metre.

2. Panicle length and panicle weight

Patnaik (1969) reported that 75 to 80 per cent of the total amount of nitrogen should be applied at transplanting followed by the rest top dressed some time during the period from internode elongation to the emergence of the boot leaf stage for the full development of panicle. But Muraleedharan et al. (1972) observed that the length of panicle was not significantly influenced by the timing of nitrogen application. Ramanujam and Rao (1971) noticed that panicle length was increased with increase in nitrogen applied in 3 equal split dressings at transplanting, and at 30 and 40 days after transplanting. Panda and Leeuwrik (1972) reported that nitrogen application increased panicle length when two-third of the dose was applied at transplanting and the rest top dressed at boot stage. Nair et al. (1979) noticed that nitrogen application at later stages especially giving half the dose at panicle initiation has resulted in maximum panicle weight. Singh and Singh (1979) suggested that application of nitrogen in split dressings increased the panicle length. Wang (1981) observed that nitrogen application at the primordial panicle stage of the plant increased panicle weight.

3. Number of grains per panicle

Chiu (1968) reported that split application of nitrogen increased the percentage of fertile grains. Halappa *et al.* (1970) noticed that application of nitrogen in 2 or 3 split dressings increased the grain per ear. According to Panda and Leeuwrik (1972) application of nitrogen increased number of fertile and sterile spikelets per panicle when two-third of nitrogen was applied at transplanting and remainder top dressed at boot stage. Muraleedharan *et al.* (1972) reported that application of 50 kg nitrogen per hectare at tillering and panicle initiation significantly increased the number of spikelet per panicle. Thenababu (1972) suggested that panicle with unfilled or partly filled grains resulted when there was excess nitrogen during the reproductive stage and when the nitrogen status of the growing medium was changed from a low to a higher level at the stage of reduction division and anthesis. Verma and Srivastava (1972) observed that application of nitrogen in three splits with half the amount of nitrogen applied at transplanting and one-fourth at tillering and the remainder at boot stage increased number and weight of filled grains per panicle. Furuyama and Minami (1974) reported that the spikelet number was increased by top dressing of nitrogen at early panicle formation stage. Rao and Murty (1975b) reported that 66.8 grains per panicle was produced by 3 split application viz., 40 kg nitrogen at thinning + 30 kg nitrogen at maximum tillering + 30 kg nitrogen at booting stage where as 70 kg nitrogen at thinning + 30 kg nitrogen at booting stage produced only 62.2 grains per panicle. According to Hub et al. (1979) application of 180 to 200 kg nitrogen per hectare 24 days before heading in rice increased the number of spikelets per panicle without decreasing the grain maturity ratio and was more effective than application at 15 days before heading. Wang (1981) reported that nitrogen application at the primordial panicle stage increased spikelet number.

4. Thousand grain weight

Chiu (1968) observed that split application of nitrogen increased yield by increasing the thousand grain weight. Halappa et al. (1970) obtained 29.8 g for thousand grain weight when nitrogen was applied in 2 to 3 split dressings. Ramanujam and Rao (1971) observed that thousand grain weight decreased when nitrogen dose was more than 90 kg per hectare applied in three equal splits at transplanting, 30 and 40 days after transplanting. Panda and Leeuwrik (1972) reported that nitrogen increased thousand grain weight when two-third of the nitrogen was applied at transplanting and remaining nitrogen top dressed at the boot stage.

According to Verma and Srivastava (1972) split application of nitrogen significantly increased thousand grain weight. Nair *et al.* (1979) reported that nitrogen application, half at panicle initiation has resulted in maximum panicle weight and thousand grain weight. Singh and Singh (1979) suggested that application of nitrogen in split dressings increased thousand grain weight. Ghobrial (1980) observed that top dressing nitrogen at maximum tillering and panicle initiation significantly improved nitrogen use efficiency by increasing the grain weight. He also reported that 3 split dressings were no better than 2 given at maximum tillering and panicle initiation.

C. Yield.

1. Grain yield

Rao and Murty (1975a) reported that by soil application of (a) 70 kg nitrogen at thinning + 30 kg nitrogen at booting or (b) 40 kg nitrogen at thinning + 30 kg nitrogen before maximum tillering + 30 kg nitrogen at booting stage, paddy yield was increased to the tune of about 30 per cent with (b) as compared to (a).

Abdullah *et al.* (1976) observed that single dosages of basal nitrogen had no significant effect, but gave significant yield increase when applied as a top dressing 7 days before primordium initiation. He also observed that split application of nitrogen at 14 days after transplanting, 7 days before primordium initiation and at the flag leaf and heading stages gave increased yield. According to Sarkar and Sinha (1976) application of nitrogen in 2 split dressings at 15 days after sowing and at the panicle initiation stage gave higher paddy yield compared with nitrogen applied 15 days after sowing. Tewari and Singh (1976) noticed that application of 25 per cent nitrogen at sowing and remainder in 2 equal top dressings at the tillering and panicle initiation stages gave the highest paddy yield of 4.46 per hectare when compared with the application of entire dose of nitrogen basally which gave yield of 3.75 t per hectare.

Bhatti and Khan (1977) reported that split application of nitrogen gave higher yields than single application, but the increase was not sufficient to cover extra cost. In field trials Bhaumik and Ghosh (1977) noticed that application of nitrogen 35 per cent basal, 33 percent before tillering and remainder before flowering gave the highest grain yield with a dose of 150 kg nitrogen per hectare. Maiti and Chatterjee (1977) found that rice variety Jaya gave highest yields when 25 to 30 per cent nitrogen was applied at establishment, 40 to 50 per cent at tillering and 25 to 30 per cent at panicle initiation compared with the application of 50 to 60 per cent at establishment and 25 per cent at tillering and panicle initiation stage with the variety Cauvery. According to Nair and Sreedharan (1977) in trials with rice given 50 to 70 kg nitrogen per hectare in 2 to 3 split dressings at (a) sowing, (b) tillering and (c) panicle emergence, paddy yield was the highest with nitrogen (4.87 t) applied in 2 equal split dressings at (b) and (c) and the lowest (3.69 t) with nitrogen applied in 2 split dressings 75 per cent at (a) and 25 per cent at (b) Panda et al. (1977) found that application of 50 kg nitrogen per hectare in 3 split dressings, 25 per cent at transplanting, 50 per cent at tillering and 25 per cent at panicle initiation stages of rice, gave paddy yields of 2.11 t per hectare compared with 1.56 to 1.93 t when nitrogen was applied in 2 split dressing and 1.38 to 1.64 t when nitrogen was applied in a single dressing at any one of the 3 stages. Roy et al. (1977) obtained highest paddy yield 4.52 t per hectare with 120 kg nitrogen per hectare applied in 4 equal split dressings at transplanting, tillering, panicle initiation and boot stages. Yield decreased with three split application and lowest yield was noticed when the entire dose of nitrogen was applied basally at transplanting. Balasubramanion *et al.* (1978) reported that yield with a basal dressing (a) 25 (b) 50 (c) 75 and (d) 100 kg nitrogen per hectare were 4.04, 4.81, 4.91 and 5.4 t per hectare respectively. Application of nitrogen in 4 top dressing to crop given (a) (b) (c) and in 2 top dressings to those given (d) gave the highest yield of 5.88, 5.94, 6.08 and 5.67 t per hectare indicating that amount of total nitrogen applied to rice can be reduced by applying 25 kg nitrogen per hectare as a basal dressing and 80 kg nitrogen per hectare in 4 top dressings at 60,70, 80 and 90 days after sowing. Gaffer and Chand (1978) found that highest grain yield of 5.8 t per hectare was obtained by the application of 110 kg nitrogen per hectare applied in 3 equal split dressings at transplanting, active vegetative and lag vegetative stages. Panikar *et al.* (1978) observed that maximum yield of 3528 kg per hectare was obtained by the application of nitrogen 50 per cent at planting + 25 per cent at panicle initiation and 25 per cent at tillering. Rajan and Mahapatra (1978) reported that highest paddy yields were obtained with 100 kg nitrogen per hectare applied in four equal split dressings at sowing, late tillering, panicle, primordial initiation and booting stages. Singh *et al.* (1978) showed that, application of 100 kg nitrogen per hectare in 3 split dressings 50 per cent basal as Sulphur-coated urea and the remaining nitrogen as urea in split dressing at the tillering and panicle initiation stages gave the highest yield of 7.5 t paddy per hectare.

Bhapkar et al. (1979) observed that varieties TN-1 and IR-8 gave higher paddy yields with 80 kg nitrogen per hectare applied in 2 equal split dressings at transplanting and maximum tiller stages than when applied in a single dressing at transplanting. Houng and Liu (1979) reported that grain yield was increased by nitrogen application at tillering and young panicle formation. Nair et al. (1979) observed that skipping basal application of nitrogen and applying half the dose at active tillering and the other half at panicle initiation stage has given the maximum grain yield of 4874 kg per hectare.

Devi et al. (1980) reported that maximum yields were obtained with a nitrogen dose of 50 kg per hectare given at sowing + 2 further applications of 25 kg nitrogen per hectare each, either at booting and heading or at panicle initiation and booting. Mishra and Singh (1980) observed that paddy yields were 3.4 to 3.49 t when nitrogen was applied in 2 to 3 split dressings at transplanting, tillering, panicle initiation or botting stages and was 3.26 t when applied at transplanting and 2 t per hectare without nitrogen. In a field trial with rice cultivars IR-880-C9 and Naylamp, Ojeda and Freyre (1980) noticed that, the grain yield ranged from 5.99 and 6.53 t per hectare when nitrogen was applied 50 per cent at sowing and 50 per cent at flowering to 7.08 and 7.54 t when nitrogen was applied 33 per cent each at sowing, tiller initiation and full tillering, and 7.21 and 7.66 t with nitrogen applied 25 per cent at each of the 4 growth stages. Rodriguez et al. (1980) reported that application of nitrogen in 3 or 4 equal splits gave the highest grain yield. Subramanian and Venketaraman (1980) observed that application of 90 kg nitrogen per hectare when applied in 3 split dressings, 50 per cent at transplanting and the remainder as top dressings at the tillering and panicle initiation stages gave the highest yield. Krishnarajan and Balasubramanian (1981) reported that split application of 60 kg urea at planting and panicle initiation stages gave high yields. Lozano and Abruna (1981) observed that yields of rough rice increased from 3.83 to 7.95 t per hectare when nitrogen rates were increased from 0 to 224 kg per hectare applied as a single application. But rice yields were found to increase from 3.83 to 8.21 t per hectare when nitrogen rates were increased from 0 to 112 kg per hectare applied in 2 equal split dressings at sowing and 45 days later. Heeran and Lewin (1982) reported that high grain yields were obtained by application of nitrogen at panicle initiation.

In a study on the effect of split application of nitrogen on the yield of rice Hoque et al. (1977) found that highest grain yield was obtained by a single application of 90 kg nitrogen per hectare. Reports from IRRI showed that split application of nitrogen at transplanting, 30 days after transplanting and at 5 to 7 days prior to panicle initiation had no effect on the grain yield (Anon, 1978). Ojeda and Lopoz (1979) reported that grain yields were negatively correlated with nitrogen application during the reproductive stage of rice. Giri and Bhatade (1980) observed that nitrogen applied in 2 equal split dressings at sowing and 40 to 45 days later gave higher grain yields than that applied in a single dressing at sowing though the difference was not statistically significant. Brandon et al. (1980) noticed higher grain yields in all cultivars of rice by the application of the entire dose of nitrogen basally as compared to split application. Mossa and Vargasz (1980) suggested that split application of nitrogen had no significant effect on grain yield. Mishra et al. (1982) reported that application of urea in 3 splits did not give any yield advantage over two split application.

2. Straw yield

Narasaiah et al. (1967) reported that time of application of nitrogen did not show any marked effect on straw yield. Ramanujam and Rao (1971) observed that straw yield was increased with increase in nitrogen dose applied in 3 equal split dressings at transplanting and at 30 and 40 days after transplanting. In a field trial with rice when 120 kg nitrogen + 120 kg phosphorus per hectare were applied (a) 50 per cent at planting + 50 per cent at panicle initiation (b) 50 per cent at planting + 25 per cent at 21 days after planting + 25 per cent at panicle initiation or (c) 50 per cent at planting + 25 per cent at panicle initiation + 25 per cent as foliar application at 4 to 6 weeks after planting, Rao et al. (1973) reported that straw yields were higher with (b) than with (a) and (c). Bhaumik and Ghosh (1977) noticed that straw weight was the highest with a dose of 50 kg nitrogen per hectare applied 33 per cent as basal dressing, 33 per cent before tillering and the remainder before flowering. Hoque et al. (1977) reported considerable increase though not significant in the straw yield of rice when nitrogen was applied in 3 splits. Gaffer and Chand (1978) obtained the highest straw yield of 7.7 t per hectare when 110 kg nitrogen per hectare was applied in 3 equal split dressings at transplanting, active vegetative and lag vegetative stages.

D. Quality of grain.

Latchanna and Rao (1969) showed that the highest increase in protein content of rice grain was noticed by the application of nitrogen in 2 split dressings, one at planting and the other 50 days later at the boot stage. Taira (1970) suggested that the protein content of the grain was not increased by basal dressing or top dressing of nitrogen at the young panicle formation stage. He also reported that protein content of grain increased by nitrogen top dressing after heading. Thenababu (1972) reported that high nitrogen level at heading increased the nitrogen content of the grain. Kumar and George (1974b) reported that application of nitrogen at booting or heading and increase in the rate of basal nitrogen increased protein contents of both grain and straw. Abraham *et al.* (1974) observed maximum protein content of grain by the application of 120 kg nitrogen per hectare after flowering. Nagarajan *et al.* (1975) reported that nitrogen application at flag leaf and heading stages resulted in increased grain protein contents. 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 as single dose at sowing. Singh and Modgal (1978a) reported that application of nitrogen in 2 to 4 split dressings increased sugars compared to single application. They also reported that application of nitrogen at the panicle emergence stage decreased content of carbohydrate fractions in the grain. Subramaniam and Morachan (1979) showed that grain nitrogen contents were the highest with nitrogen applied in 3 split dressings at transplanting, tillering and flower initiation stages. Castillo et al. (1981) reported that application of urea during flowering increased protein content of the endosperm, and lipid content, which naturally declined during maturation. It was increased by nitrogen application during reproductive stage. Inocencio et al. (1981) reported that glutelin content the most variable protein characteristic, increased with application of nitrogen at flowering and was higher in cultivar Naylamp.

E. Nitrogen content and uptake of nutrients.

Chaudhry et al. (1966) reported that the uptake of nitrogen was maximum with 3 split application of nitrogen

50 per cent at planting, 25 per cent at tillering and 25 per cent at boot leaf stage. Westfall (1970) observed that residual nitrogen was negligible when 60-140 kg nitrogen per hectare was applied to rice as 40 per cent preplant, 40 per cent tillering and 20 per cent at panicle differenciation or 60 per cent preplant and 40 per cent at tillering. In an experiment at Bengkhan station with N^{15} studies, Koyama et al. (1973) reported that basal and top dressing each of 37.5 kg nitrogen per hectare resulted in a plant uptake of 83 kg nitrogen, 36 per cent of it from the fertilizer and 64 per cent from the soil. He also noted that 33.33 per cent was absorbed from basal fertilizer and 66.6 per cent from the top dressing fertilizer. He observed that the percentage distribution of mineralized soil nitrogen taken up by rice was 60 per cent upto the end of tillering, 36 per cent during panicle formation and 4 per cent during ripening. According to Singh and Bharadwaj (1973a) split application of 50 per cent or more nitrogen at transplanting and the rest at tillering and panicle initiation stages increased the total nitrogen content of rice. Furuyama and Minami (1974) suggested that top dressing of nitrogen at early panicle formation increased nitrogen uptake. Rao and Murty (1975a) reported that uptake of nitrogen was more with nitrogen

applied 40 kg at thinning + 30 kg at maximum tillering + 30 kg at booting stage than with 70 kg nitrogen applied at thinning + 30 kg nitrogen at booting. Nagarajan et al. (1975) on the basis of N^{15} studies concluded that application of nitrogen at flag leaf and heading stages resulted in high fertilizer uptake. Singh and Modgal (1978b) reported that application of nitrogen in 2 to 4 split dressings increased the plant content of total nitrogen than by application of nitrogen in a single dressing. In pot culture studies with rice given N^{15} enriched Ammonium sulphate, Houng and Liu (1979) showed that nitrogen recovery was 20 per cent with basal fertilizer, 40 per cent with fertilizer applied at tillering, 60-90 per cent with application at the young panicle stage and 40 to 60 per cent with application after heading. Hub et al.(1979) reported that application of 180 to 200 nitrogen per hectare, 24 days before heading in rice increased plant nitrogen content at meiosis. Fertilizer nitrogen constituted 30 to 36 per cent of the total nitrogen uptake and consisted of a higher proportion in the grain. The residual effect of nitrogen fertilizers was very small. Singh and Modgal (1979) reported that uptake of nitrogen increased with increasing level of applied nitrogen at all stages of crop growth. He also reported that split application of nitrogen in 3 equal dressings either through soil or soil + foliage resulted in higher nitrogen concentration and uptake. Ojeda and Freyre (1980) observed that nitrogen content of leaves was higher when nitrogen was applied during the vegetative stage. Baizhigitov et al. (1980) reported that application of nitrogen in 3 split dressings increased the plant content of nitrogen especially during the growth stages.

Singh and Bharadwaj (1973b) reported that phosphorus uptake was markedly affected by time of nitrogen application. Uptake was more when nitrogen was applied in 3 splits, 25 kg at transplanting, 25 kg at tillering and 50 kg at panicle initiation stage.

Shiga and Yamaguchi (1976) found that plant phosphorus content at the stages of greatest tillering and the amount of soil phosphorus for the different rates of applied nitrogen was similar.

Baizhigitov et al. (1980) reported that application of nitrogen in splits increased the content of phosphorus in plants.

Singh and Modgal (1978b) observed that the split application of nitrogen through soil alone or soil and foliage was found to be more conducive to phosphorus and potassium uptake.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field trial was carried out to determine the effects of different levels of nitrogen, phosphorus and potash and the time of application of nitrogen on the growth and yield of a medium duration tall indica rice variety Mashuri during second crop season at Pattambi. The various methods employed and the materials used are described below.

Location

The field experiment was conducted in the wet lands of the Regional Agricultural Research Station, Pattambi. This research station is situated at 10° 48' North latitude and $76^{\circ}12'$ East longitude. The altitude of the place is 25.36 meters above mean sea level.

Soil

The soil of the experimental area is of sandy loam type as indicated by the mechanical analysis of the soil. It is acidic in reaction with a pH of 5.4. Data on the mechanical composition and chemical analysis of the soil before commencing the experiment are given in Table 1.

Season

The field experiment was carried out during the second crop season (Mundakan) of the year 1982 which

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

1. Physical properties	
(i) Mechanical composition	
Coarse sand	44.20%
Fine sand	17.59%
Silt	12.80%
Clay	25.41%
2. Chemical characteristics	
Total nitrogen	.12%
Available P_2O_5	.0024%
Available K_2O	.007%
pH	5.4

normally extends from August-September to December-January.

Climate

The tract enjoys a warm humid tropical climate and receives a good amount of rainfall through South West monsoon and some amount through North East monsoon. The meteorological parameters like rain fall, minimum and maximum temperature and relative humidity pertaining to the period of field experimentation were obtained from the meteorological observatory of the research station and presented in Appendix I. The average weekly values of meteorological parameters for the past 10 years corresponding to the second crop season of the tract are furnished in Appendix I and Fig.1.

MATERIALS

Variety under trial

The variety used for the trial was Mashuri, which is a medium duration, tall indica rice cultivar. It is a progeny of a cross between Taichung-65 x Maying Ebos 80/2 evolved in Malaysia. The variety has a duration of 135-145 days in the first crop season and 120-125 days in the second crop season. It responds well to nitrogen application but shows a tendency for lodging at higher levels of nitrogen application.

FIG. 1. WEATHER CONDITIONS DURING THE CROP SEASON AND THE WEATHER - CONDITIONS FOR THE PAST TEN YEARS.

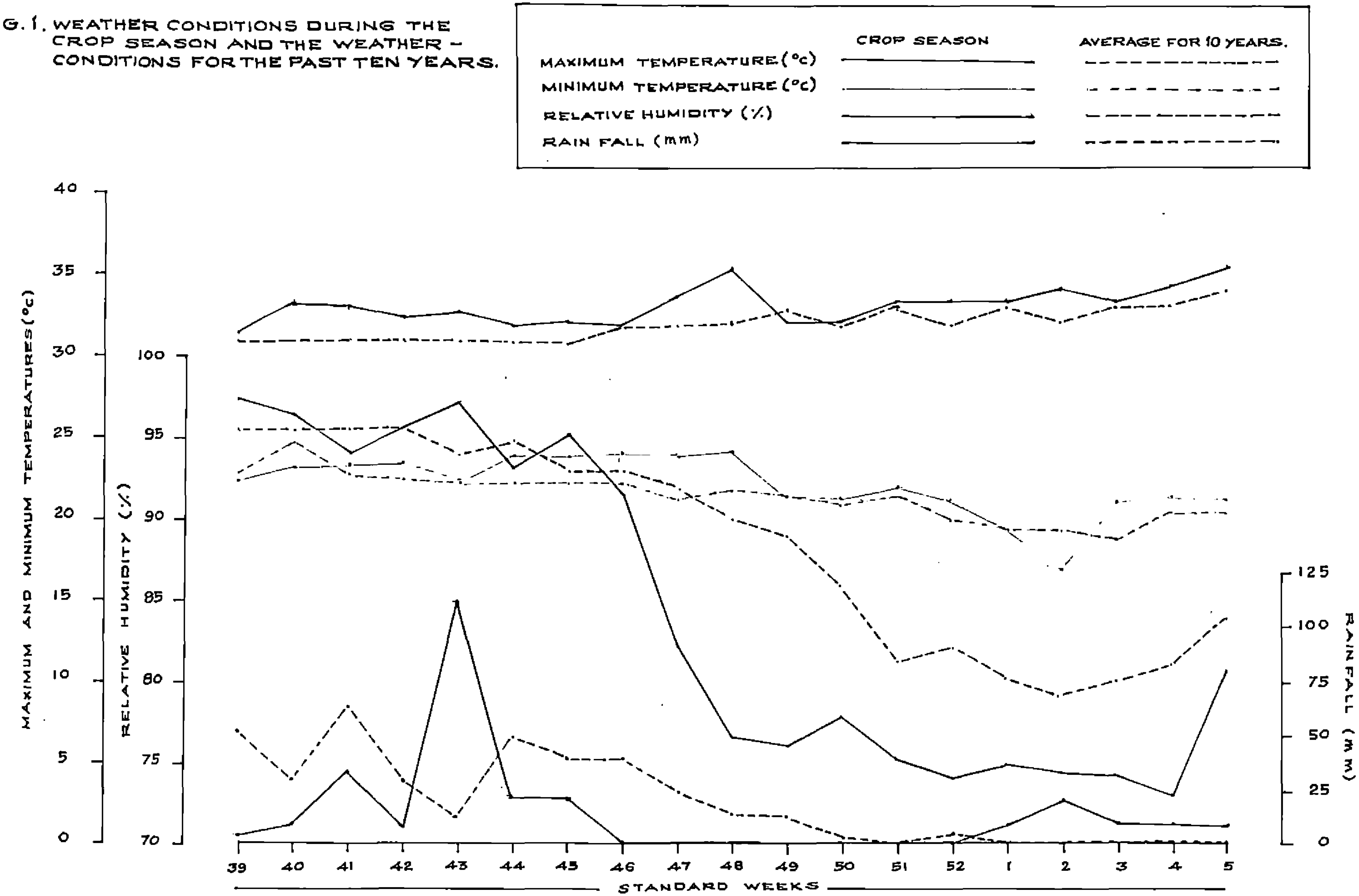
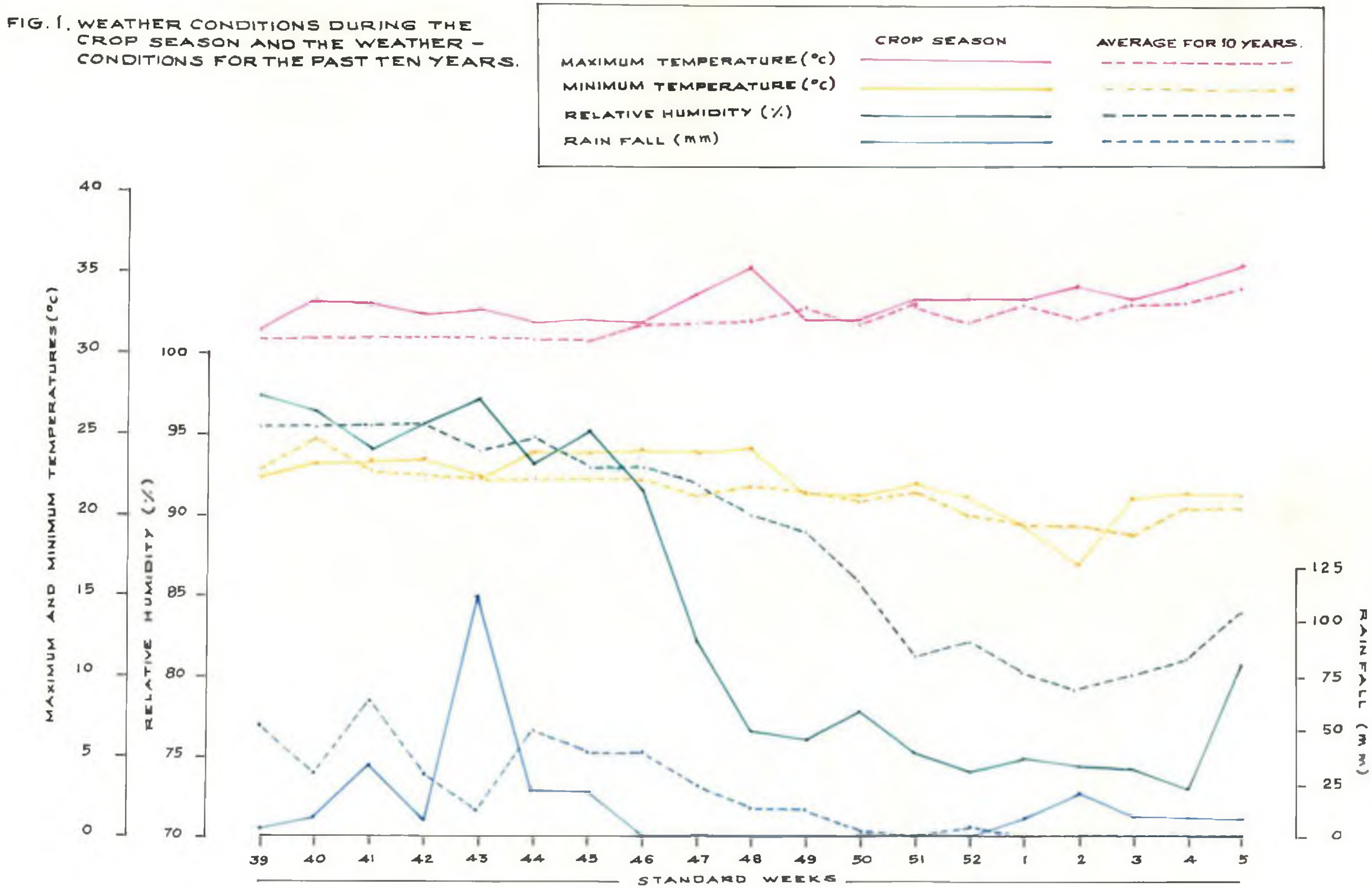


