EFFECT OF UREA-BASED FERTILISERS ON GROWTH AND YIELD OF RICE

BY

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CERTIFICATE

Mr.A.NAGABHUSHANAM has satisfactorily prosecuted the course of ressearch and that the thesis entitled **"EFFECT OF UREA-BASED FERTILISERS ON GROWTH AND YIELD OF RICE"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also cetify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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This is to certify that the thesis entitled **"EFFECT OF UREA-BASED FERTILISERS ON GROWTH AND YIELD OF RICE"** submitted in partial fulfilment of the requirements for the degree of ''Master of Science in Agriculture' of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr.A.NAGABHUSHANAM** under my guidance and supervision. the subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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ABSTRACT

Name : ARUNAKULA NAGABHUSHANAM

Title : EFFECT OF UREA-BASED FERTILISERS ON GROWTH AND YIELD OF RICE

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A field experiment was conducted to study the effect of urea-based fertilisers on growth and yield of rice during Kharif 1989 on sandy loam soil of Tirupati campus of Andhra Pradesh Agricultural University. There were 12 treatments consisted of rock phosphate coated urea (RPCU), large granule urea (LGU), neemcake blended urea (NBU), gypsum coated urea (GCU) each applied in a single basal dose and in two equal splits ($\frac{1}{2}$ basal + $\frac{1}{2}$ at PIS), prilled urea (PU) applied in three splits ($\frac{1}{2}$ basal + $\frac{1}{4}$ at active tillering + $\frac{1}{4}$ at PIS), green leaf manure (Glm) + PU ($\frac{1}{2}$ N Glm as basal + $\frac{1}{2}$ N through PU in two equal splits at active tillering and PIS), farm yard manure (FYM) + PU ($\frac{1}{2}$ N through FYM as basal + $\frac{1}{2}$ N through PU in two equal splits at active tillering and PIS) and control. The experiment was laid out in a randomised block design with three replications. The amount of N applied was 100 kg N ha^{-1} in all the treatments except control. A common dose of 60 kg P_2O_5, 40 kg K_2O and 25 kg $ZnSO_4$ was applied at the time of transplanting. The test variety was NLR 13969.

Plant height, total tillers, LAI and dry matter were higher with basal application of urea-based fertilisers (UBF) at tillering while split application of UBF took over advantage during later stages of crop growth. Taller plants were with LGU split, LGU basal, Glm + PU and NBU split applications. Higher number of tillers, LAI and dry matter was with LGU split application. Dry matter accumulation in leaf blade, sheath, culm and panicle were higher with split application of LGU. Number of days taken to 50 per cent flowering varied from 67.3 to 69.3.

Number of panicles was higher with LGU split application whereas maximum number of filled grains panicle^{-1} was with RPCU split application. Thousand grain weight was not influenced by UBF. Split application of NBU and LGU recorded more spikelet sterility percentage. Higher panicle weight and length was with RPCU and NBU split applications, respectively. Lower number of panicles, filled grains panicle^{-1}, sterility percentage, panicle weight and panicle length was with control.

Higher grain yield of 5793 kg ha^{-1} was with LGU split followed by NBU split (5573 kg ha^{-1}). Application of Glm + PU gave comparable grain yield with PU split application. Straw yield was also higher with LGU split (6103 kg ha^{-1}) followed by NBU split and RPCU split applications. Lower grain and straw yield was with control. Ammonia volatilisation loss was more with PU split, while it was less with Glm + PU.

N uptake of grain and straw as well as total N uptake at harvest was more with split application of LGU but comparable with NBU split application. Glm + PU resulted in higher N uptake compared to PU split. LGU split application recorded maximum P and K uptake but on par with NBU split application in K uptake. Higher response to N (28.57 kg grain kg^{-1} N) and apparent recovery of N (48 per cent) was with LGU split which was comparable with NBU split application. N uptake, response to N and recovery were lower in control. Higher net returns (Rs.7,957 ha^{-1}) was with LGU split application.

Results revealed that the application of large granule urea in two equal splits ($\frac{1}{2}$ as basal + $\frac{1}{2}$ at PIS) was the best urea-based fertiliser for increasing the grain yield of low land rice. Application of green leaf manure in combination with PU resulted in less N losses and saving 50 per cent N through inorganic fertiliser.

LIST OF ABBREVIATIONS USED

AT : Active tillering

F : Flowering

FYM : Farm Yard Manure

GCU : Gypsum coated urea

Glm : Green leaf manure

LGU : Large granule urea

M : Maturity

NA : Not analysed

NBU : Neem cake blended urea

NS : Non significant

NUE : Nitrogen use efficiency

PIS : Panicle initiation stage

PU : Prilled urea

RPCU : Rock phosphate coated urea

T : Tillering

UBF : Urea-based fertilisers

** : Significant at 1% level

INTRODUCTION

CHAPTER I

INTRODUCTION

Rice (Oryza sativa L.) is the most important cereal contributing about 62 per cent of the total food grain production in India. In India, it is grown over an area of 41.5 m ha with a production of 107.5 mt of grain (FAO, 1990). In Andhra Pradesh, the area under rice is 3.12 m ha producing 7.06 mt of grain (AD, 1990).