FIG. 1. WEATHER CONDITIONS DURING THE CROP SEASON AND THE WEATHER – CONDITIONS FOR THE PAST TEN YEARS.



The seeds for the experiment were obtained from the State Seed farm at Ulloor, Trivandrum.

Fertilizers used

Fertilizers mentioned below were used for the experiment.

Urea	-	46 per cent N
Super phosphate	-	16 per cent P_2O_5
Muriate of potash	-	50 per cent K_2O

METHODS

Treatments

The treatments consisted of combinations of Seven levels of NPK and three times of application as listed below.

(i) Levels of N, P and K

1. L_1 70:45:45 kg NPK per hectare
2. L_2 70:35:35 kg NPK per hectare
3. L_3 60:35:35 kg NPK per hectare
4. L_4 60:25:25 kg NPK per hectare
5. L_5 50:35:35 kg NPK per hectare
6. L_6 50:25:25 kg NPK per hectare
7. L_7 0: 0: 0 kg NPK per hectare

(ii) Time of nitrogen application

1. T_1 50 per cent nitrogen as basal + 25 per cent nitrogen 20 days after transplanting + 25 per cent nitrogen 40 days after transplanting.

2. T_2 25 per cent nitrogen as basal + 50 per cent nitrogen 20 days after transplanting + 25 per cent nitrogen 40 days after transplanting.

3. T_3 25 per cent nitrogen as basal + 25 per cent nitrogen 20 days after transplanting + 50 per cent nitrogen 40 days after transplanting.

Treatment combinations

1. L_1T_1 70:45:45 kg NPK per hectare with 50 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

2. L_1T_2 70:45:45 kg NPK per hectare with 25 per cent nitrogen as basal + 50 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

3. L_1T_3 70:45:45 kg NPK per hectare with 25 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 50 per cent nitrogen at 40 days after transplanting.

4. L_2T_1 70:35:35 kg NPK per hectare with 50 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

5. L_2T_2 70:35:35 kg NPK per hectare with 25 per cent nitrogen as basal + 50 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

6. L_2T_3 70:35:35 kg NPK per hectare with 25 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 50 per cent nitrogen at 40 days after transplanting.

7. L_3T_1 60:35:35 kg NPK per hectare with 50 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

8. L_3T_2 60:35:35 kg NPK per hectare with 25 per cent nitrogen as basal + 50 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

9. L_3T_3 60:35:35 kg NPK per hectare with 25 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 50 per cent nitrogen at 40 days after transplanting.

10. L_4T_1 60:25:25 kg NPK per hectare with 50 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

11. L_4T_2 60:25:25 kg NPK per hectare with 25 per cent nitrogen as basal + 50 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

12. L_4T_3 60:25:25 kg NPK per hectare with 25 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 50 per cent nitrogen at 40 days after transplanting.

13. L_5T_1 50:35:35 kg NPK per hectare with 50 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

14. L_5T_2 50:35:35 kg NPK per hectare with 25 per cent nitrogen as basal + 50 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

15. L_5T_3 50:35:35 kg NPK per hectare with 25 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 50 per cent nitrogen at 40 days after transplanting.

16. L_6T_1 50:25:25 kg NPK per hectare with 50 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

17. L_6T_2 50:25:25 kg NPK per hectare with 25 per cent nitrogen as basal + 50 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting.

18. L_6T_3 50:25:25 kg NPK per hectare with 25 per cent nitrogen as basal + 25 per cent nitrogen at 20 days after transplanting + 50 per cent nitrogen at 40 days after transplanting.

19. L_7T_1 0:0:0 kg NPK per hectare (control)

20. L_7T_2 0:0:0 kg NPK per hectare (control)

21. L_7T_3 0:0:0 kg NPK per hectare (control)

Design and Layout of the experiment

The experiment was laid out in a split plot design. The allocation of the various treatment combinations to different plots was done as per the method advocated by Yates (1964). The plan of layout is diagramatically represented in Fig. 2. The details of the layout are furnished below.

Design	:	Split plot design
Replications	:	3
Gross plot size	:	5.0 m x 4.0 m
Border	:	2 rows
Total number of plots	:	63

FIG. 2. LAY OUT PLAN - SPLIT PLOT EXPERIMENTS.

REPLICATION-I

L_3T_3	L_3T_2	L_3T_1
L_5T_1	L_5T_3	L_5T_2
L_2T_2	L_2T_3	L_2T_1
L_7T_1	L_7T_2	L_7T_3
L_1T_3	L_1T_1	L_1T_2
L_4T_1	L_4T_2	L_4T_3
L_6T_2	L_6T_1	L_6T_3

REPLICATION-II

L_4T_1	L_4T_3	L_4T_2
L_6T_3	L_6T_2	L_6T_1
L_1T_3	L_1T_1	L_1T_2
L_3T_1	L_3T_2	L_3T_3
L_5T_2	L_5T_3	L_5T_1
L_2T_2	L_2T_1	L_2T_3
L_7T_1	L_7T_2	L_7T_3

REPLICATION-II

L_2T_2	L_2T_3	L_2T_1
L_7T_1	L_7T_2	L_7T_3
L_4T_1	L_4T_2	L_4T_3
L_5T_1	L_5T_3	L_5T_2
L_3T_3	L_3T_2	L_3T_1
L_6T_3	L_6T_1	L_6T_2
L_1T_2	L_1T_1	L_1T_3

MAIN PLOT

LEVELS OF FERTILIZERS

L_1	70:45:45	NPK kg/ha.
L_2	70:35:35	"
L_3	60:35:35	"
L_4	60:25:25	"
L_5	50:35:35	"
L_6	50:25:25	"
L_7	0:0:0	"

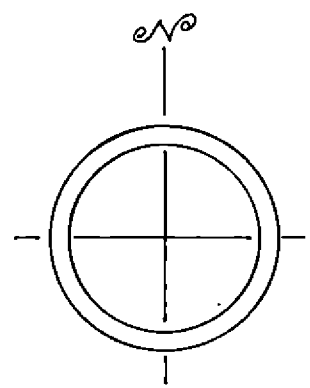
SUB PLOT

TIME OF APPLICATION

T_1- 50% N BASAL +
25% N 20 DAYS AFTER TRANSPLANTING +
25% N 40 DAYS AFTER TRANSPLANTING.

T_2- 25% N BASAL +
50% N 20 DAYS AFTER TRANSPLANTING +
25% N 40 DAYS AFTER TRANSPLANTING.

T_3- 25% N BASAL +
25% N 20 DAYS AFTER TRANSPLANTING +
50% N 40 DAYS AFTER TRANSPLANTING.



Field Culture

<u>rsery</u>

An area of 130 square metres was prepared for a wet nursery. At the time of land preparation, cattle manure at the rate of 1 kg per square metre was added and incorporated thoroughly. Fifteen kg of seeds were used to get sufficient number of healthy seedlings. The seeds were sown by broadasting in the nursery on 26th September 1982. Seedlings were ready for transplanting on 21st October 1982.

<u>Main field</u>

Land preparation

The area was ploughed thoroughly. The layout of the experiment was made after measuring out the area for each plot. One soil sample was collected each from the area representing the three replications. Bunds were constructed and plastered well and irrigation channels were made between every two plots. The area with in the plot was perfectly levelled. The basal dose of fertilizers were applied to each plot according to the treatments.

Transplanting

Healthy seedlings of 25 days growth were uprooted from the nursery and transplanted in the main field at the rate of two seedlings per hill at a depth of 2 to 3 cm. The seedlings were transplanted by rope planting method giving the appropriate plant and row spacings. Gap filling was done one week after transplanting.

Fertilizer application

Nitrogen as urea was applied in three splits as basal dressing, 20 days after transplanting and 40 days after transplanting. Measured quantities of fertilizers were applied to each plot according to treatments. Phosphorus as super phosphate and potash as muriate of potash were applied to different plots in appropriate quantities according to the treatment.

Weeding

Scanty growth of weeds was observed, and weeding was carried out 15 days after transplanting. No further weeding was required.

Irrigation and drainage

The crop received frequent showers from the North East monsoon. Water level was maintained at about 1.5 cm during transplanting. Subsequently it was increased gradually to about 5 cm depth and maintained throughout. The water in the field was drained 10 days before harvest and the dry condition was maintained till harvest.

Plant protection

Routine plant protection measures were carried out according to necessity. In general, the stand of the crop was good.

Harvest

The crop was harvested after 120 days of growth. The border rows of all plots were harvested and threshed separately. One panicle each from the observational plants were collected for observation of panicle characteristics and chemical analysis of grain. The crop in each net plot was harvested, threshed winnowed and cleaned. The grain and straw of each plot were sun dried separately for two days and plot-war yield of grain and straw were recorded before and after sun drying.

Observations

Two rows of plants were left out from four sides of each plot was borders. Twenty hills were selected and marked as observational plants with in the net plot for biometric observations. These observational plants were selected randomly. Observations were taken at active tillering, maximum tillering, panicle initiation, flowering and harvest stages respectively.

A. Observations on growth characters.

Observations were taken at 20 days interval so as to include all the critical growth stages of the crop such as active tillering, maximum tillering, panicle initiation, flowering and harvesting.

i. Height of the plant

Within each net plot, the twenty hills marked out for observation were subjected to height measurements during the five growth stages mentioned earlier. Height was measured from the base of the hill to the tip of the longest leaf. At harvest, height was measured from the base of the hill to the tip of the panicle. Plant height was measured in centimetres and recorded.

ii. Number of leaves per hill

Total number of fully opened green leaves from the observation plants were counted, average worked out and recorded.

iii. Number of tillers per hill

Total number of tillers on each hill with in the observational unit was counted, average worked out and recorded.

iv. Dry matter production

Plant sample was dried first and then subjected to oven-drying at $80^{\circ} \pm 5^{\circ}C$. Total weight of oven-dry plant sample was taken and dry matter production in kilogram per hectare was noted.

B. <u>Observation on yield components.</u>

Twenty panicles from each plot was taken and were used for recording the various grain and panicle characteristics and for chemical analysis of the grain.

i. Number of productive tillers per hill

The number of productive tillers per hill was counted for each of the twenty observation hills. The mean value was worked out for each treatment.

ii. Length of panicle

The length was measured from the neck to the tip of panicle and the average was worked out for each plot and expressed in centimetres.

iii. Weight of panicle

The mean weight of twenty panicles was worked out for each treatment and expressed in grams.

iv. Number of grains per panicle

The entire spikelets were counted including number of filled grains, number of half filled grains and unfilled grains. The mean of the number of spikelets for twenty panicles was worked out.

v. Number of filled grains per panicle

The filled grain per panicle were separated out and the average computed for twenty panicles.

vi. Number of half filled grains per panicle

The number of half filled grains were also separated out from each panicle and average worked out for twenty panicles and recorded.

vii. Number of unfilled grains per panicle

The unfilled grains were separated out from the spikelets removed from each panicle and these were counted and the mean computed for twenty panicles.

viii. Thousand grain weight

One thousand filled grains were counted out from the grain harvested from each plot. These were weighed and the weight was recorded in grams.

C. <u>Observations on grain and straw yield</u>.

i. Grain yield

Each plot was harvested leaving the two outer rows and threshed. The wet weight of grain was taken immediately. The grain was then sun dried for two days to a moisture content of fourteen per cent. The dried grain was winnowed cleaned and weight recorded. The yield was expressed in kg per hectare.

ii. Straw yield

The straw was also weighed immediately after harvest and sun dried for two days. The weight of straw per hectare was computed from the per plot weight of wet and dry straw.

iii. Grain : straw ratio

The ratio between the grain and straw yields was worked out for individual plots.

iv. Harvest Index

The harvest index was worked out from the data on grain and straw yield obtained for each plot and multiplied by 100 to get the percentage. The formula used is given below.

$$\text{Harvest Index per cent} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Chemical Analysis

A. Plant Analysis.

The chemical analysis of the plant samples collected at the harvest stage was done. The observational plants, the grain and straw were taken and was oven-dried at $80^{\circ}C \pm 5^{\circ}C$ till a constant weight was obtained. It was then finally grained using a Wiley mill and sieved through a 2 mm sieve. This was then digested and the digest was chemically analysed. The nitrogen, phosphorus and potash contents of grain and straw were determined separately.

i. Nitrogen content

The total nitrogen content of the digest of each sample was analysed employing the modified micro-kjeldahl method (Jackson 1967).

ii. Phosphorus content

The total phosphorus content was determined calorimetrically using the Vanado-molybdo-phosphoric yellow colour method (Jackson 1967). The colour intensities were read in a Klett-summerson photoelectric calorimeter.

iii. Potash content

An 'EEL' flame photometer was used to determine the total potash content.

B. Uptake studies.

The total quantities of the three major nutrients, viz., nitrogen, phosphorus and potash absorbed by the crop at harvest was calculated. The value of total uptake was obtained as the product of the content of these nutrients in the plant and the weight of dry matter. The values were expressed in kilogram per hectare.

C. Grain protein content.

The percentage of protein in the grain was calculated and recorded as the product of the content of nitrogen in the grain and a factor 6.25 (Simpson *et al*. 1965)

D. Soil Analysis.

Soil samples were taken from the experimental area before and after the experiment. Representative soil samples from each replicated area taken before experiment and total nitrogen available phosphorus and available potassium were analysed. Soil samples from each plot (63 plots) after the experiment were also taken and analysed for N.P. and K. Total nitrogen content was estimated by the modified micro-kjeldahl method. Available phosphorus content by Bray's method (Jackson 1967) and available potash by ammonium acetate method (Jackson 1967).

Statistical Analysis

Data on yield, yield attributes, growth characters, chemical analysis of plant and soil samples were statistically analysed by using the analysis of variance technique and significance was tested by F-test (Snedecor and Cochran, 1967).

RESULTS

RESULTS

A field experiment was conducted at Regional Agricultural Research Station, Pattambi during the second crop season of 1982-83 for assessing the effect of various nutrient levels and time of application of nitrogen on the growth and yield of a medium duration tall indica rice variety Mashuri. The observations recorded were statistically analysed.

A. Growth characters.

1. Height of plants

Data on the mean height of plants taken at active tillering, maximum tillering, panicle initiation, flowering and harvesting stages are presented in Tables 2(i) to 2(v) and their analyses of variance in Appendix II.

It was observed that the height was increased at all stages of growth by increasing the nutrient levels. At active tillering stage the nutrient level 50:25:25 kg NPK per hectare (L_6) produced the tallest plants though not significant. At maximum tillering and panicle initiation stages, treatment L_1 viz. 70:45:45 kg NPK per hectare gave significantly taller plants (82.32 cm, 86.57 cm) which was on par with treatments L_2, L_4 and L_6. At flowering stage treatment L_6 (50:25:25 kg NPK/ha) produced tallest plants (99.01 cm) which was on par with all other levels except control. At harvesting stage treatment L_2 (70:35:35 kg NPK/ha) produced tallest plants (103.45 cm) which was significantly different from treatment L_5 (50:35:35 kg NPK/ha) and absolute control. At all stages of growth the absolute control recorded minimum values of plant height, which was significantly inferior to all other levels and treatments L_3, L_4, L_5 and L_6 were on par.

The time of application of nitrogenous fertilizer did not exert any significant influence on height of plants at any of the growth stages except at maximum tillering stage. At this stage tallest plants were noticed in treatment T_2 (25 per cent nitrogen basal + 50 per cent nitrogen at 20 days after transplanting + 25 per cent nitrogen at 40 days after transplanting) which was significantly superior to other times of application of nitrogen. The treatments T_1 and T_3 were on par.

The various treatment combinations did not show any profound influence on the height of plants at any of the growth stages though taller plants of 61.33 cm was produced by treatment L_6T_1 at active tillering, 84.62 cm by L_1T_2 at maximum tillering, 87.74 cm by L_1T_1 at panicle initiation, 100.73 cm by L_6T_1 at flowering and 106.16 by L_2T_1 at harvesting. The differences between treatment combinations were not significant.

Table 2(i)- Height of plants at active tillering stage (cm)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	60.74	58.22	58.39	59.12
L_2	70:35:35	59.62	58.23	58.58	58.81
L_3	60:35:35	56.06	58.66	57.59	57.44
L_4	60:25:25	56.51	55.45	56.72	56.23
L_5	50:35:35	58.81	57.24	56.72	57.59
L_6	50:25:25	61.33	57.03	59.33	59.23
L_7	0: 0: 0	53.48	56.34	56.52	55.45
	Mean	58.08	57.31	57.70	

SE for fertilizer levels - 1.883
SE for time of nitrogen - 0.694
SE for L x T - 2.408

Table 2(ii)- Height of plants at maximum tillering stage (cm)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	83.59	84.62	78.75	82.32
L_2	70:35:35	82.88	84.19	78.92	82.00
L_3	60:35:35	76.58	81.46	77.31	78.44
L_4	60:25:25	76.72	81.04	79.25	79.00
L_5	50:35:35	77.75	80.26	74.15	77.39
L_6	50:25:25	81.73	79.63	77.43	79.60
L_7	0: 0: 0	69.39	70.09	71.34	70.27
	Mean	78.38	80.19	76.74	

CD for fertilizer levels - 4.463
CD for time of nitrogen - 1.785
SE for L x T - 2.782

Table 2(iii) - Height of plants at panicle initiation stage (cm)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	87.74	87.23	84.73	86.57
L_2	70:35:35	85.18	88.54	84.72	86.14
L_3	60:35:35	80.74	85.03	83.53	83.10
L_4	60:25:25	81.12	85.33	86.58	84.34
L_5	50:35:35	81.60	82.95	80.02	81.52
L_6	50:25:25	84.40	82.63	83.17	83.40
L_7	0: 0: 0	72.37	72.03	75.65	73.35
	Mean	81.88	83.39	82.63	

CD for fertilizer levels - 4.438
SE for time of nitrogen - 0.144
SE for L x T - 2.253

Table 2(iv)- Height of plants at flowering stage (cm)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	99.95	98.38	98.64	98.99
L_2	70:35:35	97.82	98.80	100.29	98.97
L_3	60:35:35	93.02	96.48	98.53	96.01
L_4	60:25:25	92.98	95.61	99.79	96.13
L_5	50:35:35	93.85	97.82	93.45	95.04
L_6	50:25:25	100.73	96.30	100.00	99.01
L_7	0: 0: 0	83.27	83.27	86.30	84.28
	Mean	94.52	95.24	96.72	

CD for fertilizer levels - 4.465
SE for time of nitrogen - 1.196
SE for L x T - 3.297

Table 2(v) - Height of plants at harvest (cm)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	103.42	100.10	100.06	101.19
L_2	70:35:35	105.16	100.97	104.23	103.46
L_3	60:35:35	96.83	100.40	102.70	99.98
L_4	60:25:25	99.35	103.14	104.59	102.36
L_5	50:35:35	98.92	101.16	97.59	99.29
L_6	50:25:25	101.33	99.13	102.00	100.82
L_7	0: 0: 0	89.42	89.08	90.68	89.73
	Mean	99.20	99.14	100.29	

CD for fertilizer level - 3.646

SE for time of nitrogen - 1.078

SE for L x T - 2.868

2. Number of leaves per hill

The data on the mean leaf number at various stages are presented in Tables 3(i) to 3 (iv). The analyses of variance are given Appendix III.

The data clearly revealed that the number of leaves increased with higher levels of NPK at all growth stages upto panicle initiation. At active tillering and flowering stages the highest level of nutrients namely 70:45:45 kg NPK per hectare gave the highest number of leaves 15.25 and 22.21 respectively, though not significant. At maximum tillering stage, treatment 70:35:35 kg NPK per hectare gave the highest number of leaves (26.30) which was significantly superior to treatments L_5, L_6 and L_7 and was on par with L_1, L_4 and L_3. At panicle initiation stage treatment L_1 (70:45:45 kg NPK/ha) produced the highest number of leaves (27.52) which was significantly superior to treatments L_3, L_5 and L_7 and was on par with L_2, L_4 and L_6. The control plots registered the minimum number of leaves at all growth stages. However, the differences between the sub plot treatments were not significant. Among the subplot treatments T_2 showed the highest number of leaves at maximum tillering, panicle initiation and flowering stages. Treatment T_1 gave the highest number of leaves at active tillering stage. The interaction effect also was not significant. But the highest leaf number was noted in the

Table 3(i) - Number of leaves per hill at active tillering stage

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	16.25	14.92	14.59	15.25
L_2	70:35:35	14.84	14.27	14.43	14.51
L_3	60:35:35	12.72	13.36	14.02	13.36
L_4	60:25:25	13.93	15.57	13.10	14.20
L_5	50:35:35	13.92	13.02	13.24	13.39
L_6	50:25:25	15.90	13.00	15.30	14.73
L_7	0: 0: 0	13.39	13.95	12.50	13.28
	Mean	14.42	14.01	13.88	

SE for fertilizer levels - 1.318
SE for time of nitrogen - 0.516
SE for L x T - 1.725

Table 3(ii)- Number of leaves per hill at maximum tillering

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	25.80	26.54	24.35	25.57
L_2	70:35:35	26.81	26.61	25.47	26.30
L_3	60:35:35	23.72	25.91	24.64	24.76
L_4	60:25:25	24.10	26.63	23.53	24.78
L_5	50:35:35	23.40	24.29	21.48	23.06
L_6	50:25:25	23.80	21.33	22.83	22.66
L_7	0: 0: 0	18.87	21.70	19.47	20.01
	Mean	23.80	24.72	23.11	

CD for fertilizer levels - 2.892
SE for time of nitrogen - 0.6895
SE for L x T - 1.99502

Table 3(iii)- Number of leaves per hill at panicle initiation

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application T_1	T_2	T_3	Mean
L_1	70:45:45	27.18	27.52	27.86	27.52
L_2	70:35:35	25.36	26.58	26.05	26.00
L_3	60:35:35	23.37	24.35	24.59	24.10
L_4	60:25:25	24.57	26.96	25.01	25.51
L_5	50:35:35	23.35	24.84	22.84	23.68
L_6	50:25:25	26.33	25.97	25.87	26.06
L_7	0: 0: 0	20.04	21.75	19.80	20.53
	Mean	24.32	25.42	24.57	

CD for fertilizer levels - 2.781
SE for time of nitrogen - 0.693
SE for L x T - 1.966

Table 3(iv)- Number of leaves per hill at flowering

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application T_1	T_2	T_3	Mean
L_1	70:45:45	22.76	21.64	22.23	22.21
L_2	70:35:35	21.19	21.27	20.57	21.01
L_3	60:35:35	19.69	21.38	21.31	20.80
L_4	60:25:25	19.69	22.12	20.04	20.62
L_5	50:35:35	20.19	20.69	19.27	20.05
L_6	50:25:25	21.13	19.03	21.73	20.63
L_7	0: 0: 0	16.82	18.07	15.53	16.81
	Mean	20.21	20.60	20.10	

SE for fertilizer levels - 1.565
SE for time of nitrogen - 0.529
SE for L x T - 1.939

treatment combination of L_1T_1 at tillering (16.25) and flowering stages (22.76) and 26.81 for treatment L_2T_1 at maximum tillering stage and 27.52 for L_1T_2 at panicle initiation stage.

3. Tiller number

The data on the mean values for the number of tillers per hill at different growth stages of the crop are presented in Table 4(i) to 4(v) and their respective analyses of variance in Appendix IV.

It is evident from the data that an increase in nutrient level exerted considerable influence on the number of tillers per plant at all stages of growth. At active tillering stage treatment L_1 produced the highest tiller number of 5.65, though not significant.

At maximum tillering and panicle initiation stages treatment L_2 produced the highest tiller number of 7.82 and 6.82 which were significantly higher than treatments L_5 and L_7 and was on par with L_1, L_4, L_6 and L_3. The tiller number observed in the control plots were much less than all other treatments except L_5 which was on par. The treatment L_1 gave the highest tiller number of 6.01 which showed significant superiority over treatments L_3, L_6, L_5 and L_7 and was on par with L_4 and L_2 at flowering.

Table 4(i)- Number of tiller per hill at active tillering

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	6.04	5.17	5.73	5.65
L_2	70:35:35	5.64	4.93	5.14	5.24
L_3	60:35:35	4.88	4.88	5.03	4.93
L_4	60:25:25	5.18	4.93	4.87	4.99
L_5	50:35:35	5.42	4.96	4.67	5.01
L_6	50:25:25	6.10	4.80	5.47	5.46
L_7	0: 0: 0	4.98	5.22	4.45	4.88
	Mean	5.46	4.98	5.05	

SE for fertilizer levels - 0.315
CD for time of nitrogen - 0.320
SE for L x T - 0.461

Table 4(ii)- Number of tillers per hill at maximum tillering stage

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	7.13	7.95	7.60	7.56
L_2	70:35:35	7.92	8.05	7.49	7.82
L_3	60:35:35	6.54	7.62	6.86	7.01
L_4	60:25:25	7.07	7.79	6.37	7.08
L_5	50:35:35	6.53	7.08	6.24	6.61
L_6	50:25:25	7.00	7.27	6.93	7.07
L_7	0: 0: 0	5.91	6.39	5.93	6.08
	Mean	6.87	7.45	6.77	

CD for fertilizer levels - 0.786
CD for time of nitrogen - 0.431
SE for L x T - 0.580

Table 4(iii)- Number of tillers per hill at panicle initiation stage

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	6.27	6.78	6.77	6.60
L_2	70 :35 :35	7.14	6.87	6.45	6.82
L_3	60 :35 :35	5.79	6.96	6.02	6.25
L_4	60 :25 :25	6.12	7.00	5.78	6.30
L_5	50 :35 :35	6.26	6.13	5.76	6.05
L_6	50 :25 :25	6.50	6.43	6.00	6.31
L_7	0: 0: 0	5.37	5.82	5.35	5.51
	Mean	6.21	6.57	6.02	

CD for fertilizer levels - 0.641
CD for time of nitrogen - 0.357
SE for L x T - 0.478

Table 4(iv)- Number of tiller per hill at flowering stage

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	5.62	6.43	5.98	6.01
L_2	70 :35 :35	5.74	5.60	5.55	5.63
L_3	60 :35 :35	5.19	5.64	5.15	5.32
L_4	60 :25 :25	5.61	5.98	5.50	5.70
L_5	50 :35 :35	5.28	5.39	4.85	5.18
L_6	50 :25 :25	5.27	4.97	5.47	5.23
L_7	0: 0: 0	4.87	4.97	4.28	4.71
	Mean	5.37	5.57	5.26	

CD for fertilizer levels - 0.496
SE for time of nitrogen - 0.185
SE for L x T - 0.461

Table 4(v)- Number of tillers per hill at harvest

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	5.77	5.98	5.56	5.77
L_2	70 :35 :35	5.69	5.75	5.23	5.56
L_3	60 :35 :35	5.40	5.57	5.39	5.45
L_4	60 :25 :25	5.58	5.87	5.27	5.57
L_5	50 :35 :35	5.24	5.27	4.73	5.08
L_6	50 :25 :25	5.50	4.77	5.40	5.22
L_7	0: 0: 0	4.58	4.84	4.46	4.63
	Mean	5.40	5.43	5.15	

CD for fertilizer levels - 0.612

SE for time of nitrogen - 0.149

SE for L X T - 0.427

The same treatment gave the highest tiller number of 5.77 at harvest stage which was significantly superior to treatments L_5 and L_7 and was on par with L_4, L_2, L_3 and L_6.

As regards the time of application of nitrogen treatment T_1 gave significantly higher number of tillers (5.46) at active tillering stage. Treatment T_2 produced significantly higher number of tillers as compared to T_1 and T_3 at stages of maximum tillering and panicle initiation. But the difference was not significant at flowering and harvest stages.

The interaction effects were not significant in this attribute in any of the stages. The mean table revealed that higher tiller numbers were obtained with treatments L_6T_1 at active tillering stage, L_1T_2 at maximum tillering, L_2T_1 at panicle initiation, L_1T_2 at flowering and harvesting stages.

4. Dry matter production

Data on the mean value for dry matter production are presented in Table 5 and the corresponding analysis of variance in Appendix V.

Table 5- Dry matter production at harvest (kg/ha)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	7388.77	7111.11	7333.33	7277.74
L_2	70:35:35	6777.77	6899.78	7055.55	6907.40
L_3	60:35:35	6500.00	6611.11	6611.11	5859.07
L_4	60:25:25	5944.44	6266.66	6055.55	6092.55
L_5	50:35:35	5833.33	6222.22	5888.59	5981.48
L_6	50:25:25	5888.89	5833.33	6000.00	5907.41
L_7	0: 0: 0	5222.22	5666.66	4944.44	5277.77
	Mean	5917.35	6371.43	6269.84	

SE for fertilizer levels - 626.517

SE for time of nitrogen - 357.248

SE for L x T - 994.038

The data revealed the effect of NPK levels in increasing the dry matter production though the effect was not significant. Treatment L_1 receiving the highest level of nutrients produced the highest dry matter (7277.74 kg/ha) whereas a minimum 5277.77 kg per hectare dry matter was observed in the control plot.

The dry matter production was not influenced significantly by the time of application of nitrogen. But the highest value of 6371.43 kg per hectare dry matter was observed in treatment T_2.

The interaction effect also did not show any significant difference. But the highest value was given by L_1T_1 and minimum value by the control plot.

B. <u>Yield components and yield.</u>

1. Productive tiller count

The data on the mean number of productive tillers are furnished in Table 6(i) and 6(ii) and the analyses of variance in Appendix V.

The data showed that the treatment effect was significant in this respect only at the harvest stage. Treatment L_1 (70:45:45 kg NPK/ha) gave the highest productive tiller count (4.97) which was significantly superior to L_5 and L_7 and found on par with L_2, L_3, L_4 and L_6.

Table 6(i)- Number of productive tillers per hill at flowering stage

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	2.39	1.60	1.52	1.84
L_2	70:35:35	1.34	1.40	1.52	1.42
L_3	60:35:35	1.08	1.32	1.32	1.24
L_4	60:25:25	0.69	0.59	0.94	0.74
L_5	50:35:35	1.38	1.51	1.09	1.32
L_6	50:25:25	2.13	1.67	1.95	1.92
L_7	0: 0: 0	1.17	0.917	0.98	1.02
	Mean	1.45	1.29	1.33	

SE for fertilizer levels - 0.484
SE for time of nitrogen - 0.172
SE for L x T - 0.609

Table 6(ii)- Number of productive tillers per hill at harvest

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	4.93	4.99	5.00	4.97
L_2	70:35:35	4.98	4.73	4.78	4.83
L_3	60:35:35	4.40	4.66	4.67	4.58
L_4	60:25:25	4.61	4.74	4.48	4.61
L_5	50:35:35	4.40	4.72	4.02	4.38
L_6	50:25:25	4.90	4.23	4.70	4.61
L_7	0: 0: 0	4.27	4.21	3.99	4.15
	Mean	4.64	4.61	4.52	

CD for fertilizer levels - 0.410
SE for time of nitrogen - 0.136
SE for L x T - 0.349

The time of application of nitrogen had no significant effect on number of productive tillers either at flowering or harvest stages, but highest numbers were observed in treatment T_1 both at flowering (1.45) and harvest (4.64) stages.

The interaction also did not show any significant difference. But treatment combination L_1T_1 gave the highest number (2.39) at flowering and L_1T_3 at harvest (5.00) stages.

2. Length of panicle

The mean values for the length of panicle are presented in Table 7 and the analysis of variance in Appendix V.

It could be seen from the data that though the treatment effects were not significant in this respect, the length of panicle was the highest in treatment L_5 (21.52) and minimum in absolute control (20.83)

The time of application of nitrogen also did not show any significant influence in the length of panicle. But the highest values were noted in the Treatment T_3.

The interaction also did not show any significant effect on the length of panicle. But the highest length was observed in treatment combination L_4T_2 (21.97).

Table 7 - Length of panicle (cm)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	20.58	21.26	21.56	21.14
L_2	70:35:35	21.25	20.10	21.46	20.93
L_3	60:35:35	20.73	20.98	21.43	21.05
L_4	60:25:25	20.91	21.97	20.56	21.15
L_5	50:35:35	21.40	20.63	21.31	21.52
L_6	50:25:25	21.72	21.34	21.44	21.02
L_7	0: 0: 0	20.28	21.21	21.01	20.83
	Mean	20.98	21.07	21.25	

SE for fertilizer levels - 0.688
SE for time of nitrogen - 0.318
SE for L x T - 0.971

3. Weight of panicle

The mean value for the weight of panicle are presented in Table 8 and the analysis of variance in Appendix V.

The data showed that the panicle weight did not differ significantly by the levels of NPK. But the treatment L_2 (70:35:35 kg NPK/ha) produced the heaviest panicles whereas control plot gave the lowest value for panicle weight. The time of application of nitrogen also did not influence the panicle weight significantly. However, the treatment T_3 gave the highest panicle weight of 2.44g.

The interaction effect also was not significant in this respect. But the highest was noted in treatment L_3T_2 (3.46g).

4. Number of grains per panicle

The Table 9 furnishes the data on the number of grains per panicle. The analysis of variance are presented in Appendix VI.

It is evident from the data that the effect due to the levels of NPK on number of grains was not significant. However, treatment L_6 gave the highest number of grains (133.33) followed by L_4 (130.69) and L_5 (129.43). The treatment L_7 gave the minimum value.

Table 8- Weight of panicle (g)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	2.62	2.62	2.09	2.44
L_2	70 :35 :35	2.76	2.45	2.89	2.70
L_3	60 :35 :35	2.23	3.46	2.31	2.67
L_4	60 :25 :25	1.83	2.15	2.15	2.07
L_5	50 :35 :35	2.45	2.15	2.67	2.25
L_6	50 :25 :25	2.24	2.19	2.50	2.31
L_7	0: 0: 0	2.51	2.26	2.02	2.26
	Mean	2.33	2.41	2.44	

SE for fertilizer levels - 0.389
SE for time of nitrogen - 0.209
SE for L x T - 0.597

Table 9- Number of grains per panicle

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	118.26	124.36	133.06	125.23
L_2	70 :35 :35	162.13	108.57	132.58	126.65
L_3	60 :35 :35	112.34	126.42	131.89	123.22
L_4	60 :25 :25	110.61	140.00	141.45	130.69
L_5	50 :35 :35	129.31	132.05	126.92	129.43
L_6	50 :25 :25	135.61	132.65	132.14	133.33
L_7	0: 0: 0	99.96	123.66	124.39	116.00
	Mean	120.70	126.67	131.77	

SE for fertilizer levels - 14.057
SE for time of nitrogen - 5.557
SE for L x T - 18.485

As regards the effect of time of nitrogen application on the number of grains per panicle, even though the treatment T_3 gave the highest value of 131.77 there was no significant difference between the treatments.

The interaction effects were not significant. But the combination L_4T_3 gave the highest value of 141.45.

5. Half filled grains per panicle

The mean number of half filled grains per panicle are presented in Table 10 and the analysis of variance in Appendix VI.

The data revealed that the number of half filled grains was influenced by the level of NPK though not significant. There was an increase on the half filled grains with decreasing nutrients level. The highest level of nutrients namely 70:45:45 kg NPK per hectare gave a lower number of half filled grains and the lowest value was given by 70:35:35 kg NPK per hectare. The highest value was obtained by the treatment L_6, 50:25:25 kg NPK per hectare.

The time of nitrogen application failed to show any significant effect on the number of half filled grains per panicle. But the highest value was obtained with treatment T_2.

The interaction effect showed the highest value of 9.94 with the treatment combination L_6T_1 and lowest value of 6.25 with L_2T_1. But there was no significant difference between the treatment combinations.

6. Unfilled grains per panicle

Data on the mean number of unfilled grains per panicle are furnished in Table 11 and the corresponding analysis of variance in Appendix VI.

It was observed that the unfilled grains per panicle was not influenced by difference levels of nutrients. However, the number of unfilled grains per panicle was the highest in the control plots received no nutrients (24.94). It was minimum in treatments L_1 (20.08) and L_6 (20.04).

The time of application of nitrogen also did not exert any significant influence in this attribute. But the highest value was obtained with treatment T_3 (23.80).

The treatment combinations also did not show any significant difference.

7. Thousand grain weight

Table 12 furnishes the data on the thousand grain weight and the Appendix VI provides the corresponding analysis of variance.

Table 10- Number of half filled grains per panicle

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	6.44	6.97	8.17	7.20
L_2	70:35:35	6.25	6.66	7.43	6.78
L_3	60:35:35	8.10	6.70	10.44	8.42
L_4	60:25:25	9.77	9.17	6.44	9.57
L_5	50:35:35	7.97	8.84	7.33	9.61
L_6	50:25:25	9.94	9.79	8.90	9.89
L_7	0: 0: 0	6.28	9.50	8.00	7.92
	Mean	7.82	8.23	8.10	

SE for fertilizer levels - 1.637
SE for time of nitrogen - 0.797
SE for L x T - 2.376

Table 11- Number of unfilled grains per panicle

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	18.97	17.94	21.67	20.08
L_2	70:35:35	25.09	16.31	19.76	20.38
L_3	60:35:35	20.38	19.87	27.89	22.70
L_4	60:25:25	19.11	24.83	24.83	23.33
L_5	50:35:35	18.98	25.39	21.94	22.13
L_6	50:25:25	17.83	20.28	22.00	20.04
L_7	0: 0: 0	21.98	27.22	25.61	24.94
	Mean	20.34	21.69	23.80	

SE for fertilizer levels - 4.626
SE for time of nitrogen - 1.915
SE for L x T - 6.205

There was no significant difference in the thousand grain weight with different nutrient levels. The treatment L_4 gave the highest value of 17.88 g.

The time of nitrogen application also failed to show any significant influence on the thousand grain weight. The highest value of 17.74 g was given by treatment T_3.

The interaction also did not show any significant difference in the thousand grain weight.

8. Grain yield

The data pertaining to the grain yield as influenced by the various NPK levels and time of application of nitrogen are presented in Table 13 and the analysis of variance in Appendix VII.

The data clearly revealed the significant influence of NPK levels on grain yield. The highest grain yield of 3899.98 kg per hectare, was obtained by the highest level of nutrients namely 70:45:45 kg NPK per hectare (L_1) tried. It was significantly superior to control treatment and on par with other levels of NPK. The treatment L_3 gave an yield of 3656.76 kg per hectare which was also significantly superior to zero level of NPK. The subplot treatment did not give significant difference in grain yield. But the highest value of 3728.35 kg per hectare was observed for the treatment T_3.

Table 12- Thousand grain weight (g)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	18.27	17.94	17.16	17.74
L_2	70 :35 :35	17.88	17.72	17.75	17.64
L_3	60 :35 :35	16.39	17.05	17.75	17.39
L_4	60 :25 :25	17.24	17.90	18.01	17.88
L_5	50 :35 :35	17.41	17.64	17.42	17.50
L_6	50 :25 :25	15.71	17.33	17.63	16.89
L_7	0 : 0 : 0	17.73	17.09	17.45	17.46
	Mean	17.31	17.66	17.74	

SE for fertilizer levels - 0.673
SE for time of nitrogen - 0.291
SE for L x T - 0.922

Table 13 - Yield of grain (kg/ha)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	3942.65	3725.04	4032.26	3899.98
L_2	70 :35 :35	3917.82	3778.90	3878.65	3858.46
L_3	60 :35 :35	3609.83	3712.24	3648.23	3656.76
L_4	60 :25 :25	3609.83	3896.82	3814.64	3773.76
L_5	50 :35 :35	3725.04	3648.23	3801.84	3725.04
L_6	50 :25 :25	3758.12	3735.18	3814.64	3769.00
L_7	0 : 0 : 0	3001.79	3123.40	3008.90	3044.46
	Mean	3652.15	3659.93	3728.35	

CD for fertilizer level - 367.829
SE for time of nitrogen - 57.040
SE for L x T - 208.995

The interaction also did not show any significant difference in grain yield. However, the highest yield was recorded by treatment combination L_1T_3.

9. Straw yield

The Table 14 furnishes the data pertaining to the straw yield as influenced by levels of NPK and time of nitrogen application. The corresponding analysis of variance are presented in Appendix VII.

The yield of straw was significantly influenced by the levels of NPK and the highest yield of 4879.25 kg per hectare was recorded by the treatment L_1. Straw yield was the highest with nutrients level 70:45:45 kg NPK per hectare and superior to treatments L_3, L_4, L_5, L_6 and L_7 and on par with L_2.

The time of nitrogen application did not give any significant difference in the straw yields giving the highest value of 4344.89 kg per hectare with treatment T_2.

The interaction effect was also found not significant for the straw yields. High value was obtained with treatment combination L_1T_3.

10. Grain : Straw ratio

The data on mean values of grain straw ratio are presented in Table 15 and corresponding analysis of variance in Appendix VII.

The NPK levels did not exert any significant influence on the grain:straw ratio. But the highest value of 0.96 was observed in the 'no' nutrients treatment and the lowest value of 0.80 for higher level of nutrients namely, 70:45:45 kg NPK per hectare.

The grain:straw ratio was significantly influenced by the time of nitrogen application and T_1 gave the highest value of 0.90.

The interaction effect was also found significant. The highest value of 0.98 was obtained with the treatment combination L_7T_1 which was significantly superior to treatment combinations L_2T_1, L_6T_1, L_6T_2, L_4T_3, L_4T_1, L_3T_2, L_1T_3, L_3T_1 and L_1T_2. The treatment L_1T_2 gave the lowest value which was on par with other combinations such as L_2T_2, L_1T_3, L_3T_2 and L_3T_1.

C. Quality character.

1. Protein content of grain

Data on the protein content of grain are furnished in Table 16 and the corresponding analysis of variance in Appendix VII.

Table 14- Yield of straw (kg/ha)

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	4710.70	4915.52	5011.52	4879.25
L_2	70:35:35	4404.48	4928.32	4256.27	4529.36
L_3	60:35:35	4307.48	4595.50	4038.66	4313.88
L_4	60:25:25	4249.87	4179.47	4403.48	4277.61
L_5	50:35:35	3840.24	4281.36	4141.29	4087.56
L_6	50:25:25	4230.69	4275.48	4243.47	4249.87
L_7	0: 0: 0	3072.20	3238.61	3232.60	3177.67
	Mean	4116.40	4344.89	4189.53	

CD for fertilizer levels - 403.202
SE for time of nitrogen - 97.688
SE for L x T - 280.666

Table 15- Grain:straw ratio

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	0.84	0.76	0.80	0.80
L_2	70:35:35	0.89	0.77	0.91	0.86
L_3	60:35:35	0.84	0.81	0.91	0.85
L_4	60:25:25	0.85	0.95	0.87	0.89
L_5	50:35:35	0.97	0.80	0.92	0.90
L_6	50:25:25	0.89	0.88	0.91	0.89
L_7	0: 0: 0	0.98	0.97	0.93	0.96
	Mean	0.90	0.85	0.89	

SE for fertilizer levels - 0.055
CD for time of nitrogen - 0.037
CD for L x T - 2.135

The data showed that there was significant difference in the protein content of grain with different levels of nutrients giving the highest value of 8.41 per cent for the highest level of NPK (L_1). The absolute control gave the lowest percentage of protein in the grain.

The time of application of nitrogen did not show any significant influence in this attribute. However, the highest value (7.54) was noticed in treatment T_3.

The interaction effect was also not significant. But the treatment combination L_1T_3 gave the highest value (8.97).

D. Plant nutrient status.

1. Nitrogen content of plant

The data pertaining to the nitrogen content of plant are presented in Tables 17(i) and 17(ii) and the respective analyses of variance in Appendix VIII.

It is evident that nitrogen content of plant was significantly influenced by the nutrients levels. The highest level of NPK (L_1) gave the highest value for percentage of nitrogen content in grain and straw. The nitrogen content of control plots were significantly inferor to all other levels of NPK in both cases.

Table 16- Protein content (%) in grain

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	7.95	8.31	8.97	8.41
L_2	70 :35 :35	8.15	6.85	8.66	7.95
L_3	60 :35 :35	7.80	7.95	7.15	7.63
L_4	60 :25 :25	7.88	7.88	7.15	7.63
L_5	50 :35 :35	7.00	7.51	7.88	7.46
L_6	50 :25 :25	7.07	7.51	6.49	7.02
L_7	0 : 0 : 0	5.61	6.27	6.27	6.05
	Mean	7.35	7.47	7.54	

CD for fertilizer levels - 1.1134

SE for time of nitrogen - 0.3157

SE for L x T - 0.8523

Table 17(i)- Nitrogen content (%) in straw

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	0.77	0.76	0.75	0.76
L_2	70:35:35	0.74	0.74	0.74	0.74
L_3	60:35:35	0.64	0.65	0.70	0.67
L_4	60:25:25	0.61	0.71	0.63	0.65
L_5	50:35:35	0.69	0.64	0.69	0.67
L_6	50:25:25	0.62	0.62	0.61	0.62
L_7	0: 0: 0	0.46	0.51	0.56	0.51
	Mean	0.65	0.66	0.67	

CD for fertilizer levels - 0.0832
SE for time of nitrogen - 0.0264
SE for L x T - 0.0686

Table 17(ii)- Nitrogen content (%) in grain

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	1.4	1.33	1.44	1.35
L_2	70:35:35	1.3	1.1	1.42	1.27
L_3	60:35:35	1.25	1.27	1.14	1.22
L_4	60:25:25	1.26	1.26	1.13	1.22
L_5	50:35:35	1.12	1.20	1.26	1.20
L_6	50:25:25	1.13	1.20	1.04	1.12
L_7	0: 0: 0	0.90	1.00	1.00	0.97
	Mean	1.18	1.20	1.21	

CD for fertilizer levels - 0.178
SE for time of nitrogen - 0.0505
SE for L x T - 0.1262

The nitrogen content of plant was not influenced significantly by the time of nitrogen application. But split application of nitrogen, 25 per cent as basal + 25 per cent 20 days after transplanting + 50 per cent 40 days after transplanting produced highest value.

The interaction effect was also found not significant.

2. Phosphorus content of plant

Data on mean values of phosphorus content of plant are furnished in Tables 18(i) and 18(ii). The corresponding analyses of variance is given in Appendix VIII.

The data showed that the various levels of nutrients had no significant effect in the phosphorus content of plant, though highest values were obtained with highest levels of NPK (L_1). The control plots (L_7) recorded minimum value for the phosphorus content of plant.

As regard the time of nitrogen application no significant difference was noticed.

The interaction effect was also not significant.

3. Potassium content of plant

The data on the potassium content of plants are furnished in Tables 19(i) and 19(ii) and their analyses of variance in Appendix VIII.

Table 18(i) - Phosphorus content (%) in straw

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	0.28	0.34	0.27	0.30
L_2	70:35:35	0.26	0.26	0.22	0.25
L_3	60:35:35	0.26	0.27	0.26	0.26
L_4	60:25:25	0.28	0.22	0.26	0.25
L_5	50:35:35	0.27	0.22	0.28	0.26
L_6	50:25:25	0.24	0.21	0.22	0.22
L_7	0: 0: 0	0.23	0.21	0.21	0.22
	Mean	0.26	0.25	0.25	

CD for fertilizer levels - 0.0284
SE for time of nitrogen - 0.0261
SE for L x T - 0.0631

Table 18(ii) - Phosphorus content (%) in grain

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	0.59	0.54	0.56	0.56
L_2	70:35:35	0.42	0.51	0.54	0.49
L_3	60:35:35	0.42	0.53	0.50	0.48
L_4	60:25:25	0.47	0.50	0.51	0.49
L_5	50:35:35	0.47	0.46	0.48	0.47
L_6	50:25:25	0.47	0.44	0.44	0.45
L_7	0: 0: 0	0.43	0.44	0.40	0.42
	Mean	0.467	0.49	0.49	

SE for fertilizer levels - 0.0616
SE for time of nitrogen - 0.0351
SE for L x T - 0.0977

Table 19(i)- Potash content (%) in straw

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	1.45	1.51	1.60	1.52
L_2	70:35:35	1.35	1.21	1.43	1.33
L_3	60:35:35	1.32	1.39	1.38	1.36
L_4	60:25:25	1.34	1.33	1.32	1.33
L_5	50:35:35	1.33	1.34	1.35	1.34
L_6	50:25:25	1.33	1.27	1.21	1.27
L_7	0: 0: 0	1.37	1.29	1.15	1.27
	Mean	1.36	1.33	1.35	

SE for fertilizer levels - 0.1124
SE for time of nitrogen - 0.0915
SE for L x T - 0.2274

Table 19(ii)- Potash content (%) in grain

	Fertililizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	0.57	0.54	0.59	0.57
L_2	70:35:35	0.49	0.50	0.47	0.48
L_3	60:35:35	0.42	0.43	0.33	0.40
L_4	60:25:25	0.41	0.43	0.33	0.39
L_5	50:35:35	0.42	0.44	0.41	0.43
L_6	50:25:25	0.40	0.38	0.42	0.40
L_7	0: 0: 0	0.37	0.47	0.36	0.40
	Mean	0.44	0.46	0.42	

CD for fertilizer levels - 0.092
SE for time of nitrogen - 0.4895
SE for L x T - 0.1139

It is observed that there was significant difference in the potassium content of grain with levels of nutrients. The highest level of nutrients namely 70:45:45 kg NPK per hectare gave significantly higher value of 0.57 per cent which was on par with treatment L_2 and superior to other levels. The potassium content of straw was found notsignificant with levels of nutrients and highest value was found with highest level of NPK (L_1)

The potassium content of plant did not differ significantly with the various times of nitrogen application.

The interaction effect also did not show any significant difference in the potash content of the plant. The treatment combination of L_1T_3 gave the highest value.

E. <u>Uptake of nutrients</u>.

1. Uptake of nitrogen

The data on the uptake of nitrogen expressed in kg per hectare are presented in Table 20 and analysis of variance in Appendix IX.

The data revealed that there was significant increase in the nitrogen uptake with increased levels of nutrients. The highest value of 71.67 kg per hectare was obtained in treatment L_1 which was found superior to all other treatments except L_2. The zero level of NPK (L_7) was significantly inferior to all other treatments.

The subplot treatment of the time of application showed no significant difference between treatments. But the highest value of 53.88 kg per hectare was observed in treatment T_2.

The interaction effect was not significant.

2. Uptake of phosphorus

The data on the phosphorus uptake as influenced by levels of nutrients and time of nitrogen application are presented in Table 21 and their respective analysis of variance in Appendix IX.

A significant increasing trend in the uptake of phosphorus was noticed with increasing levels of NPK. It was observed that the highest level of NPK(L_1) gave the highest phosphorus uptake which was superior to all other lower levels of NPK but on par with treatment L_2. The treatment L_7 gave the lowest value of 16.75 kg per hectare which was on par with treatments L_3, L_4, L_5 and L_6.

As regards the time of application of nitrogen no significant difference in phosphorus uptake was noticed between treatments. However, treatment T_2 gave the highest uptake over other times of nitrogen application.

The combined effect of the levels of nutrients and the time of application of nitrogen was also found to be not significant.

Table 20- Uptake of Nitrogen (kg/ha) at harvest

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	69.773	69.870	75.380	71.670
L_2	70 :35 :35	63.650	65.560	63.270	64.160
L_3	60 :35 :35	54.650	54.270	50.010	52.970
L_4	60 :25 :25	48.110	53.380	49.400	50.290
L_5	50 :35 :35	46.720	52.980	46.750	48.810
L_6	50 :25 :25	46.290	43.040	51.070	46.800
L_7	0: 0: 0	31.460	38.030	33.510	34.330
	Mean	43.710	53.380	52.770	

CD for fertilizer levels - 12.088094

SE for time of nitrogen - 2.657595

SE for L x T - 7.9834

Table 21- Uptake of phosphorus (Kg/ha) at harvest

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	30.44	30.10	28.76	29.77
L_2	70 :35 :35	19.44	24.16	24.88	22.83
L_3	60 :35 :35	20.04	21.33	21.16	20.84
L_4	60 :25 :25	19.02	19.77	19.99	19.59
L_5	50 :35 :35	19.90	19.38	19.70	19.66
L_6	50 :25 :25	17.76	16.46	16.76	16.99
L_7	0: 0: 0	18.91	17.56	13.77	16.75
	Mean	20.79	21.25	20.72	

CD for fertilizer levels - 7.481628

SE for time of nitrogen - 1.3534435

SE for L x T - 4.5097

3. Uptake of potassium

The analysis of variance table for the uptake of potassium are presented in Appendix IX and the results in Table 22.

Although the result did not show any significant difference in the uptake of potassium due to different levels of NPK, treatment L_1 gave the highest value of 107.31 and L_7 the minimum value of 64.73 kg per hectare.

Similarly the time of application of nitrogen also did not show any significant influence on potassium uptake. The treatment T_2 gave the highest value (87.32 kg/ha). The interaction effect was also not significant. But the combination L_1T_3 registered the highest potassium uptake.

F. Soil Analysis.

1. Total nitrogen content of the soil after the experiment

Table 23 furnishes the total nitrogen content of soil after the experiment and the analysis of variance in Appendix IX.

The data revealed that there was no significant difference in the total nitrogen content of the soil after the experiment. But the highest value of 0.117 per cent was obtained with treatment L_1 which received the highest level of nutrients and lowest value of 0.093 per cent with treatment L_7 which received no nutrients.

Table 22 - Uptake of potassium (kg/ha) at the harvest

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	102.825	102.897	116.208	107.310
L_2	70 :35 :35	114.588	83.154	80.586	92.770
L_3	60 :35 :35	56.279	108.420	82.950	82.550
L_4	60 :25 :25	85.120	85.340	71.590	80.680
L_5	50 :35 :35	76.950	80.680	79.350	78.990
L_6	50 :25 :25	81.850	78.750	78.490	79.698
L_7	0 : 0 : 0	65.280	71.970	56.940	64.730
	Mean	83.41	87.32	80.87	

SE for fertilizer levels - 12.4295
SE for time of nitrogen - 8.249
SE for LxT - 21.7269

Table 23- Total nitrogen content of soil (%) after the experiment

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70 :45 :45	0.121	0.100	0.130	0.117
L_2	70 :35 :35	0.112	0.114	0.114	0.113
L_3	60 :35 :35	0.112	0.114	0.107	0.111
L_4	60 :25 :25	0.110	0.106	0.120	0.112
L_5	50 :35 :35	0.108	0.109	0.106	0.108
L_6	50 :25 :25	0.110	0.103	0.110	0.108
L_7	0 : 0 : 0	0.098	0.104	0.095	0.093
	Mean	0.11	0.107	0.112	

SE for fertilizer levels - 0.0100166
SE for time of nitrogen - 0.00931
SE for L x T - 0.0225

The nitrogen content of soil also did not differ significantly with times of nitrogen application after the experiment.

2. Available phosphorus content of the soil after the experiment

The data on the available phosphorus content of soil after the experiment are furnished in Table 24 and the analysis of variance in Appendix IX.

It was observed from Table 24 on the available phosphorus content of the soil after the experiment that there was no significant difference with levels of nutrients. But the highest value of 39.31 kg phosphorus per hectare was observed with the highest level of NPK(L_1) and the lowest value of 32.52 kg phosphorus per hectare with control plot.

The phosphorus content of soil after the experiment was found unaffected with times of nitrogen application.

3. Available potassium content of the soil after the experiment.

Data on the available potassium content of the soil after the experiment are furnished in Table 25 and the corresponding analysis of variance in Appendix IX.

Table 24- Available phosphorus content of the soil (kg/ha) after the experiment.

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	42.14	40.81	34.97	39.31
L_2	70:35:35	35.23	38.15	33.35	35.58
L_3	60:35:35	38.69	31.25	32.96	34.30
L_4	60:25:25	41.07	31.45	32.58	35.03
L_5	50:35:35	34.97	34.97	29.40	33.11
L_6	50:25:25	30.72	29.92	37.89	32.84
L_7	0: 0: 0	36.03	27.79	33.73	32.52
	Mean	36.98	33.48	33.56	

SE for fertilizer levels - 5.03
SE for time of nitrogen - 2.26
SE for L x T - 7.0109

Table 25 - Available potassium content of the soil (kg/ha) after the experiment.

	Fertilizer levels (NPK kg/ha)	Time of nitrogen application			Mean
		T_1	T_2	T_3	
L_1	70:45:45	137.20	134.40	132.72	134.77
L_2	70:35:35	142.60	136.60	138.78	139.33
L_3	60:35:35	128.80	133.00	126.00	129.27
L_4	60:25:25	123.26	126.06	122.06	123.79
L_5	50:35:35	117.60	103.60	118.72	113.31
L_6	50:25:25	114.74	118.16	114.80	115.90
L_7	0: 0: 0	107.23	105.28	107.52	106.68
	Mean	124.49	122.44	122.94	

SE for fertilizer levels - 14.385
SE for time of nitrogen - 4.089
SE for L x T - 18.881

The data revealed that the available potassium content of the soil after the experiment was not significantly affected with levels of NPK. The lowest value was obtained with control plot and an increasing trend with increasing NPK level was noticed in the potassium content of soil after the experiment.

The potassium content of soil after the experiment did not differ significantly with difference times of nitrogen application.

DISCUSSION

DISCUSSION

An experiment was carried out during the second crop season of 1982-83 to study the effect of different levels of nutrients along with time of application of nitrogen on the performance of a rice cultivar Mashuri at the Regional Agricultural Research Station, Pattambi. The results obtained from the study are discussed hereunder.

A. Growth characters.

1. Height of plants

The results presented in Tables 2(i) to 2(v) revealed that there was significant increase in the height of plants at various growth stages due to different levels of nutrients. The highest level of NPK application produced significantly taller plants during the different growth stages. The significant influence of nutrients especially nitrogen in enhancing vegetative growth of plants is a well known phenomenon. Nitrogen with its role in cell multiplication (Tisdale and Nelson, 1975) would naturally increase the height of plants. Supply of larger quantities of nitrogen in the treatment has led to an enhanced rate of vegetative growth which is reflected in plant height. Many other workers have reported similar results in rice (Lenka and Behera, 1967 ; Ramanujam and Rao, 1971 ; Raju, 1979).

As regards time of nitrogen application it was revealed that the different treatments did not exert much influence on this growth attribute. The tallest plants were observed in treatment T_1 during the active tillering stage, though the effect was not significant. In treatment T_1 50 per cent of nitrogen was applied basally which might have led to an enhanced growth of plant in this treatment which was expressed in increased plant heights. In the subsequent growth stages, treatment T_2 produced taller plants though the effect was significant only at the maximum tillering stage. Better absorption of the nitrogen by the plants in treatment T_2 might be the reason for producing taller plants in this treatment.

The fact that the no manure control recorded the least plant height during all growth stages clearly points out the necessity of fertilizer application for the satisfactory growth of rice plants.

2. <u>Number of leaves per hill</u>

Results presented in Tables 3(i) to 3(iv) showed that the significant effect of treatments on this growth attribute was revealed only in two growth stages observed. At both these stages, the treatment having higher level of NPK application produced more number of leaves. In other stages also the leaf number was more in the highest NPK level, though not significant. This clearly brings out the fact that a higher level of NPK application is necessary for the better growth of plants as is seen by a higher number of leaves. Similar results on the increase in leaf number by NPK application was reported by Sumbali and Gupta (1972). Moreover, the trend noticed in this trial confirms to the accepted behaviour of nitrogen in enhancing vegetative growth (Tisdale and Nelson, 1975).

As far as time of nitrogen application is concerned, treatment T_2 gave higher number of leaves at later stages of crop growth, though not significant. This may be due to the fact that the vegetative growth was enhanced by a higher amount of nitrogen availability in this treatment by the late application of nitrogen in larger amounts.

3. Tiller number

The results presented in Tables 4(i) to 4(v) revealed that there was significant difference between NPK levels in tiller production. Higher number of tillers were observed with higher levels of NPK and the largest number at flowering and harvest stages was observed with the highest level of NPK namely, 70:45:45 kg per hectare.

The influence of NPK nutrition on tiller production had already been highlighted by many workers, the most pronounced being that of nitrogen. Lenka *et al.* (1976)

and Murty and Murty (1978) reported that nitrogen had significant role in enhancing tillering. Research findings of Nair et al. (1972), Fageria (1982) support the results obtained in the present study that increased rate of phosphorus application has led to an increased tiller number. For potassium also, the results obtained by Kulkarni et al. (1975), Singh and Singh (1979) are in conformity with the findings of the present study. The result revealed the lowest value for the treatment receiving no NPK at all stages of growth, thereby indicating the favourable influence of nitrogen, phosphorus and potassium on the growth and tiller production.

It would be seen from the result that at active tillering stage the treatment T_1 (50 per cent nitrogen as basal + 25 per cent nitrogen at 20 DAT + 25 per cent nitrogen at 40 DAT) gave significantly superior number of tillers. This may be due to the fact that a higher proportion of nitrogen made available at the early stage of crop growth in this treatment might have produced higher number of tillers at this stage. The influence of time of application of nitrogen in enhancing tillering has been reported by many workers like Patnaik (1969), Takur and Saxena (1970). Further, it could be seen from the result that treatment T_2 (25 per cent nitrogen as basal + 50 per cent nitrogen at 20 DAT + 25 per cent nitrogen at 40 DAT) produced significantly higher number of tillers at maximum tillering and panicle initiation stages. This is consequent to greater availability of nitrogen due to the application of nitrogen in larger proportion during later growth stages in this treatment. The effect of nitrogen in enhancing tiller production of rice plant is an established fact. Rao and Murty (1975b) concluded from their experiments that application of nitrogen in split doses increased the tiller survival. All these might have contributed for the higher tiller number observed in the treatment.

The results made it obvious that the treatment combination L_1T_2 produced the highest number of tillers. The cumulative effect of both increased level of fertilizers 70:45:45 kg NPK per hectare supplied with the proper timing of nitrogen application, namely, 25 per cent nitrogen as basal + 50 per cent nitrogen at 20 DAT + 25 per cent nitrogen at 40 DAT might have resulted in this increase.

4. Dry matter production

Results showed that (Table 5) there was an increase in the dry matter production in accordance with the increase in levels of nutrition. The influence of nitrogen in increasing the plant weight has been reported by Black (1973). An enhanced rate of nitrogen application leads to an

increase in vegetative (taller
plants with more number h more
tillers. The supply of might
have influenced dry matt producing
a well developed root sy general
plant growth which in tu uptake
of all nutrients. This e result
of Terman et al. (1970) in dry
matter production with i ed phos-
phorus. The increase in as
observed (Table 20,21 an dy also
might have contributed t matter
production. This result he findings
of Ramanujam and Rao (19 78).

It was seen from th of
application had no signi matter
production. However, hig n was
obtained with treatment ed to the
increased number of leav vegetative
growth of the plant with the split application of nitrogen in this treatment. It is further observed that the content and uptake of nutrients were also high with split application of nitrogen (Table 17(ii), 19(ii), 20, 21 and 22) which may also have contributed to the high rate of dry

matter production. The results further indicated that the treatment combination L_1T_1 gave the highest dry weight.

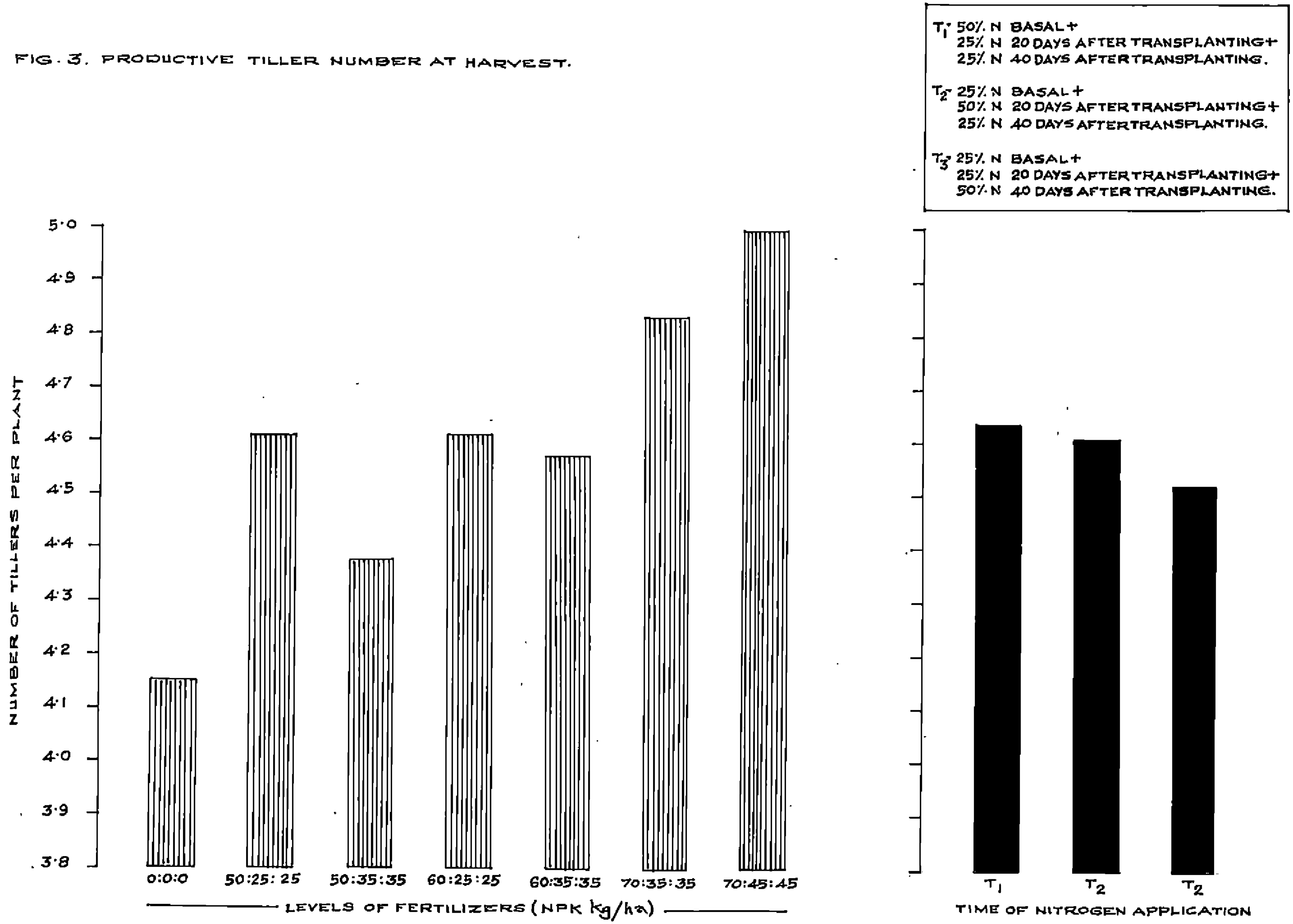
B. Yield components and yield.

1. Productive tiller count

The results presented in Table 6(i) and 6(ii) and Fig.3 showed that the number of productive tillers was influenced by the NPK level. The treatment 70:45:45 (L_1) produced the highest productive tiller number which was significantly superior to treatments L_5 and L_7. The results obtained pointed out the significant effect of nitrogen on the increased number of productive tillers. Findings of Subbiah and Morachan (1974), Gowda and Panikar (1977) Dixit and Singh (1979) on rice are in conformity with the results obtained in this investigation. The beneficial effect of phosphorus on productive tiller number has been established by Nair et al. (1972) and Bhattacharya and Chatterjee (1978). The observation in the present investigation is also in line with the earlier findings. The favourable influence of higher levels of potassium on this attribute was observed in the present study. The role of potassium in increasing the number of productive tillers had been reported by Kulkarni et al. (1975) and Padmaja (1976) in rice.

The data showed that the treatment T_1 produced higher number of productive tillers, though not significantly

FIG. 3. PRODUCTIVE TILLER NUMBER AT HARVEST.



superior to other treatments. Muraleedharan _et al_. (1972) reported that there was no significant effect on number of panicles per square metre with the time of nitrogen application. But the higher number of productive tillers observed with time of nitrogen application as 50 per cent basal + 25 per cent 20 DAT + 25 per cent 40 DAT may be due to the proper utilisation of nitrogen in the initial stages of crop growth. Similar results were also obtained by Verma and Srivastava (1972) Rao and Murty (1975b) and Nair _et al_. (1972).

2. Length of panicle

The Table 7 on the length of panicle showed that there was no significant difference in the length with levels of nutrients. This is in accordance with the findings of Sadayappan _et al_. (1974). Alexander _et al_. (1974a) could not observe any difference in panicle length by phosphorus application and Rao _et al_. (1974) reported that potassium levels had no influence on the length of panicle.

The table 7 also indicated that the length of panicle was not influenced by the time of nitrogen application. The result is in conformity with the findings of Muraleedharan _et al_. (1972) who observed that the length of panicle was not significantly influenced by the timing of nitrogen application.

The result of this experiment and the findings referred in literature cited above show that the length of panicle is mostly a genetically controlled character which is little influenced by fertilizer management practices. The length of panicle is a varietal character which is not influenced by variation in time and level of nitrogen application as reported by Kumar (1969) and Mathew (1971).

3. Weight of panicle

The result presented in Table 8 showed that the weight of panicle was not significantly influenced by the levels of NPK. The highest panicle weight was obtained with 70:35:35 kg NPK per hectare (L_2). Chang and Su (1977) and Subbiah *et al.* (1975) reported that the weight of panicle increased with increasing rates of nitrogen. Bhattacharya and Chatterjee (1978) revealed that phosphorus manuring would produce more grains of heavier weights. The beneficial role of phosphorus and potassium in increasing panicle weight also had been reported by Place *et al.* (1970).

As regards time of nitrogen application, the result showed that treatment T_3 (25 per cent basal + 25 per cent 20 DAT + 50 per cent 40 DAT) produced heavier panicles, though they were not significantly different. This may be due to the application of nitrogen at a later stage in larger proportion and consequent higher utilization of nitrogen at the later stages of the crop. Nair *et al.* (1979) and Wang (1981) also reported that nitrogen application at the later stages of the crop increased the panicle weight.

4. Number of grains per panicle

It is revealed from the results furnished in Table 9 that there was no significant different between treatments in this respect. Similar result was reported by Natarajan *et al.* (1974) who observed no significant increase in number of grains per panicle with incremental doses of nitrogen application. Alexander *et al.* (1974b), Sadanandan and Sasidhar (1976) could not find any effect of phosphorus on number of grains. Kalyanikutty and Morachan (1974) reported that the number of grains per panicle was not affected by the rates of application of potassium.

It could be seen from the Tables 10 and 11 that the half filled grains and unfilled grains were increased with decreased NPK levels. This indicated that the development of half filled and unfilled grains were more when the soil nutrient status was not adequate. The full development of grain could not take place due to lack of optimum nutrient contents in the soil. In this context it is interesting to note that the highest number of unfilled grains was obtained in control plots. This implies the need of adequate level of nutrition for the production of normal grains in panicles. According to Gupta *et al.* (1970) and Panda and Leeuwrik (1972), nitrogen increased fertile spikelets per panicle. Battacharya and Chatterjee (1978) opined that phosphorus application produced more number of filled spikelets per panicle.

As regards the time of nitrogen application, the results showed that the treatment differences were not significant in the number of grains per panicle. The effect was not significant with respect to unfilled grains also.

5. Thousand grain weight.

The result presented in Table 12 showed that the thousand grain weight was not influenced by the levels of NPK. Several rice workers have reported that thousand grain weight was unaffected by nitrogen application (Muthuswamy *et al.*, 1972; Natarajan *et al.*, 1974; Lenka *et al.*, 1976). Similarly, Alexander *et al.* (1974a) reported that phosphorus application did not affect thousand grain weight. According to Kalyanikutty and

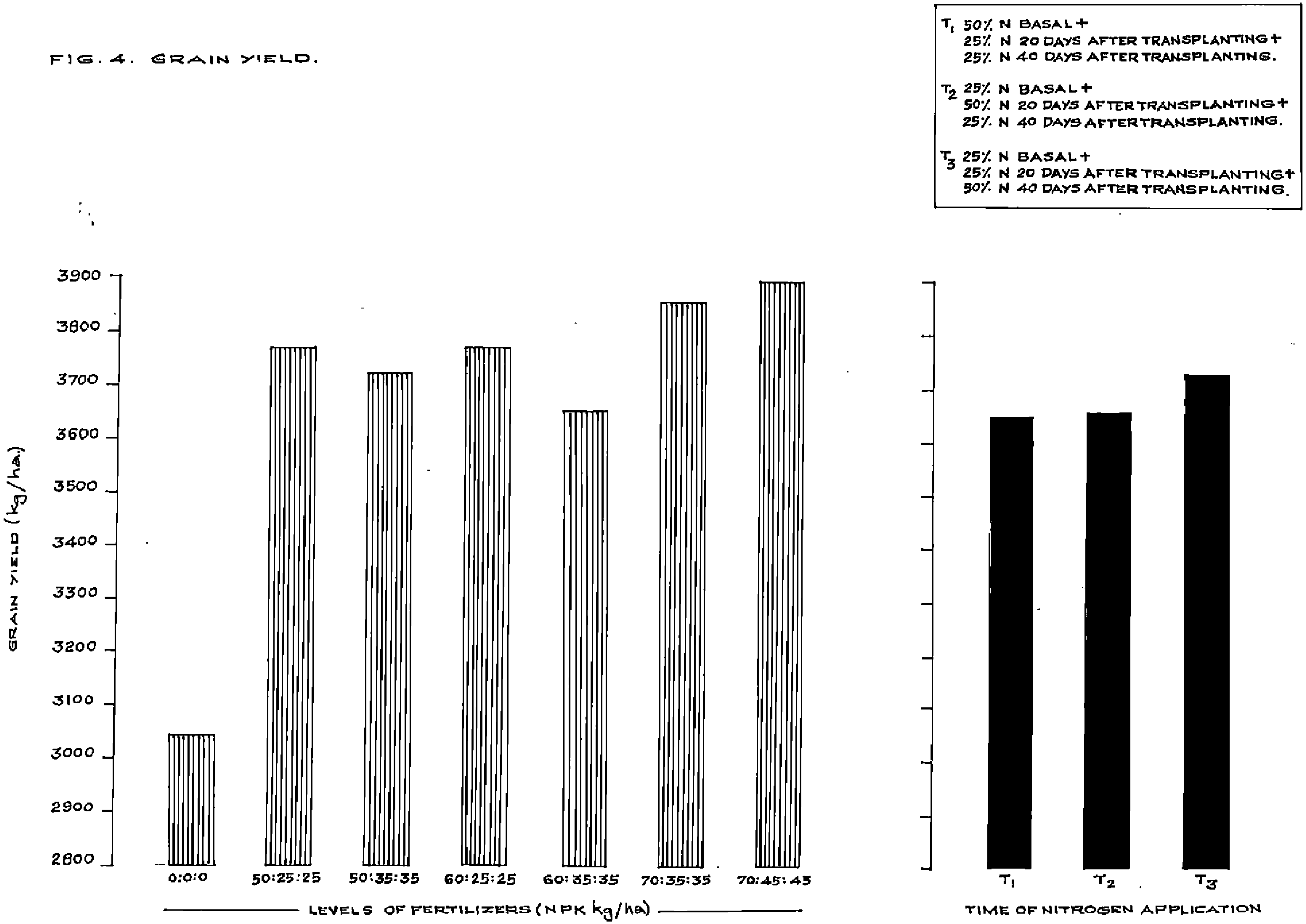
Morachan (1974) thousand grain weight was not influenced by potassium application also.

The time of nitrogen application did not give significant difference in this respect. But the highest weight was obtained with 50 per cent nitrogen applied at 40 days after transplanting than either basal application or nitrogen applied 20 days after transplanting. This resulted in better availability of nitrogen at this stage of grain development along with other nutrients. According to Nair et al. (1979) nitrogen application half at panicle initiation has resulted in maximum panicle weight. Similar results were reported by Kumar (1969) also.

6. Grain yield

The data presented in Table 13 and Fig.4 showed that the highest level of nutrients application produced the highest grain yield. The treatment with 70:45:45 kg NPK per hectare (L_1) resulted in the highest grain yield which was significantly superior to the absolute control and was on par with other treatments. A reference to the data on growth characters such as plant height, leaf number, tiller number and yield attributes such as productive tiller number, length of panicle, weight of panicle and thousand grain weight indicated that all these attributes showed remarkable improvement with higher levels of

FIG. 4. GRAIN YIELD.



nutrition. The combined effect of all these might have resulted in the production of the highest grain yield in this treatment. The data on nutrient uptake (Table 20, 21 and 22) also showed that the uptake was more in treatment L_1 which also might have led to a better development of growth and consequent higher yield. The beneficial effect of NPK fertilization in increasing the grain yield of rice has been proved by many workers. (Reddy et al., 1978; Panda and Das, 1979; Agarwal, 1980). Nitrogen has got a very important role to play in photosynthesis which is directly related to carbohydrate manufacture and grain yield. This influence of nitrogen on the grain yield of rice is stressed by several workers like Rethinam et al. (1975), Sahu and Moorthy (1975) and Pillai et al. (1975). Similarly the role of phosphorus in increasing the grain yield of rice has been stressed in the works of Padmakumari et al. (1969), Dev et al. (1970) Khatua and Sahu (1970). The beneficial influence of potassium in increasing the grain yield may probably be through its role in the manufacture and translocation of starch (Russel, 1973).

As regards the time of application of nitrogen, the results indicated that the highest grain yield was obtained with treatment T_3 (25 per cent nitrogen basal + 25 per cent

nitrogen 20 days after transplanting + 50 per cent nitrogen 40 days after transplanting), though not significant. For treatment T_3, 50 per cent of the dose of the nitrogen is applied at 40 days after transplanting whereas in other treatments only 25 per cent of the dose of nitrogen was applied during this stage. The continued availability of nitrogen during the later growth stages of the plant might have resulted in a better absorption and consequent higher yield in this treatment. The better availability of nitrogen might also have helped in the proper uptake of other nutrients which in turn helped in better growth and yield of plants in this treatment.
The favourable influence of split application of nitrogen in increasing the grain yield was reported by several earlier workers like Rao and Murthy (1975a) , Sarkar and Sinha (1976), Bhatti and Khan (1977), Mishra and Singh (1980).

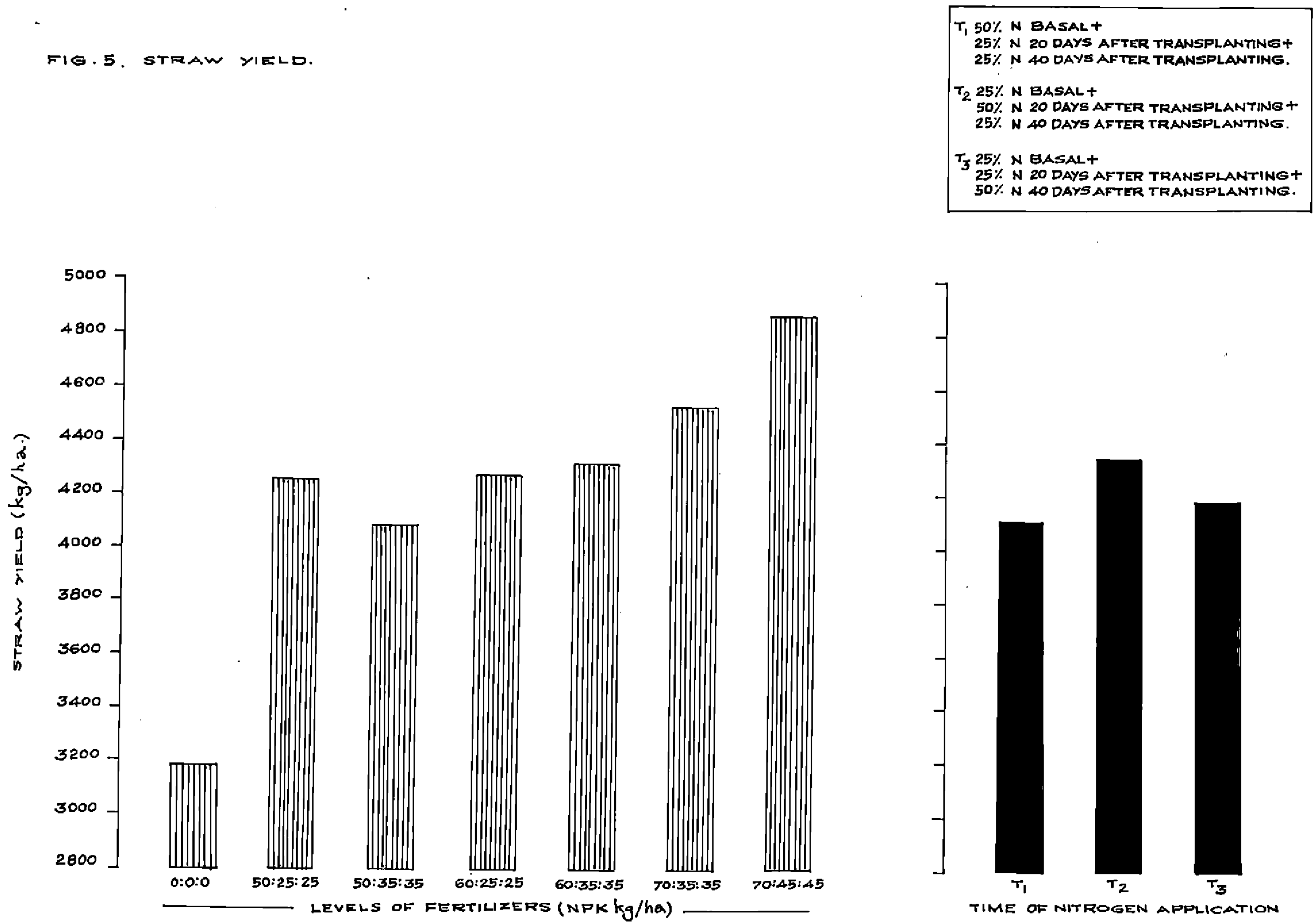
7. <u>Straw yield</u>

The result presented in Table 14 and Fig.5 showed that the highest value was observed in the treatment L_1 (70 : 45 : 45 kg NPK/ha). It was also observed that there was a progressive increase in straw from zero to the highest level of NPK. The straw yield in the highest level of NPK (L_1) was significantly superior to other treatments, except L.

Nitrogen may be the main nutrient influencing the straw yield to a great extent. A perusal of the data on plant height, number of leaves, number of tillers and number of productive tillers showed that the highest values were noticed in the treatment which received the largest amount of nitrogen. Role of nitrogen in enhancing the vegetative growth of rice has already been discussed. 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 and straw yields as in dwarf indicas (Tanaka et al. 1958). The beneficial effect of nitrogen in increasing straw yield of rice has been revealed by several research workers like Rathinam et al. (1975), Venkateswarlu (1978), Bhatti et al. (1982).

The time of nitrogen application did not give any significant difference in the straw yield. But the treatment which received 50 per cent nitrogen 20 days after transplanting was superior to treatments with 50 per cent nitrogen as basal or 50 per cent nitrogen at 40 days after transplanting. The data on the plant height, number of leaves and the number of unproductive tillers, revealed that the application of nitrogen 50 per cent at 20 days after transplanting produced the highest values in these

FIG. 5. STRAW YIELD.



growth attributes than other times of nitrogen application. The application of nitrogen 50 per cent at 20 days after transplanting has produced better vegetative growth of the plant than other times of nitrogen application. This might have contributed to the higher straw yield obtained in this treatment. Hoque et al.(1977), Gaffer and Chand (1978) also reported similar results.

8. Grain:straw ratio

The grain:straw ratio provided in Table 15 revealed that there was no significant influence for the levels of NPK. The Table 15 showed that there was a reduction in grain:straw ratio when the nutrient levels were increased. Minimum grain:straw ratio was observed by the treatment receiving 70:45:45 kg NPK per hectare and the highest by control plot. Being a tall indica variety, the application of fertilizer especially nitrogen in higher doses resulted in considerable increase in straw production, thereby recording a lesser grain:straw ratio. With the highest level of nutrients (L_1) 70:45:45 kg NPK per hectare which has produced the highest grain yield the straw production has also increased considerably. The treatments receiving lesser quantities of nutrients, especially nitrogen, recorded higher grain:straw ratio thereby indicating that the stra production was comparatively lesser in these treatments.

Similar results had been reported by Tanaka et al. (1958) and Have (1971).

There was significant difference in the grain:straw ratio between the various times of nitrogen application. The treatment which received 50 per cent nitrogen 20 days after transplanting gave significantly lower grain:straw ratio. This is due to the fact that the grain yield was not increased to the same extent as the increase in straw yield owing to nitrogen availability. The highest value was obtained with treatment T_1 which received 50 per cent nitrogen as basal + 25 per cent nitrogen 20 days after transplanting and 25 per cent nitrogen 40 days after transplanting. Thus greater availability of nitrogen in the early growth stages promoted rapid vegetative growth. Reference to the data on plant height, number of leaves and tiller number showed higher values with treatment T_2. This enhanced vegetative growth in this treatment led to higher straw yields.

The treatment combinations L_1T_2 produced the lowest grain:straw ratio. This may be due to the individual and cumulative effects of the treatments L_1 and T_2 on this aspect.

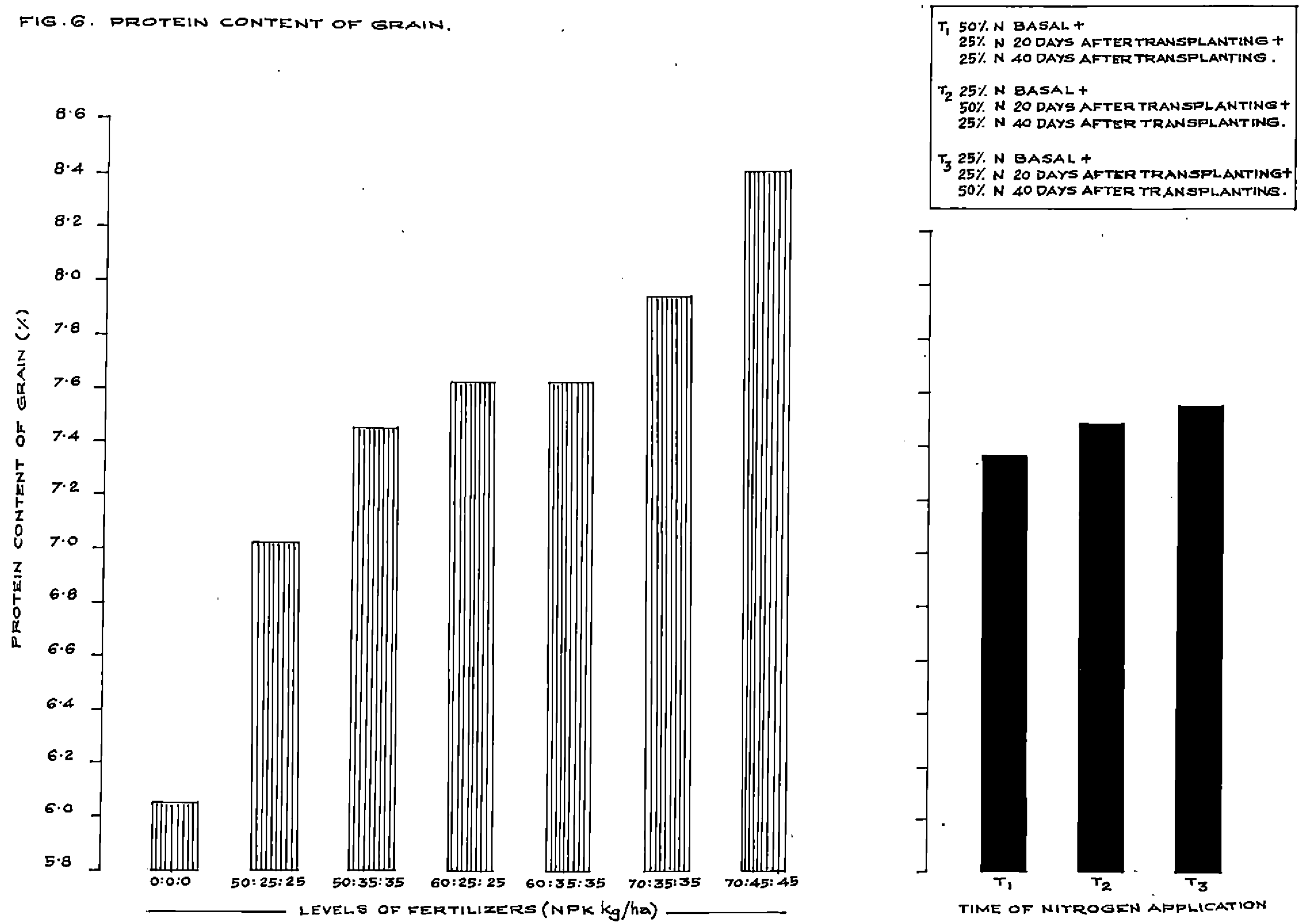
C. Quality character

1. Protein content of grain

The protein content of grain provided in Table 16 and graphically illustrated in Fig.6 showed that there was significant difference in the protein content of grain with different levels of NPK giving the highest value for the highest level of NPK(L_1) and lowest value for control treatment. It is known that the major factor controlling the protein content of grain is nitrogen supply. Tisdale and Nelson (1975) pointed out that eventhough the kind of protein formed is largely influenced by genetic factors, the amount of protein is governed by environmental factors, especially supply of nitrogen. Since nitrogen is the major constituent of protein, high rates of nitrogen application led to higher protein content of grain in rice. Similar results were reported by Abraham *et al.* (1974) and Rabindra *et al.* (1977). According to Agarwal (1978) phosphorus and potassium also had favourable influence on protein content of grain.

The time of application of nitrogen did not show any significant influence in this attribute. However, the highest value was noticed in the treatment receiving 50 per cent of the nitrogen at 40 days after transplanting.

FIG. 6. PROTEIN CONTENT OF GRAIN.



Nitrogen being a major constituent of proteins, the application of 50 per cent of nitrogen at this stage just prior to panicle formation might have helped more protein formation in the grains as compared to other treatments. Several workers have shown that split application of nitrogen increased protein content of grain (Pisharady *et al.*, 1976; Thenababu, 1972; Taira, 1970).

The various treatment combinations failed to show any significant influence on grain protein content. But the treatment combination (L_1T_3) recorded the highest grain protein content which might be due to cumulative effects of the NPK level (L_1) and time of application (T_3).

D. Plant nutrient status.

1. Nitrogen content of plant

The Tables 17(i) and 17(ii) on nitrogen content of plants revealed that the highest level of NPK namely 70:45:45 kg per hectare gave highest amount of nitrogen in grain and straw. The nitrogen content of zero level was significantly inferior to all other levels of NPK in both cases. It is clear from the results that the increased supply of nutrients had increased the nitrogen content of grain and straw significantly. The effect of nitrogen nutrition in increasing the nitrogen content of rice plant has been reported by many workers (Ramanujam and Rao, 1971;

Koyama and Niamsrichand, 1973). The high content of nitrogen observed with higher levels of NPK may be due to the enhanced growth of vegetative and reproductive parts of plants which facilitated higher rate of absorption of this nutrient. The increase in nitrogen content with enhanced rates of phosphorus application noticed in the study is in line with the findings of many earlier workers (Varma, 1971; Loganathan and Raj, 1972). Thandapani and Rao (1974) observed that increase in rates of applied phosphorus from 0 to 75 kg per hectare was accompanied by linear increase in nitrogen content of roots and grain. The application of phosphorus might have produced more roots which in turn might have facilitated more absorption of nutrients. The supply of phosphorus and potassium might have led to the proper uptake of nitrogen.

The result also showed that the times of nitrogen application had no significant influence on the nitrogen content of grain and straw. But higher values were obtained with application of 50 per cent of nitrogen at 40 days after transplanting. The higher nitrogen content of grain and straw in this treatment may be due to the better availability of nitrogen by late application in large proportion. Singh and Bharadwaj (1973a) reported that split application of nitrogen at transplanting, tillering and panicle initiation stages increased the total nitrogen content of rice plant.

Singh and Modgal (1978a) reported that split application of nitrogen in two to four split dressings increased the plant content of total nitrogen than by application of nitrogen in a single dressing. Subramaniam and Morachan (1979) showed that grain nitrogen contents were the highest with nitrogen applied in three split dressing at transplanting, tillering and flower initiation stages.

2. Phosphorus content of plant

As regards the phosphorus content, the results presented in Table 18(i) and 18(ii) showed that various levels of NPK had no significant effect on the phosphorus content of grain and straw. But the highest values were obtained with higher levels of NPK. The higher levels of phosphorus uptake might probably be due to the favourable effect of balanced fertilization. The increase in plant phosphorus content with higher doses of nutrient supply noticed in this study is in line with the findings of Oommen *et al.* (1972) and Suseelan *et al.* (1978). Trials conducted by Sadayappan and Kolandaiswamy (1974) and Raju (1978) revealed that there was an increased phosphorus condent in straw with increased nitrogen application. Similar trend was noticed for grain also. Pathak *et al.* (1972), Agarwal (1978) also reported that grain phosphorus content was increased with higher rates of application of phosphorus.

The various times of application of nitrogen did not influence the phosphorus content of grain and straw. In the case of straw phosphorus increase was noticed with 50 per cent of nitrogen at transplanting. The availability of nitrogen at transplanting might have stimulated vegetative growth which in turn led to better absorption of phosphorus. Baizhigitov et al. (1980) reported that the application of nitrogen in splits increased the content of phosphorus in plants.

3. Potassium content of plant

The result presented in Table 19(i) and 19(ii) indicated that there was significant difference in the potassium content of grain with different levels of fertilizer. The highest level of NPK namely 70:45:45 kg per hectare gave significantly higher value for potassium content of grain, but failed to produce significant difference in potassium content of straw. Naturally the higher dose of NPK might have led to a better absorption of potassium by grain and hence registering higher potassium content in this treatment. Due to the better absorption of potassium by grain, the content of it in straw might have been decreased. Singh et al. (1976) observed that potassium content of the grain increased with increased application of the nutrient, owing to the greater absorption and translocation. Sadanandan et al. (1969) found that the percentage content of potassium significantly increased with higher doses of potassium. According to Sadayappan and Kolandaiswamy (1974) increased application of nitrogen is found to increase the plant potassium content. Agarwal (1978) reported that increase in the rate of applied phosphorus upto 60 kg per hectare increased the potassium content of the plant.

The times of nitrogen application did not have significant effect on the potassium content of grain and straw the treatment combination L_1T_3 produced the highest content of potassium in plants though not significant.

E. Uptake of nutrients.

1. Uptake of nitrogen

The Table 20 on the uptake of nitrogen showed that the highest uptake of nitrogen was obtained with treatment L_1 which was found superior to all other levels except L_2. A reference to the Tables 17(i) and 17(ii) on the nitrogen content of grain and straw showed that the highest values were obtained with treatment L_1. The Table 5 on the dry matter production also showed that the highest value was obtained with highest level of NPK (L_1). So the uptake of nitrogen which was computed from the values also showed the highest value in this treatment. The effect of nitrogen application on the uptake of nitrogen had been reported by many workers. Similar results were reported by Prasad and

Jha (1973), Ramaswamy and Raj (1974). Varma (1971) in a trial with high yielding rice reported that nitrogen uptake in grain and straw increased with rates of applied phosphorus. Reddy et al. (1978) also reported that nitrogen uptake increased with increase in rates of nitrogen + phosphorus + potassium from 100 + 50 + 50 to 200 + 100 + 100 kg per hectare. Muthuswamy et al. (1974) showed that increasing the rate of nitrogen, phosphorus and potassium increased nitrogen uptake. The absorption and uptake of nitrogen with the application of potassium had been reported by Esakkimuthu et al. (1975), Mengel et al. (1976), Singh et al. (1976).

Even though there was no significant difference in the uptake of nitrogen with different times of nitrogen application, the application of 50 per cent of nitrogen 20 days after transplanting gave higher values than the other times of nitrogen application. The Table 5 pertaining to the dry matter production at harvest showed that the treatment T_2 gave the highest value. However, the uptake of nitrogen was also the highest in this treatment. The influence of split application of nitrogen on the uptake of nitrogen had been reported by many workers like Chaudhry et al. (1966); Koyama et al. (1973); Singh and Bharadwaj (1973a); Rao and Murty (1975a).

2. Uptake of phosphorus

The result presented in Table 21 showed a significant increase in the uptake of phosphorus with increasing levels of NPK. A reference to the Table 18(i) and 18(ii) on the grain and straw content of phosphorus also showed that the highest level of phosphorus content was with higher level of NPK. Table on dry matter production (Table 5) also showed higher values with higher levels of NPK. So the highest uptake of phosphorus noticed in treatment L_1 was due to the cumulative and complimentary effects of these treatments. Trials conducted by Iruthayaraj and Morachan (1980) revealed that uptake of phosphorus was higher with higher levels of nitrogen. Higher levels of phosphorus is also found to increase its uptake (Gupta et al.1975). Potassium was found to have a pronounced influence on the uptake and translocation of phosphorus.

The data also showed that the time of application of nitrogen had no significant difference in phosphorus uptake. However, it could be observed that application of nitrogen 50 per cent at 20 days after transplanting (T_2) was found to give higher uptake. A reference to the data on dry matter production (Table 5) showed that the highest values were obtained with treatment T_2(50 per cent nitrogen 20 days after transplanting). Hence the high uptake of phosphorus may be due to the high dry matter production in this treatment. Similar results were obtained by Singh and Bharadwaj (1973b) who reported that phosphorus uptake was influenced by time of nitrogen application. Uptake was more when nitrogen was applied in three splits.

Loganathan and Raj (1972) noticed that the uptake of phosphorus in variety Co 32 was changed by the application of potassium at 40 and 80 kg per hectare. Mohanty and Patnaik (1974) observed that potassium application has increased phosphorus uptake.

3. Uptake of potassium

The Table 22 on the uptake of potassium showed no significant difference due to different levels of NPK. But the treatment with highest level of fertilizers produced highest uptake values. The Tables 5 and 19(i) and 19(ii) on the dry matter production and potassium content of grain and straw revealed that the highest values were obtained with the highest levels of NPK. Consequently the highest values of uptake of potassium in this treatment may be due to the additive effect of all these. Muthuswamy *et al.* (1974) reported that increasing the rate of nitrogen, phosphorus and potassium increased their uptake. Sadayappan and Kolandaiswamy (1974) noticed an increase in potassium content with increase in nitrogen level.

Ramaswami and Raj (1974) observed that phosphorus application increased potassium uptake. Singh *et al.* (1976); Agarwal (1978); Singh and Jaiprakash (1979) also reported that potassium application increased potassium uptake in rice.

Similarly, the time of application also did not show any significant influence on potassium uptake. But treatment T_2 gave the highest value. A reference to the Tables 5 and 19(ii) on dry matter production and potassium content of grain showed that the highest values were in the treatment T_2. So the highest uptake of potassium in this treatment may be due to the complementary effect of these two. Similar results were obtained by Singh and Modgal (1978b) who observed that the split application of nitrogen was found to be more conducive for potassium uptake.

F. Soil Analysis.

1. Nitrogen content of soil after the experiment

The Table 23 on the total nitrogen content of the soil after the experiment showed that there was no significant difference between the fertilizer levels and times of nitrogen application. But the data clearly showed a trend of depletion of total nitrogen with lower levels of NPK as compared to initial status of soil nitrogen. But for the highest levels of NPK there was no depletion of nutrient status of soil even after the experiment. This reveals the fact that the lower levels are not adequate to maintain soil fertility status after meeting the crop demands.

2. Available phosphorus content of soil after the experiment

It was seen from the result presented in Table 24 that there was no significant difference between the NPK levels and times of nitrogen application on the available phosphorus content of soil after the experiment. But the data, showed that there was depletion of available phosphorus content of the soil except for the highest level. This shows that there was depletion of phosphorus after plant uptake with the lower levels of NPK. The data clearly showed the need for application of high levels of NPK for the maintenance of nutrient status of soil.

3. Available potassium content of soil after the experiment

The data on the available potassium content of soil after the experiment provided in Table 25 showed that there was no significant difference in the potassium content with levels of NPK and times of nitrogen application after the experiment. This result showed that the potassium content increased in the soil after the experiment with higher rate of NPK application. The table on the uptake of potassium showed non-significant difference with levels of

NPK but higher uptake was noticed with higher rate of NPK application. It can be concluded that the highest level of potassium application tried in the experiment is sufficient to build up soil potassium status even after meeting plant demands.

SUMMARY

SUMMARY

An experiment was conducted at the Regional Agricultural Research Station, Pattambi during the second crop season of 1982-83 to study the effect of different levels of fertilizers and time of application of nitrogen on growth and yield of rice variety Mashuri. The experiment consists of seven nutrient combinations of nitrogen varying from zero to seventy, phosphorus and potassium varying from zero to forty five kg per hectare with three times of application of nitrogen(50 per cent as basal + 25 per cent 20 DAT + 25 per cent 40 DAT, 25 per cent as basal + 50 per cent 20 DAT + 25 per cent 40 DAT, 25 per cent as basal + 25 per cent 20 DAT + 50 per cent at 40 DAT)

The experiment was laid out in the split plot design with the levels of fertilizers in main plots and time of application of nitrogen in sub-plots. The results of the experiment are summarised below.

1. Plant height was increased at all stages of growth by increasing the nutrient levels. The time of application of nitrogenous fertilizer did not exert any influence on height of plant at any of the growth stages, except at maximum tillering stage. The interaction effect was also not significant in this respect.

2. The number of leaves increased with higher levels of nutrient application at all growth stages upto flowering. The control plot registered the minimum number of leaves at all growth stages. However, the difference between the sub plot treatments and the treatment combinations were not significant.

3. An increase in nutrient level exerted considerable influence on the number of tillers per plant at all stages of growth. The treatment L_1 (70:45:45 kg NPK per hectare) gave the highest tiller number at flowering and harvest stages. The tiller number observed in the control plots were much less than all other treatments. As regards time of nitrogen application, treatment T_1 gave significantly higher number of tillers at active tillering stage and T_2 produced significantly higher number of tillers at maximum tillering and panicle initiation stages. The interaction effects were not significant.

4. Dry matter production was the highest in treatment L_1 receiving the highest level nutrients and minimum with treatment L_7, receiving no nutrient. The dry matter production was not significantly influenced by time of nitrogen application and treatment combinations.

5. Nutrient level 70:45:45 kg NPK/ha (L_1) gave the highest productive tiller count. The time of application of nitrogen had no significant effect on number of productive tillers, but highest numbers were obtained in treatment T_1. The interaction also did not show any significant difference.

6. Length of panicle and weight of panicle were not significantly influenced by the level of nutrients. But the length of panicle was the highest in treatment L_5 and heaviest panicle in treatment L_2. The time of application of nitrogen did not show any significant influence on length and weight of panicle. The interaction also were not significant.

7. The different levels of nutrients, time of nitrogen application and their combination, failed to produce any significant influence on number of grains per panicle, half filled grains per panicle and unfilled grains per panicle.

8. There was no significant difference in the thousand grain weight with different levels of nutrients. The time of nitrogen application also failed to show any significant influence on the thousand grain weight. The interaction effect also was not significant.

9. The grain and straw yields were significantly influenced by the nutrient levels. Treatment L_1 gave the highest yield. The grain and straw yields were not significantly influenced by the time of nitrogen application. The interaction effect was also found not significant giving highest value with treatment combination L_1T_3.

10. The nutrient levels did not exert any significant influence on the grain:straw ratio. But it was significantly influenced by the time of application of nitrogen and treatment T_2 gave the lowest value. The interaction effect was also found significant and the lowest value was obtained with treatment combination L_1T_2.

11. The protein content of the grain was significantly influenced by the different nutrient levels giving the highest value for the highest level of NPK(L_1). The absolute control gave the lowest percentage of protein in the grain. The time of application of nitrogen and the interaction effects were not significant. in this quality attribute.

12. The nitrogen and potassium content of the plant was significantly influenced by the nutrient levels. The phosphorus content of the plant was not significantly influenced by the levels of NPK. The highest contents of nitrogen, phosphorus and potassium were obtained in the treatment L_1 (70:45:45 kg NPK per hectare). The NPK content of plant was not significantly influenced by the time of application of nitrogen. The interaction effects were also not significant.

13. Uptake of nitrogen and phosphorus increased significantly with increase in nutrient levels. Highest level of NPK (L_1) gave the highest nitrogen, phosphorus and potassium uptake values though there was no significant difference in the uptake of potassium. Similarly the time of application of nitrogen did not exert any significant influence on the uptake of NPK. The interaction effect was also not significant.

14. The various treatments did not show any significant influence on the total nitrogen, available phosphorus and available potassium content of the soil.

REFERENCES

REFERENCES

Aaron, D.S., Morachan, Y.B., and Murugesan, M. (1971). Response of IR-8 paddy strain to fertilizer in Coimbatore District. Madras Agric. J. 58(5):379-384.

*Abdullah, N., Sisworo, W.H., Hendratno, K. and Thajib, M.H. (1976). Nitrogen fertilizer utilisation by rice plant at various physiological stages of growth. Ruigkasan publikasi dan haporan penelitian pertaman, 6(1): 18-19.

Abraham, C., Sadanandan, N. and Sasidhar, V.K. (1974). A note on the protein content of grain as affected by the application of urea and neem-coated urea to rice variety- Triveni. Agric. Res. J. Kerala 12(2): 202-204.

Agarwal, M.M. (1978). Effect of nitrogen, phosphorus and potash on the yield, uptake and quality of rice. Indian J. Agric. Res. 12(1): 35-56.

Agarwal, M.M. (1980). Phosphorus and potassium requirement of rice in relation to time of application. Indian J. Agri. Res. 14(1): 53-56.

*Ageeb, O.A.A. and Yousif, Y.H. (1978). P and K nutrition of rice (Oryza sativa L.) in the Sudan Kenana. Exp. Agric. 14(1): 33-39.

*Ahmed, I.U. and Faiz, S.M.A. (1969). A study on the effect of different levels of nitrogen and water on the growth, yield and quality of IR-8- 288 rice. Pakist J. Soil Sci. 2: 1-15.

*Alenshin, E.P. and Tur, N.S. (1971). Effect of N on tillering intensity and yield of rice. Trudy vsesoyuqmgo Nauchno-Issledovtael S kogo Inatitula Risq. 1: 50-53.

Alexander, K.M., Sadanandan, N. and Sasidhar, V.K. (1974a) Effect of various levels of nitrogen and phosphorus on the yield and other agronomic characters of rice variety, Triveni. Agric. Res. J. Kerala 11(2): 109-113.

Alexander, K.M., Sadanandan, N. and Sasidhar, V.K. (1974b). Effect of different levels of nitrogen and phosphorus on the uptake of P by rice variety- Triveni. Agric. Res. J. Kerala 12(2):140-144.

Ali, A.M. and Morachan, Y.B. (1973). Uptake and quality studies in rice. Madras Agric. J. 60(8): 755-759.

Anonymous (1978). Constraints on rice yields. Annual report for 1977, IRRI, pp.345-346.

*Baizhigitov, K.B., Sutormina, N.V. and Moiseeva, I.G. (1980). Effect of dates of application of nitrogen fertilizers and nitrification inhibitor on kinetics and uptake of nutrients by rice plants. Agrokhimiya 3: 18-21.

Balasubramanion, A., Venketaraman, R. and Palaniappan, S.P. (1978). Time of N application for mid duration rice varieties. Madras Agric. J. 65(3): 196-197.

Bavappa, K.V.A., and Rao, K.H. (1956). The response of rice to lime and potash manuring in South Kanara. Madras Agric. J. 43(10): 505-507.

Bhapkar, D.G., Deove, B.P. and Waghmare, R.E. (1979). Effect of split application of N at different growth phases of paddy. J. Maharashtra Agric. Univ. 4(1): 64-68.

Bharadwaj, R.B.L., Rao, Y.V. and Gautam, R.C. (1974). Response of upland Rice to Rate and Time of Application of phosphorus. Indian J. Agron. 19(2): 113-118.

Bhattacharya, K.K. and Chatterjee, B.N. (1978). Growth of rice as influenced by phosphorus. Indian J. Agric. Sci. 48(10): 589-597.

*Bhatti, A. and Khan, A.W. (1977). Comparative study on the time of application of N fertilizer to paddy at various stages of growth. Agriculture Pakistan. 28(1): 47-53.

Bhatti, A., Rehman, H, and Gurmani, A.H. (1982). Efficiency of Urea applied by various methods to paddy. Int. Rice Comm. Newsl. 31(2): 39-43.

Bhaumik, D.K. and Ghosh, A. (1977). Effect of different levels of nitrogen on inter relationship among different characters of some short standard high yielding rice varieties. Indian Agriculturist. 21(4): 227-246.

Bhuiya, Z.H., Islam, S.M.N., Haque, M.S. and Mian, M.M.H. (1979). Effect of N, P and K fertilisers on the performance of Dharial rice. Yield and protein content. Bangladesh J. Scient. Ind. Res. 14(3/4): 311-315.

*Bhuiyan, N.I. (1981). A study of N in soil plant system in relation to growth and yield of wet land rice as influenced by nitrogen supply and crop management. Dissertation Abstracts International B.41(8): 2844-2845.

Black, C.A. (1973). Soil plant Relationships. John wiley and Sons., Inc. New York. 2nd Ed. p. 792.

Bora, P.K. and Goswami, N.N. (1980). Effect of phosphorus fertilization on priming of native P by rice in acid soils of Assam. IRRN, 5(5): 23.

Bora, P.K. and Goswami, N.N. (1983). Effect of phosphorus fertilization and soil moisture regimes on P content of rice crop. IRRN. 8(1): 19-20.

*Brandon, D.M., Wilson, F.E., Leonards, W.J. and White, L.M. (1980). Determination of N requirements of new rice varieties and use of plant analysis to predict mid season N fertilizer needs. Annual Progress Report, Louisiana State University, 36-750.

Bredero, T.J. (1965). The nitrogen response mechanism of the variety BG 79. Int. Rice Comm. Newsl. 14: 21-25.

*Cabello, R. (1979). Effect of population density with different nitrogen rates on the yield and its components in the rice cultivars IR-8 and IR-880. Cultivos Tropicales 1(3): 61-74.

*Castillo, Do, Hernandez, Ao., Rodriguez, E. and Duffay, I. (1981). Changes in protein and lipid composition of the endosperm of rice during maturation due to timing of nitrogen (Urea) application. Ciencia Y Tecnica enla Agricultura Arroz 4(1): 49-60.

*Chamura, S and Mizusawa, K. (1979). Studies on the relation between N, P and K uptake by rice roots and yield components in young seedling cultivations. Bull. Fac. Agric. Niigate Univ. 31: 1-9.

Chang, W.L. and Su, H.P. (1977). Nitrogen and spacing responses of semi-dwarf and tall indica rice cultivars at Al-Hassa Oasis. J. Taiwan Agric. Res. 13(1): 214-236.

Chaudhry, M.S., Pandey, R.G. and Nanda, B.B. (1966). Technical report for 1966. C.R.R.I, Cuttack. 7-24.

Chavan, A.R. and Magar, N.G. (1971). Effect of fertilizer on the protein content of rice. Curr. Sci. 40(23): 642.

Chhabra, R. and Abrol, I.P. (1981). Fertilizer phosphorus requirement of rice and wheat grown on sodic soils. IRRN 6(4): 22.

Chiu, S.M. (1968). Effect of split application of fertilizer on rice yield. J. Taiwan Agric. Res. 17(3): 1-6.

Chow, H.T. (1980). Comparative studies on the ecological characteristics of rice. Effect of nitrogen application on growth and yield of rice. J. Sci. Engng. 17: 191-201.

Daniel, K.V. (1970). Nitrogen requirements of semi dry rice in Trivandrum. Kerala. Indian J. Agric. Sci. 40(3): 288-290.

Dargan, K.S. and R.K.Chillar (1978). Studies on the effect of N and missing application of P and K. Agron. J. 23(1): 14-18.

Dev, G., Randhawa, N.S., Nayyar, K.L. and Singh V. (1970). Response of high yielding varieties of rice (T (N)-1 and IR-8). 2. To graded doses of Phosphate. J. Res. Punjab Agric. Univ. 7(4): 449-453.

Devi, G.D., Vijayagopal, P.D and Sasidhar, V.K. (1980). Studies on fractional application of nitrogen on the yield of rice. Agric. Res. J. Kerala 18(1):23-26.

Dixit, R.S. and Singh, M.M. (1977). Levels of NPK for rainfed paddy. Int. Rice Comm. Newsl. 26(2): 26.

Dixit, R.S. and Singh, M.M. (1979). Response of rice varieties for nitrogen levels under rainfed/direct seeded conditions. Int. Rice Comm. Newsl. 18(2): 26-28.

Dixit, R.S. and Singh, M.M. (1980). Response of rainfed rice to nitrogen levels and sowing times. Int. Rice Comm. Newsl. 29(2): 28-29.

Dutta, L. and Barua, J.N. (1978). The Chemical composition of rice as affected by the nitrogenous fertilizer-1. Indian J. Agric. Chem. 11(1): 59-63.

Esakkimuthu, N., Krishnamoorthy, K.K. and Loganathan, S. (1975). Influence of Nitrogen and potassium and method of application of potassium on yield and nutrient uptake in rice. J. Indian Soc. Soil Sci. 23(4): 452-457.

Eunus, M. and Sadeque, M.A. (1974). Note on the effect of different levels of nitrogen and plant spacing on the yield of transplanted rice. Indian J. Agric. Sci. 44(9): 618-620.

*Fageria, N.K. (1980). Rice in water deficient Cerrado soils and its response to P. Pesquisa Agropecuaria Brasileira 15(3): 259-265.

Fageria, N.K., Barbosa Filho, M.P. and Carvalho, J.R.P. (1982). Response of upland rice to P fertilization on an oxisol of Central Brazil. Agron. J. 74(1):51-56.

Fagi, A.M. and Datta, S.K.De. (1981). Environmental factors affecting Nitrogen efficiencyin flooded tropical rice. Fert. Res. 2(1): 53-67.

*Furuyama, Y. and Minami, M. (1974). Studies on the nutritional and physiological characteristics of the rice varieties in Hokkaido. Response to split application of nitrogen fertilizer. Bulletin Hokkaido Prefectural Agricultural Experiment Stations. 29: 148-160.

Gaffer, M.A. and Chand, T. (1978). Effect of different levels of urea-N applied at different stages of plant growth on the yield of IRRI- Shail-1 under rainfed culture. Int. Rice Comm. Newsl. 27(2):19-20.

Ghobrial, G.L. (1980). Effect of level, time and splitting of urea on the yield of irrigated directed seeded rice. Plant and Soil 56(2):209-215.

Ghosh, A.K., Nanda, B.B., Govindaswami, S. and Nayak, B.B. (1971). Influence of nitrogen on the physico-chemical characteristics of rice grain. Oryza. 8(1): 87-100.

Giri, D.G. and Bhatade, S.S. (1980). Nitrogen and its time of application in upland rice. Res. Bull. Marathwada Agric. Univ. 4(1).

Gopalakrishnan, R., Pisharady, P.N., Nair, R.R. and Pillai, G.R. (1971). Effect of time of application of Nitrogen on the yield of IR-8 rice. Indian J. Agric. Sci. 41(2):98-101.

Gopalakrishnan, V., Gururajan, B. and Rajagopalan, K. (1975). Response of Co 36 rice variety to N,P and K levels under different dates of sowing. Madras Agric. J. 62(9):582-583.

Gopalaswamy, A. and Raj, D. (1977). Effect of fertilizer doses and varietal variations on soil constituents, nutrient uptake and yield of rice varieties. Madras Agric. J. 64(8): 511-515.

Gowda, N.K.M. and Panikar, S.N. (1977). Effect of varying levels of nitrogen on yield and yield attributes of high yielding varieties of paddy. Mysore J. Agric. Sci. 11(1): 48-51.

Gupta, A.P., Kaishtha, B.P., Manchanda, M.L. and Agarwal, S.C. (1975). Effect of split application of phosphorus on the yield and P uptake of paddy. Riso 24(4) 329-333.

Gupta, N.D., Roy, D.R. and Paul, L.M. (1970). Nitrogen requirement of IR-8 and Taichung(Native)-1 rices in Tripura. Indian J. Agron. 15(4): 322-324.

Halappa, G., Sangiah, M., Rao, B.V.V. and Vijayamma, R. (1970). Studies on the influence of fertilizer application on yield, tillering and grain formation in IR-8 paddy. Mysore J. Agric. Sci. 4(3): 306-312.

*Halm, A.T. and Dartey, K. (1977). Nitrogen, phosphorus and Potassium requirements ofrice in a rain-fed environment of Bawku-Manga in Ghana. Ghana J. Agric. Sci. 10 (1):3-5.

Have, H. ten. (1971). Optimum time of nitrogen application for transplanted rice. Fert. News. 16:9-19.

*He, C.C. and Ge, Y.P. (1981). Effect of N top dressing in late rice at full heading. Hubei Agric. Sci. 8: 17-18.

*Heeran, D.P. and Lewin, L.G. (1982). Response of ongrarice to N fertilizer rate and timing in New South Wales. Australian Journal of Experimental Agriculture and Animal Husbandry 22 (114/115):62-66.

Hoque, M.S., Talukder, A.S., Bhuiya, Z.H., Main, M.M.H. and Hoque, S.A. (1977). A study on the effect of split application of urea-N on the yield of IR-20 rice under Bangladesh conditions. Int. Rice Comm. Newsl. 26(2):17

*Houng, K.H. and Liu, T.P. (1979). Absorption rate of fertilizer N applied at different growth stages and its effect on the grain yield of rice. Memories of the College of Agriculture. National Taiwan University. 19(1):1-18.

*Hub, B.L., Ahn, Y.S. and Hong, C.W. (1979). Study on the timing of nitrogen top-dressing for the panicle of new rice cultivars. Research Reports of the office of Rural Development, Soil Science, Fertilizer, Plant protection and micrology 21:19-24.

*Inocencio, E., Castillo, D. and Ramirez, E. (1981). Distribution and composition of protein in the endosperm of two rice varieties grown with 6 nitrogen treatments. Ciencia Y Tecnicaenla Agricultura Arroz, 4(1):81-94.

Iruthayaraj, M.R. and Morachan, Y.B. (1980). Note on the effect of seasons, stages, water management and nitrogen levels on the uptake of phosphorus in two swamp rice varieties. Indian J. Agric. Res. 14(4): 254-258.

Jackson, M.L. (1967). Soil Chemical Analysis. Prentice Hall of India Private Ltd., 2nd Ed. New Delhi. pp.498.

Jakhro, A.A. (1982). Effect of P fertilizer sources in calcareous soil. IRRN 7(1):16.

*Jones, R.A.D., Tarawali, G., Johnson, S.D. and Turay, A.F. (1979). The effect of time and method of P application on the yield of rice on continuously cultivated mangrove swamp. Tech. Newsl. 1(1):1-2.

Kadrekar, S.B. and Mehta, V.B. (1975). Effect of graded levels of nitrogen and phosphate in protein content of rice. Res. J. Mahatma Phule Agric. Univ. 6(2): 99-103.

Kalyanikutty, T.K. and Morachan, Y.B. (1974). Influence of N.P.K. on the growth, yield and composition of rice varieties differing in inherent yield potentials. Madras Agric. J. 61(8):239-244.

Karim, A., Chowdhury, M.Y. and Islam, T. (1968). A study on the effects of NPK fertilizers on the quality of rice grains. Sci. Res. 4(4): 198-206.

Khatua, K.B. and Sahu, B.N. (1970). Response of high yielding dwarf- indica rice to different sources and levels of phosphate fertilizers. Oryza 7(1):17-20.

Kothandaraman, G.V., Krishnaswamy, R. and Krishnamoorthy, K.K. (1975). Studies on the quality of IR-20 rice as influenced by fertilization. Madras Agric. J. 62(6): 346-348.

Koyama, T. and Niamsrichand, N. (1973). Soil-plant nutrition studies on tropical rice. 6. The effect of different levels of nitrogenous fertilizer application on plant growth, grain yield and nitrogen utilization by rice plants. Soil Sci. Plant Nutr. 19(4): 265-274.

Koyama, T., Chammek, C. and Niamsrichand N. (1973). Nitrogen application technology for tropical rice as determined by field experiment using ^{15}N tracer technique. Tech. Bull. Trop. Agric. Res. Cent. pp.3-79.

Krishnamoorthy, V.S., Ramanathan, S., Raja M.E. and Krishnamoorthy, K.K. (1977). Influence of nutrient rates of NPK on rice yield and uptake of P using tracer technique. Madras Agric. J. 64(12): 784-787.

Krishnan, P. (1968). Studies on the uptake of nutrient and response of rice (Var-IR.8) at different levels of Nitrogen, phosphorus and potassium. Thesis submitted to the University of Kerala for M.Sc.(Ag)degree.

Krishnarajan, J. and Balasubramanian, P. (1981). Management trial for increasing N use efficiency of wet land rice. IRRN 6(4):21.

Krishnaswamy, R., Kothandaraman, G.V., Jayaraj, G. and Krishnamoorthy, K.K. (1974). Yield and quality of IR-8 rice as influenced by fertilization. Madras Agric. J. 61(8): 262-267.

Kulkarni, V.A.(1973). The effect of nitrogen fertilization on protein content and milling yield of semi-dwarf and tall tropical varieties of rice. Oryza. 10(2): 5-14.

Kulkarni, K.R., Raju, S., Munegowda, M.K. and Sadasiviah, T. (1975). Further studies on response of paddy to fertilizers in Shimoga District. Mysore J. Agric. Sci. 9(1): 14-21.

Kumar, C.R.M. (1969). Studies on the effect of top dressing with nitrogen at distinct growth phases of rice variety IR-8. Thesis submitted to University of Kerala for M.Sc(Ag) degree.

Kumar, C.R.M. and George, C.M. (1974a). Studies on the effect of top dressing with N at distinct growth phases of rice (IR-8). Agric. Res. J. Kerala 10(2):93-99.

Kumar, C.R.M. and George, C.M. (1974b). Note on the effect of top dressing of nitrogen on the protein content of rice variety IR-8. Curr. Sci. 43(6):186-187.

Kumar, S.D. and Sharma, H.C. (1980). Response of direct-sown rice to levels of N under rainfed condition. Indian J. Agron. 25(4):717-718.

*Lal, M. and Mahapatra, I.C. (1975). Effect of phosphate carriers varying in water soluble and citrate soluble P content on uptake of major nutrients (N.P.K.)by rice. Riso. 24(1):49-58.

Latchanna, A. and Rao, Y.Y. (1969). Protein content of high yielding varieties of rice on influenced by level and time of application of nitrogen. Andhra Agric. J. 16(5): 137-140.

Lenka, D. and Behera, P.C. (1967). Response of four Taiwan and two local varieties of paddy to high levels of nitrogen. Indian J. Agron. 12(4):353-357.

Lenka, D. (1969). Response of Indica and ponlai varieties of rice to high levels of nitrogen in wet and dry seasons. Indian J. Agric. Sci. 39(7):642-651.

Lenka, D., Misra, B., Sahu, S.K. and Reddy, D.S. (1976). Effect of water management and nitrogen application on rice. Indian J. Agron. 21(4):420-424.

Loganathan, S. and Raj, D. (1972). Characterisation of the pattern of uptake of different nutrients by certain high yielding paddy strains. Madras Agric. J. 59(4): 215-218.

Lozano, J.M. and Abruna, F. (1981). Nitrogen rates in single and split applications and yield of flooded rice. J. Agric. Univ. P. Rico 65(1):35-42.

Ma, M.T. and Du, C.L. (1982). The role of K fertilizer in boosting rice yields in red earth willy arrears of Central China. J. Soil Sci. 1: 5-11.

*Machado, M.O., Gomes, A. Da.S., Pauletto, E.A. and Ribeiro, A.S. (1981). Response of irrigated rice to the application of phosphorus and dolomitic lime stone. UEPAE de pelotas:181-185.

*Mehapatra, I.C., Abu, M.B. and Carew, A.B. (1980). Effect of time and rate of K application on rice yield under upland conditions in Sierra Leone. Warda Tech. Newsl. 2(2):10-11.

Maiti, S. and Chatterjee, B.N. (1977). Effect of different timing of N application on yield components and grain yield of direct seeded wet land rice. Oryza 13(1): 43-49.

Majumdar, D.K. (1971). Effect of sowing time and fertilizers yield attributes and yield of rice (Oryza sativa L.). Indian J. Agron. 16(1):6-9.

*Mamadaliev, A., Altunina, N. and Akhmedov, A. (1976). Studies on the effectiveness of different rates and proportion of fertilizers applied to rice on soils with a pebbel layer in Andizhan province. Tashkentiskii Selskokhozyaistvennyi Institute 66A: 78-81.

Mathew, M.P. (1971). Studies on the rate and time of top dressing nitrogen for rice variety Jaya. Thesis submitted to University of Kerala for M.Sc(Ag) degree.

Matin, M.A. and Bhuiya, Z.H. (1981). Effect of foliar and soil application of urea-N on the yield of rice. Thai J. Agric. Sci. 14(3): 253-258.

Mengel, K., Viro, M and Hehl, G. (1976). Effect of potassium on uptake and incorporation of ammonium Nitrogen of rice plants. Plant and Soil. 44 (3): 547-558.

Mengel, D.B. and Wilson, F.E. (1981). Water management and Nitrogen fertilization of ratoon crop rice. Agron. J. 73(6): 1008-1010.

Mishra, O.P. and Singh, U.P. (1980). Effect of time of N application on the yield of early rice. Indian J. Agron. 25(3): 553-554.

Mishra, B., Sharma, R.D. and Pant, G.B. (1982). Nitrogen management in flooded rice. IRRN 7(4):18.

Mohanty, S.K. and Patnaik, S. (1974). Uptake of nutrients in relation to growth of rice as influenced by varying nutrient environment in different soil types. Riso 23(4): 351-363.

Moolani, M.K. and Sood, P.R. (1966). Effect of nitrogen, phosphorus and potash on paddy yield. Riso. 15:227-260.

*Moosa, I.E. and Vargasz, J.P. (1980). Response of rice cv. CICA-8 to split application of N under field conditions. Acta Agrononica. Colombia. 30(1/4): 49-60.

Mukherji, S., Kundu, K.K. and Sircar. (1968). Studies on the physiology of the rice plant. XIX. Effect of the heavy fertilizer stress on culm characteristics of two winter varieties in relation to yield and lodging behaviour. Indian J. Agric. Sci. 38(2): 326-337.

Muraleedharan, A., Kamalam, N. and Nair, S.S. (1972). Rate and time of application of Nitrogen on dwarf indica rice under the agroclimate of Wynad. Agric. Res. J. Kerala 10(1): 56-58.

Murty, P.S.S. and Murty, M.S. (1978). Productive efficiency and nitrogen response of high yielding rice cultivars of Andhra Pradesh. Oryza 15(1): 83-85.

Muthuswamy, P., Raj, D. and Krishnamoorthy, K.K. (1972). Response of Karuna, Kaveri and Kanchi paddy varieties to forms and levels of fertilizer nitrogen. Madras Agric. J. 59(11 & 12):603-608.

Muthuswamy, P., Raj,D. and Krishnamoorthy, K.K. (1973a). Effect of forms and levels of fertilizer nitrogen on the quality of certain high yielding paddy varieties. Madras Agric. J. 60(1): 12-16.

Muthuswamy, P.,Raj, D. and Krishnamoorthy, K.K. (1973b). Mineral nutrition of high yielding rice (Oryza sativa L.) varieties. Madras Agric. J. 60(8): 764-767.

Muthuswamy, P., Raj, D. and Krishnamoorthy, K.K. (1974). Uptake of N.P and K by high yielding paddy varieties at different growth stages. Indian J. Agric. Chem. 7(1):1-5.

Nagarajan, S., Jauffer, M.M.M. and Willenberg, S.M. (1975). Timing of nitrogen application, its effect on nitrogen utilisation and protein content of rice. Plant and Soil 42(2): 349-358.

Nair, R.R. and Pisharody, P.N. (1970). Responses of rice to phosphate manuring in a water-logged laterite sandy loam of Kerala. Agric. Res. J. Kerala 8(1): 6-13.

Nair, R.R., Pillai, G.R., Pisharody, P.N. and Gopalakrishnan R. (1972). Response of rice to graded doses of phosphorus in connection with magnesium and spartin. Indian J. Agron. 17(4): 317-320.

Nair, V.M. and George, C.M. (1973). Studies on the comparative performance of three short duration rice varieties, Vellayani-I, ADT-27 and PTB-10 at varying levels of Nitrogen under Semidry conditions in Vellayani. Agric. Res. J. Kerala 11(1): 5-8.

Nair, G.K.B. and Sreedharan, C. (1977). Effect of split doses and times of nitrogen application on the content, uptake and utilization efficiency for direct sown rice in puddled soil. Agric. Res. J. Kerala 15(1): 41-46.

Nair, G.K.B., Sreedharan, C. and Sasidhar, V.K. (1979). Effect of split application of time of N application on growth, yield attributes and yield of direct sown rice in puddled soil. Agric. Res. J. Kerala 17(1):50-54.

Naphede, J.A. (1969). Influence of phosphate application to various soils on the response of rice and phosphorus uptake at different stages of plant growth. Riso. 18 (1): 37-42.

Narasaiah, Bala, D. and Rao, S.R. (1967). Studies on the effect of time of nitrogen application on yield of paddy. Indian J. Agron. 12(4): 416-422.

Natarajan, C.T., Rethinam, P. and Robinson, J.G. (1974). Response of IR-5 paddy to nitrogen. Madras Agric. J. 61(9): 643-644.

Natarajan, V., Loganathan, N.S., Palaniappan, T.A., Guruswamy, M. and Venugopal, K. (1975). Manuring of Rainfed rice. Madras Agric. J. 62(2): 41-43.

*Noguchi, Y. and Sugawara, T. (1952). The effect of potash on the rice plant. Yokendro Press. Tokyo.

*Ojeda, A. and Lopoz, H. (1979). Effect of N application during the reproductive stage of rice upon the yield and its components. Cultivos Tropicales. 1(1): 77-94.

*Ojeda, A. and Freyre, J. (1980). Effect of splitting N application on rice Oryza sativa L. Crops on a Ferralitic-quartzitic soil. Cultivos Tropicales 2(1): 105-120.

Oommen, P.K., Oza, A.M. and Subbiah, B.V. (1972). Varietal difference in the relative uptake of soil and fertilizer phosphorus by high yielding varieties of wheat and rice as revealed by studies with P^{32}. Indian J. Agric. Sci. 42(5): 370-374.

Padmaja, P. (1976). Studies on potassium in rice (Oryza sativa L.) and rice soils. Ph.D. Thesis. Orissa University of Agriculture and Technology.

Padmakumari, G., Nair, N.C. and Koshy, M.M. (1969). The response of two high yielding varieties of rice to NPK applications in an acid peat soil of Kerala. Agric. Res. J. Kerala 7(1): 10-13.

Panda, S.C. and Leeuwrik, D.M. (1972). Response of high yielding varieties of rice to high levels of nitrogen. Oryza. 9(2): 25-26.

Panda, M.M., Hati, N. and Misra, A. (1977). Split application of a low level nitrogen as urea on rice. Indian J. Agron. 22(3): 199-200.

Panda, S.C. and Das, K.C. (1979). Nitrogen for rice. Indian J. Agron. 24(2): 173-179.

Pande, H.K. and Tilak, K.V.B.R. (1970). Effect of varying levels of nitrogen and phosphate fertilization at different dates of seedling on growth and yield of upland rice. Riso. 19: 87-94.

Pande, H.K. and Narkhede, N.N. (1972). Tillering behaviour and grain yield of low land rice in relation to nitrogen fertilization. Riso. 21(1): 59-66.

Pandey, J. and Das, K.C. (1973). A note on nitrogen, phosphorus and potassium requirement of rice (IR-8). Indian J. Agron. 18(3): 388-389.

Panikar, K.S., Pillai, P.B. and Chandrasekharan, P. (1978). Influence of age of seedling, spacing and time of application of N on the yield of rice variety IR-8. Agric. Res. J. Kerala 16(2): 227-229.

Patel, J.P. (1967). Interrelation of different proportion and rates of N.P. fertilizer application, and planting patterns of rice in the Jabulpur district. Indian J. Agron. 12: 222-230.

Patel, R.B., Patel, P.G., Naik, A.G. and Patel, L.G. (1980). Response of rice varieties to nitrogen in Summer season. Indian J. Agron. 25(3): 528-529.

Pathak, A.N., Shrikrishna and Tiwari, K.N. (1972). Studies on chemical composition, yield and nutrient uptake of high yielding dwarf rice varieties in relation to fertility levels. Indian J. Agric. Res. 6(4):263-266.

Patnaik, S. (1969). Maximise rice yields through rational fertilizer use. Indian Fmg. 19(8): 9-14.

Peeran, S.N. and Anandan, B.V. (1982). Optimum spacing and nitrogen for medium duration rice. IRRN 7(6): 20.

Pillai, G.R. and George, C.M. (1973). Studies on the performance of rice var. IR-8 under varying levels of N and spacing. Agric. Res. J. Kerala 11(1): 38-42.

Pillai, G.R., Nair, R.R., Pisharody, P.N. and Gopalakrishnan R. (1975). Effect of age of seedlings and nitrogen levels on Annappurna rice. Agric. Res. J. Kerala 13(1): 43-47.

Pisharady, D.W., Nair, R.R. and Gopalakrishnan, R. (1976). Influence of applied nitrogen on grain yield, protein content and milling out turn in transplanted rice. Agric. Res. J. Kerala 14(2): 109-112.

Place, C.A., Sims, J.L. and Hall, V.L. (1970). Effects of nitrogen and phosphorus fertilization on growth yield and cooking characteristics of rice. Agron. J. 62(2): 231-243.

Poulose, K.C., George, C.M., Sreedharan, C. and Sasidhar, V.K. (1978). Comparative performance of two rice varieties (IR-8 and PTB-9) with varying levels of seed rate and nitrogen under semi-dry conditions. Agric. Res. J. Kerala 16(1): 74-75.

Prabha, R., Aiyer, R.S. and Money, N.S. (1975). Response of rice (Var-IR-1) to zinc as affected by levels of phosphate fertilizers. Agric. Res. J. Kerala 13(2): 117-122.

Prasad, B. and Jha, J. (1973). Effect of different levels of nitrogen on the uptake of nitrogen, phosphorus and potash by rice T(N)-1. Indian J. Agron. 18(3): 210-214.

Prasad, K. and Sharma, S.D. (1973). Effect of nitrogen on components of panicle morphology of rice (Oryza sativa L.). Indian J. Agric. Sci. 43(1): 9-14.

Purushothaman, S. and Morachan, Y.B. (1974). Response of IR 8 to direct seedling and transplanting at three levels of nitrogen. Madras Agric. J. 61(8): 285-288.

Rabindra, B. (1978). Effect of split application of phosphorus on rice yield. Mysore J. Agric. Sci. 12(3): 385-387.

Rabindra, B., Naidu, B.S. and Mahadevappa, M. (1977). A note on the effect of nitrogen levels on grain protein in rice. Curr. Res. 6(3): 47-48.

Rai, R.S.V. and Murty, K.S. (1976). Uptake of nutrients in relation to growth period of late duration Indica rice (Oryza sativa L.) varieties. Indian J. Plant Physiol. 19(2): 220-225.

Raj, S.M., Morachan, Y.B., Subramanian, S. and Subbiah, K.K. (1974). Effect of plant density and rate of nitrogen application on IR 20 rice. Madras Agric. J. 61(8): 289-292.

Rajan, M.S.S. and Mahapatra, I.C. (1978). Relative efficiency of slow release and split application of nitrogenous fertilizers and weed control methods on yield of direct seeded upland rice. Oryza 15(2): 117-123.

Raju, P.E. (1977). Effect of different level of nitrogen on growth and yield of high yielding rice (Oryza sativa) cultivars direct seeded in lines on puddled soil. Thesis Abstract. Agricultural College, Tirupati, A.P. 3(1/2): 22-23.

Raju, R.A. (1978). Influence of levels and sources of nitrogen on composition of NPK nutrients in straw and quality of grain in paddy. Andhra Agric. J. 25(1&2): 1-5.

Raju, R.A. (1979). Response of dwarf indica rice to varying levels and sources of nitrogen on sandy clay loam soil. Int. Rice Comm. Newsl. 28(2): 32-34.

Ramankutty, N.N. (1967). Studies on the effect of potassium on the growth, yield and nutrient uptake of two newly introduced Rice varieties (Tainan-3 and Taichung Native-1) Thesis submitted to the University of Kerala for M.Sc.(Ag) Degree.

Ramanujam, T. and Rao, J.S. (1970). Effect of nitrogen on CHO and protein content in rice (Oryza sativa L.). Madras Agric. J. 57(8): 435-436.

Ramanujam, T. and Rao, J.S. (1971). Influence of nitrogen supply on growth factors of rice (Oryza sativa L.). Madras Agric. J. 58(3): 239-244.

Ramaswami, P.P. and Raj, D. (1974). Influence on nutrient and green manure application on nutrient uptake and yield of rice. Madras Agric. J. 61(10-12): 945-949.

Rao, B.S. (1977). Effect of different levels of N on growth and yield of rice varieties. Thesis Abstracts 3(4): 250-251.

Rao, Y.Y., Reddy, T.V.R., Reddi, G.H.S. and Venkateswarlu, M.S. (1973). Studies on split and foliar application of complex fertilizers on IET 1991 rice. Indian J. Agric. Res. 7(3/4): 204-206.

Rao, C.N. and Murty, K.S. (1975a). Note on the effect of number and times of split application of nitrogen on tiller productivity and yield in upland rice. Indian J. Agric. Sci. 45(2): 72-74.

Rao, C.N. and Murty, K.S. (1975b). Effect of split application of nitrogen on tiller survial and yield in direct seeded upland rice. Indian J. Agric. Sci. 45(5): 183-188.

Rao, P.S.N. and Rao, C.B. (1980). Performance of IET 7041 in nitrogen variety trial. IRRN. 5(6):4.

Rao, T.K.G., Kolandaiswamy, S., Seshadri, P. and Sankaran, S. (1974). Studies on levels and times of application of phosphorus and potassium on rice. Madras Agric. J 61(8): 258-261.

Rastogi, A.K., Mahajan, J.P. and Sinha, S.B. (1981). Phosphorus utilization by 3 rice varieties at different stages of growth in a vertisol. J. Nucl. Agric. Biol. 10 (2): 48-50.

Reddy, R.N.S. and Prasad, R. (1977). Effect of variety rates and sources of nitrogen on growth characters, yield components and yield of rice. Riso 26(3): 217-224.

Reddy, R.K., Yogeswara Rao, Y. and Sankara Reddy, G.M. (1978). Nitrogen uptake of high yielding rice varieties in relation to seedling rates and fertility levels. Indian J. Agric. Res. 12(4): 266-268.

Reheja, P.C. (1966). Soil productivity and crop growth. Asia publishing House, Bombay.

Rethinam, P. (1974). A study of functional relationship for rice (Padma) response to nitrogen. Madras Agric. J. 61(8): 249-254.

Rethinam, P., Kolandaiswamy, S. and Sankaran, S. (1975). studies on the comparative response of nitrogen on tall and dwarf indica varieties of rice. Madras Agric. J. 62(2): 89-91.

*Rhee, K.M., Huh, B.L., Hong, C.W. and Park, C.S. (1979). Effect of K application timing on the yield and K uptake of rice cultivars Yusin and Milyang 23. Research Reports of the office of Rural Development, Soil Science. Fertilizers, Plant protection and micrology 21: 25-32.

Robinson, J.G. and Rajagopalan, K. (1977). Response of high yielding varieties of rice to graded levels of phosphorus and potassium. Madras Agric. J. 64(2): 138-139.

*Rodriguez, E., Freyrej, and Pena, J.L. (1980). Study of the effect of different dates of N application on the yield and its components of rice. Ciencia Y Tecnica en La Agricultura, Arroz. 3(2): 7-22.

Roy, R.K., Jha, J.N. and Ojha, S.N. (1977). Effect of Nitrogen management on the performance of rice variety Pankaj. Indian J. Agron. 22(4): 260.

Russel, E.W. (1973). Soil conditioners and plant growth. Longman, Group Ltd., London, 10th Edition. pp1-810.

Sadanandan, N. and Sasidhar, V.K. (1976). Studies on the response of rice variety Triveni to phosphorus application. Agric. Res. J. Kerala 14(2): 175-177.

Sadanandan, A.K., Guruswamy, M. and Sivappah, A.N. (1969). studies on the nitrogen, phosphorus and potash uptake by ADT-27 rice. Madras Agric. J. 56(4): 188-194.

Sadayappan, S. and Kolandaiswamy, S. (1974). Influence of added nitrogen and its time of application on grain protein, phosphorus and potash. Madras Agric. J. 61(9): 646-647.

Sadayappan, S. Kolandaiswamy, S. and Palaniswamy, K.M. (1974). Effect of different levels of nitrogen at critical growth phases on rice. Madras Agric. J. 61(8):245-248.

Sahu, G. and Murty, K.S. (1975). Influence of Nitrogen rate on dry matter production, nitrogen uptake and yield in high-yielding cultivars of rice. Indian J. Plant Physiol. 18(2): 115-120.

Sahu, B.N. and Ray, M. (1976). Response of tall indica rice to application of potash in combination with farm yard manure in lateritic soil of Orissa. Bull. Indian Soc. Soil Sci. 10: 259-263.

Samui, R.C. and Bhattacharya, A.K. (1976). Effect of levels of phosphorus and zinc on transplanted rice and their residual effects of berseem and direct seeded rice. Indian J. Agron. 21(4): 495-497.

Sarkar, A. and Sinha, M.N. (1976). Split application of N for rice under upland conditions. Indian J. Agron. 21(2): 170-171.

Satyanarayana, G. and Sharma, B.L. (1976). Response of direct seeded early maturing rice varieties to nitrogen application under puddled conditions. Indian J. Agron. 21: 168-170.

Sharma, S.K. and De, R. (1976). Grain yield and mineral nitrogen content in soil as influenced by water regimes, levels of nitrogen and methods of nitrogen application. J. Indian Soc. Soil Sci. 24(4): 414-420.

*Shiga, H. and Yamaguchi, Y. (1976). Effect of phosphorus fertility on soil and phosphate application on rice culture in a cool region. On the relations of applied nitrogen and variation of climate in consecutive years. Res. Bull. Hokkaido Natn. Agric. Exp. Stn. 116: 139-155.

Shrivastava, M.N., Sharma, K.K. and Saratha, M.L. (1970). A note on the mode of response to nitrogen in tall and dwarf rice varieties. Indian J. Agron. 15(2): 195-196.

*Simpson, J.E., Adair, C.R., Kohler, G.O., Dawson, E.H., Debald, H.A., Kester, E.B., Hogar, J.T., Batcher, O.M., and Halik, J.V. (1965). Quality evaluation studies for foreign and domestic rices. Tech. Bull. No.1331. U.S.D.A. service: 1-186.

Shukla, G.C. (1969). Fertilizer studies with rice. Agric. Res. Gayana. 3: 4-16.

Singh, A., Fatasra, D.S., Ram, C., Dattan Singh and Panwar, D.V.S. (1979a). Components of grain yield in rice. Cereal Res. Commun. J. (3): 241-247.

Singh, B.K. and Modgal, S.C. (1978b). Dry matter production phosphorus and potassium uptake as influenced by levels and methods of nitrogen application in rainfed upland rice. Indian J. Agric. Sci. 48(6): 337-341.

Singh, B.K., and Modgal, S.C. (1979). Pattern of dry matter accumulation and nitrogen concentration and uptake as influenced by levels and methods of nitrogen application in rainfed upland rice. Plant and Soil 52(1): 9-17.

Singh, H. and Modgal, S.C. (1978a). Studies on the nitrogen management in upland rainfed rice. Effect of time of nitrogen application on chemical composition of grains. Haryana Agric.Univ. J.Res. 8(4): 244-252.

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

Singh, M. and Singh, R.K. (1979). Split application of potassium in rice to maximise its utilisation. Indian J. Agron. 24(2): 193-198.

Singh, M. and Varma, S.C. (1971). Effect of different rates of nitrogen and phosphorus application on the yield and yield attributing characters of Taichung (Native)-1 rice. Indian J. Agron. 16(3): 257-260.

Singh, R. and Dubey, S.N. (1975). Response of rice to P and K in relation to time of application. Indian J. Agron. 30(2): 198-199.

Singh, R., Singh, J. and Bains, D.S. (1978). Response of rice to the source, the rate and the time of applying nitrogen under flooded conditions. J. Res. Punjab Agric. Univ. 15(1): 8-44.

Singh, R.A. and Singh, U.N. (1976). Response of direct seeded upland rice to levels and methods of nitrogen application under dryland conditions. Riso 25(3): 283-287.

Singh, R.P. and Bharadwaj, R.B.L. (1973a). Time of nitrogen application for upland rice. Indian J. Agric. Sci. 43(3): 245-249.

Singh, R.P. and Bharadwaj, R.B.L. (1973b). Effect of times of nitrogen application on phosphorus uptake by upland rice. Indian J. Agron. 18(1): 14-16.

Singh, R.S. (1971). Response of three types of rice to various levels of nitrogen and spacings. Indian J. Agric. Res. 5(3): 185-189.

Singh, U.S., Singh, R.P. and Singh, D.N. (1976). Effect of rate and time of application of potassium on the yield and nitrogen, phosphorus and potassium turn over by high-yielding rice. Fert. Technol. 13(2/3): 107-109.

Singh, V. and Jaiprakash (1979). Effect of nitrogen, phosphorus and potassium application on the availability of nutrients to rice. Madras Agric. J. 66(12): 794-798.

Sobhana, S. (1983). Spacing-cum-fertilization on rice variety Mashuri in the Onattukara tract. Thesis submitted to Agricultural University of Kerala for M.Sc(Ag) degree.

Srivastava, M.K. and Verma, M.L. (1974). Protein content in grain of some paddy varieties as influenced by nitrogen fertilization. Indian J. Agric. Chem. 7(1): 81-84.

Subramanian, A. and Kolandaiswamy, S. (1973). Studies on Methods of planting under different levels of nitrogen and their influence on yield of IR-8 Rice. Madras Agric. J. 60(8): 741-745.

Subramaniam, V. and Morachan, Y.B. (1979). The time of application of fertilizers and its effects on nutrient uptake of rice. Madras Agric. J. 66(6): 401-404.

Subramanian, S. and Venketaraman, C.R. (1980). A note on the time and mode of nitrogen application to Rice (IR-20) Madras Agric. J. 67(8): 546-547.

Subramanian, A., Palaniappan, S.P. and Morachan, Y.B. (1974). Effect of graded doses of nitrogen and the method of planting on the protein content of rice (IR-8) grain. Madras Agric. J. 61(9): 657-658.

Subbiah, K.K. and Morachan, Y.B. (1974). Response of short duration rice varieties to nitrogen. Madras Agric. J. 61(9): 644-645.

Subbiah, K.K., Morachan, Y.B and Michael Raj, S. (1977). Influence of levels of nitrogen on yield and yield components of rice varieties. Madras Agric. J. 64(6) 235-238.

Subbiah, K.K. Rajagopalan, K., Morachan, Y.B., Balasubramanian, K.M. and Narayanaswamy P. (1975). Nitrogen application to Co 36 rice. Madras Agric. J. 62(6): 349-352.

Sumbali, G.L. and Gupta, D.K.(1972). Response of paddy (IR-8 and Jaya) to nitrogen. Indian J. Agron. 17(4): 279-282.

Suseelan, P., George, C.M. and Sreedharan, C. (1978). Effect of phosphorus and lime application on rice variety IR-8. Agric. Res. J. Kerala 16(2): 240-241.

*Taira, H. (1970). Effect of fertilizing on the protein content in high-yield rice. Proc. Crop Sci. Soc. Japan. 39: 200-203.

Takur, B.S. and Saxena, R.S. (1970). Sources of nitrogen, methods and timesof application for rice in Gwalior District. Indian J. Agron. 15(2): 212-214.

Tanaka, A., Patnaik, S. and Abichandani, C.T. (1958). Studies on the nutrition of rice plant. Part I. Influence of nitrogen level on the growth and nutrient uptake by rice plant. Proc. Indian Acad. Sci. 4(B): 140-154.

Terman, G.L. and Allen, S.E. (1970). Fertilizer and soil P uptake by paddy rice as effected by soil P level, source and date of application. J. Agric. Sci. 75: 547-552.

Terman, G.L., Allen, S.E. and Engelstad, O.P. (1970). Response of paddy rice to rates and sources of applied phosphorus. Agron. J. 62(3): 390-394.

Tewari, A.N. and Singh, H. (1976). Time and method of nitrogen application in direct seeded rainfed rice. Indian J. Agron. 21(2): 164-165.

Thandapani, V. and Rao, J.S. (1974). Effect of phosphorus fertilization on the nitrogen, phosphorus, potassium and Calcium content of ADT-27 rice (Oryza sativa L.). Madras Agric. J. 61(6): 135-140.

Thandapani, V. and Rao, J.S. (1976). Effect of phosphorus fertilization on the physiology of rice. Madras Agric. J. 63(3): 148-150.

Thasanasongchan, A., Mabbayad, B.B. and Datta, S.K. De. Methods, Sources and time of Nitrogen application for upland rice. Philipp. J. Crop. Sci.1(4):179-185.

Thenababu, M.W. (1972). Influence of time and level of nitrogen application on growth and yield of rice. Plant and Soil 36(1): 15-29.

Tisdale, S.L. and Nelson, W.L. (1975). Soil Fertility and Fertilizers. Macmillan Publishing Co. Inc. N.Y. 3rd Ed. pp.1-694.

*Tsui, C. and Yen, L.F. (1964). Effect of nitrogen nutrition on the growth, yield and carbohydrate- nitrogen metabolism of the rice plant. Acta. bot. sin. 12(1): 75-81.

Uexkull, H.R.V. (1976). Response of HYV rice to potassium in the long term fertilizer trials in the philippines. Bull. Indian Soc. Soil Sci. 10: 177-185.

Uexkull, H.R.V. (1982). Rice: Timing is crucial in potash application. Span. 21(1): 32-34.

Usha, C. (1966). Potash utilization of rice with regard to the effect of Ca, Mg and Si. Thesis submitted to the University of Kerala for M.Sc.(Ag) Degree.

Varma, S.C. (1971). Effect of nitrogen and phosphorus application on the dry matter accumulation and uptake, translocation and recovery of nutrient by Taichung Native-1. J. Scient. Res. Banaras Hindu Univ. 22(1): 11-19.

*Velly, J. and Latrille, E. (1967). Effect of time of application and nitrogen rate on the efficiency of nitrogen and phosphorus in rice fields. Agron. Trop. Paris. 22: 351-363.

Venkatachari, A., Raj Reddy, K., Anand Reddy, R., Narsi Reddy, R. Ranga Reddy, M. and Khursheed Ahmed, M. (1976). Yield response of rice, sorghum, maize, bajira and wheat to nitrogen levels on sandy loam soils of Hyderabad region. Fert. News 21(8): 61-63.

Venktaeswarlu, K. (1978). Effect of two forms of nitrogenous fertilizers at different levels on grain, straw yields and their contributing characters and recovery of applied nitrogen in rice. Andhra Agric. J. 25(3&4): 71-77.

*Verkhotin, I.J. (1974). Effect of rates and proportion of mineral fertilizer on dark-chestnut soils in the Sioash region, Byull. Vses. Inst. Udobr. Agropochvov. 19: 58-61.

Verma, U.K., Sharma, I.P. and Singh, R.S. (1981). Effect of applied and residual phosphorus on yield of wet land rice under acid soil conditions. IRRN. 6(6):23.

Verma, U.N. and Srivastava, K.N. (1972). Response of IR-8 rice to different levels and split application of nitrogen. Indian J. Agron. 17(1):5-8.

Vijayan, G. and Sreedharan, C. (1972). Effect of levels and times of application of potash of IR-8. Oryza 9(1): 57-64.

Wang, Y.R. (1981). Effectiveness of supplied nitrogen at the primordial panicle stage on rice plant characteristics and yields. IRRN. 6(4): 23-24.

Wells, B.R. (1970). Performance of long grain rice grown on clay soils as related to rate and timing of fertilizer nitrogen. Rep. Ser. Ark. Agric. Exp. Stn. 187. pp.12

Westfall, D.G. (1970). The nitrogen uptake and efficiency of rice. Rice J. 73(7): 59-60.

Yates, F. (1964). The Design and Analysis of Factorial Experiments. Commonwealth Agricultural Bureaux Farnham Royal. Bucks, England. pp.4-14.

* Originals not seen.

APPENDICES

APPENDIX I

Meteorological data during the crop season 1982-83.

Standard weeks	Period From		Period To		Total rain-fall mm	Maximum temperature. °C	Minimum temperature °C	R.H %
39	Sept.	24	Sept.	30	2.2	31.2	22.7	97
40	Oct.	10	Oct.	7	8.2	33.2	23.0	96
41	Oct.	8	Oct.	14	31.8	33.5	23.4	94
42	Oct.	15	Oct.	21	6.5	32.5	23.2	95
43	Oct.	22	Oct.	28	117.4	32.9	22.5	97
44	Oct.	29	Nov.	4	20.6	32.5	23.1	93
45	Nov.	5	Nov.	11	20.8	32.1	23.3	95
46	Nov.	12	Nov.	18	0.8	32.7	23.6	91
47	Nov.	19	Nov.	25	-	33.8	23.0	82
48	Nov.	26	Dec.	2	-	35.7	23.9	77
49	Dec.	3	Dec.	9	-	32.9	21.9	76
50	Dec.	10	Dec.	16	0.6	32.7	21.8	78
51	Dec.	17	Dec.	23	-	33.5	22.2	75
52	Dec.	24	Dec.	30	-	33.0	21.5	74
1	Dec.	31	Jan.	7	9.2	33.4	19.8	75
2	Jan.	8	Jan.	14	19.9	34.7	17.3	74
3	Jan.	15	Jan.	21	9.1	33.9	21.1	74
4	Jan.	22	Jan.	28	9.6	34.6	21.8	73
5	Jan.	29	Feb.	4	9.3	35.4	21.4	81

Contd..

APPENDIX I (Contd.)

Average values of meteorological observations for the past ten years (1972-73 to 1981-82)

Standard weeks	Period From	Period To	Total Rainfall mm	Maximum temperature °C	Minimum temperature °C	R.H %
39	Sept. 24	Sept. 30	53.39	31.002	23.07	95.5
40	Oct.1	Oct. 7	27.47	31.092	24.84	95.5
41	Oct.8	Oct. 14	63.102	31.272	23.24	95.6
42	Oct. 15	Oct. 21	32.532	31.58	22.95	95.5
43	Oct. 22	Oct. 28	15.43	31.572	22.892	94.3
44	Oct. 29	Nov. 4	49.7	31.842	22.652	94.5
45	Nov. 5	Nov. 11	40.66	31.832	22.822	93.2
46	Nov. 12	Nov. 18	39.762	32.28	22.72	93.7
47	Nov. 19	Nov. 25	24.09	32.022	21.77	92.1
48	Nov. 26	Dec. 2	13.43	32.452	21.96	90.2
49	Dec. 3	Dec. 9	13.91	33.011	21.802	89.333
50	Dec. 10	Dec. 16	4.955	32.78	21.1888	86.333
51	Dec. 17	Dec. 23	0.2444	33.344	21.833	81.666
52	Dec. 24	Dec. 30	4.35	32.502	20.522	82.333
1	Dec. 31	Jan. 7	-	33.002	19.722	80.4
2	Jan. 8	Jan. 14	-	32.482	19.462	79.6
3	Jan. 15	Jan. 21	-	33.23	18.7	80.0
4	Jan. 22	Jan. 28	0.3	33.822	20.35	81.6
5	Jan. 29	Feb. 4	0.21	34.47	20.39	84.6

APPENDIX II

Abstract of analysis of variance table for height of the plant at tillering, panicle initiation, flowering and harvest.

Source	df	Mean square				
		At active tillering	At maximum tillering	At panicle initiation	At flowering	At harvesting
Block	2	6.3255	0.5341	2.478095	13.0479	32.9755
Main plot	6	19.4022	145.78495**	178.28898**	244.95997**	186.3535**
Error (a)	12	15.96004	18.877	11.2034	18.8937	12.5958
Sub plot	2	3.0778	62.4929**	12.0820	26.4015	8.7935
Subplot x main	12	6.1865	11.6072	11.4029	13.7796	13.8043
Error (b)	28	5.0635	7.9759	5.8175	15.0111	12.2095

* Significant at 5% level

** Significant at 1% level

APPENDIX III

Abstract of analysis of variance table for number of leaves at active tillering maximum tillering, panicle initiation and folowering

Source	df	Mean square			
		At active tillering	At maximum tillering	At panicle initiation	At flowering
Block	2	1.21848	0.84097	5.4583	11.9538
Main plot	6	5.44195	41.0848**	46.3276**	25.2934
Error (a)	12	7.81597	7.9263	7.3308	11.0259
Sub plot	2	1.65486	13.6142	7.0763	1.4713
Sub plot x main	12	2.70055	3.4589	1.2230	3.3812
Error (b)	28	2.790001	4.9921	5.0350	2.9417

* Significant at 5% level

** Significant at 1% level

APPENDIX IV

Abstract of analysis of variance table for number of tillers per hill at tillering, panicle initiation, flowering and harvest.

Source	df	Mean square				
		At active tillering	At maximum tillering	At panicle initiation	At flow-ering	At harvest
Block	2	0.170299	2.6416*	0.3480	1.6490**	0.2613
Main plot	6	0.76697	2.9815**	1.5554*	1.61597**	1.3269*
Error (a)	12	0.4456	0.5862	0.3898	0.2335	0.35521
Sub plot	2	1.3985**	2.7969**	1.6535*	0.5317	0.5080
Subplot x main	12	0.3061	0.2088	0.3240	0.2095	0.1725
Error (b)	28	0.25596	0.4647	0.31983	0.3604	0.23336

* Significant at 5% level
** Significant at 1% level

APPENDIX V

Abstract of Analysis of variance table for dry matter production, number of productive tillers, length of panicle and weight of panicle

Source	df	Mean Square				
		Dry matter production at harvest	Productive tiller at flowering	Productive tiller at harvest.	Length of panicle	Weight of panicle
Block	2	600746.725	0.9776	0.12273	4.6005	0.2857
Main plot	6	4158368.82	1.5808	0.6610*	0.40395	0.4304
Error (a)	12	1766353.61	1.0530	0.15956	2.127029	0.6825
Sub plot	2	1192658.4	0.1598	0.0849	0.3951	0.1073
Subplot x main	12	774829.55	0.1784	0.146695	0.8857	0.5113
Error (b)	28	1340073.13	0.3090	0.19429	1.05822	0.4605

* Significant at 5% level
** Significant at 1% level

APPENDIX VI

Abstract of Analysis of variance table for number of grains per panicle, half filled grains per panicle, unfilled grains per panicle and thousand grain weight.

Source	df	Mean square			
		Number of grains per panicle.	Half filled grains per panicle	Unfilled grains per panicle	Thousand grain weight
Block	2	1082.593	35.753	200.5315	0.72132
Main plot	6	295.768	7.353376	31.6294	0.92088
Error (a)	12	889.184	12.05216	96.3045	2.039
Sub plot	2	645.299	0.899597	63.808	0.65726
Sub plot x Main	12	350.146	5.58097	31.0656	1.072188
Error (b)	28	324.24	6.67165	38.4865	0.891596

* Significant at 5% level

** Significant at 1% level

APPENDIX VII

Abstract of analysis of variance table for weight of grain, weight of straw grain:straw ratio and protein content of grain.

Source	df	Mean square			
		Weight of grain	Weight of straw	Grain:straw ratio	Protein content of grain.
Block	2	92897.686	239664.23	0.040177	0.7849502
Main plot	6	754541.223**	2470855.82**	0.0219505	5.065827
Error (a)	12	128229.963	154079.29	0.013829	1.174903
Sub plot	2	36918.536	289012.62	0.015567*	0.1860999
Subplot x Main	12	28501.918	102038.08	0.0082549*	1.1015484
Error (b)	28	34162.8006	100200.92	0.0034781	1.046828

* Significant at 5% level

** Significant at 1% level

APPENDIX VIII

Abstract of analysis of variance table for nitrogen, phosphorus and potassium content in plants and grain

Source	df	Mean square					
		N content of straw	N content of grain	P content of straw	P content of grain	K content of straw	K content of grain
Block	2	0.00003612	0.0201	0.0035656	0.003473	0.361014	0.0013995
Main plot	6	0.6049616	0.1297016	0.006	0.017473	0.0642865	0.038257
Error (a)	12	0.0065537	0.030065	0.003634	0.01709	0.05680254	0.0080254
Sub plot	2	0.02569	0.004758	0.0007545	0.0034876	0.00301686	0.0089688
Subplot x main	12	0.003427	0.028139	0.001737	0.003924698	0.016894	0.00394169
Error (b)	28	0.0072988	0.020799	0.007136	0.012951	0.087993	0.0251557

* Significant at 5% level

** Significant at 1% level

APPENDIX IX

Abstract of analysis of variance table for uptake of Nitrogen, phosphorus, potassium and content of it in soil after the experiment.

Source	df	Mean square					
		Uptake of N	Uptake of P	Uptake of K	Soil N content	Soil P content	Soil K content
Block	2	9.5093	4.663	67.02335	0.0006326	212.94	418.849
Main plot	6	1326.495	177.001	1570.18	0.0003041	43.32	1329.0428
Error (a)	12	138.4885	53.051	695.22	0.0004515	113.99	931.184
Subplot	2	29.161	1.773	165.13	0.00000775	64.33	44.78
Subplot x main	12	28.448	8.656	775.3528	0.0001471	44.53	69.78
Error (b)	28	74.159	19.234	714.5226	0.000909	53.60	175.58

* Significant at 5% level

** Significant at 1% level

FERTILIZER MANAGEMENT TRIAL FOR THE RICE VARIETY MASHURI DURING MUNDAKAN SEASON

By

AJITH KUMAR R.

ABSTRACT OF A THESIS
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ABSTRACT

With a view to investigate the response of the rice variety Mashuri to fertilizer levels and times of nitrogen application, a field experiment was conducted at the Regional Agricultural Research Station, Pattambi, during the second crop season of 1982-83. The treatments consisted of seven nutrient levels (70:45:45, 70:35:35, 60:35:35, 60:25:25, 50:35:35, 50:25:25 and 0: 0: 0 kg NPK per hectare) and three times of application of nitrogen (50% as basal + 25% 20 DAT + 25% 40 DAT, 25% as basal + 50% 20 DAT + 25% 40 DAT and 25% as basal + 25 % 20 DAT + 50% 40 DAT) and their various combinations.

The experiment was laid out in split-plot design with levels of fertilizers in main plot and times of application of nitrogen in sub-plot with three replication.

The study revealed that the height of plants, number of leaves, number of tillers and dry matter production were all increased by the higher levels of nutrients at different stages of crop growth. The time of application of nitrogen and the interaction effects were not significant in increasing these growth attributes.

The different nutrient levels, time of nitrogen application and their combinations failed to produce any significant influence in length and weight of panicles, number of grains, number of half filled and unfilled grains per panicle and thousand grain weight.

The grain and straw yields were significantly increased by the highest levels of nutrients namely, 70:45:45 kg NPK per hectare. Though the time of application of nitrogen did not show any significant effect, the grain yield was the highest in treatment T_3 and straw yield in treatment T_2.

The grain protein content also showed significant difference between treatments and the treatment 70:45:45 kg NPK per hectare gave the highest value.

The content and uptake of nitrogen, phosphorus and potassium were found to be the highest in the treatment L_1 (70:45:45 kg NPK/ha). The time of application of nitrogen and the treatment combinations were not significant.

The soil nutrient status (Total nitrogen, available phosphorus and available potassium) was not significantly influenced by the various nutrient levels, time of application of nitrogen or their combinations.