Numerous experiments in India and elsewhere have shown that the recovery of fertiliser N applied to the irrigated rice crop is seldom more than 30 to 40 per cent. This poor utilisation of N fertiliser is largely caused by losses of N from the soil system through volatilisation, denitrification, leaching and runoff (Padalia et al., 1989).

With the prevailing high cost of N fertiliser, any management practice to curtail the N losses from soil will go a long way in improving the efficiency of applied N, thereby increasing the returns to the rice farmer. Split application of nitrogen at critical stages of crop growth for synchronising absorption with the periods of efficient utilisation, use of coated and controlled release of N fertiliser materials are some of the methods suggested for improving nitrogen use efficiency (NUE) of rice (De Datta, 1982).

Another way to increase the NUE is through development of nitrogenous fertilisers with limited water solubility achieved by increasing size of urea prills into urea granules of different sizes. Commercial urea is prilled but recent developments in production made it possible to produce urea granules upto 6-8 mm diameter in size (Large granule urea) without increase in production cost.

N losses can be minimised by treating urea with neem cake powder which acts as nitrification inhibitor. Combined application of organic and inorganic sources of N have been suggested as a means of minimising the loss and economising N fertiliser application. Urea-based fertilisers like gypsum coated urea (GCU) and rock phosphate coated urea (RPCU) are also being manufactured on pilot scale by Madras Fertilisers Limited, which also need further evaluation studies.

There is no ample experimental data on split application of urea-based fertilisers and surface broadcast application of LGU in comparison to PU split application and combination of organic and inorganic N fertiliser.

After reviewing the situation, the present experiment was planned and conducted keeping the following objectives.

1. To study the effect of urea-based fertilisers on growth and yield of short duration NLR 13969 rice.

2. To find out the best urea-based fertiliser and its optimum time of application to low land rice.
3. To work out the relative efficiency of different urea-based fertilisers.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Rice soils in the world are deficient in nitrogen and in India, about 67 per cent of rice soils are estimated to be short of adequate N (Mahapatra *et al*., 1985). Response of rice to N is almost universal and its supply is essential for achieving the full production potential of modern rice genotypes. The recent world energy crisis and continued escalation of fertilizer N costs warranted the need of searching alternate N sources and modified forms of N fertilizer for increasing N use efficiency. From the vast amount of literature available on nitrogen fertilisation of rice, relevant references to the present study are briefly reviewed in this chapter.

2.1 NITROGEN LOSSES FROM RICE CULTURE

Nitrogen is the most important nutrient required for rice. Rice is cultivated in about 23.6 per cent of the total cropped area in our country, consumes nearly 40 per cent of the fertiliser N (Tandon *et al*., 1981). However, a major portion of the added N is lost from the rice soil through leaching, immobilisation, denitrification and volatilisation.

The losses of nitrogen from urea are reported to range from 60 to 80 per cent for rice (Stangel, 1977). Efficiency of N is less and P is more under submerged situations than under up land conditions (Meelu and Bhandari, 1978).

The magnitude of N losses vary widely depending upon the type of soil and management practices. The physical condition of urea, which is the major source of N fertiliser in India, is not very much suited for rice culture and the N use efficiency of rice is not more than 40 per cent as at present (Pillai, 1978).

Meelu (1980) reported that utilisation of applied N for rice crop ranged from 19.1 to 39.8 per cent under field conditions and from 25.9 to 59.8 per cent under pot culture conditions. Rajkumar and Sekhon (1981) stated that on an average about 50-60 per cent loss of applied N through leaching, denitrification and volatilisation.

An attempt has been made by Weeraratna and Crasswell (1985) to estimate volatilisation and denitrification losses of N applied as 15_N tagged urea and ammonium sulphate to a lowland rice. They reported that one week after the application of urea and ammonium sulphate, N losses were 37.6 and 60.6 per cent, respectively. The corresponding figures after four weeks were 55.7 and 61.9 per cent. Experiments conducted by Santra *et al.* (1988) showed that cumulative loss through volatilisation was highest (about 13 per cent of the applied amount) when N was applied in the form of urea as basal, while this was lowest (about 6 per cent of the applied amount) when N was applied as urea in combination with dhaincha (*Sesbania aculeata*) as green manure 1 : 1 basis both in Kharif and Rabi seasons.

Sharma and Gupta (1989) reported that ammonia losses were drastically reduced when urea was blended or coated with neem (*Azadirachta indica*) cake (13.2 per cent), neem oil (11.2 per cent) and shellac material (9.1 per cent). Studies at Mandya in wet land rice on sandy loam soils revealed that the measured cumulative ammonia volatilisation loss of applied N was 2.8 and 0.36 kg ha^{-1} from prilled urea (PU) and neem cake coated urea (NCU), respectively indicating that the surface applied urea was more proned to NH_3 loss. The total leaching losses as ammonical and nitrate N were 9.5 and 12.8 per cent from NCU and PU, respectively (DRR, 1985).

2.2 RECOVERY OF APPLIED NITROGEN IN RICE SOILS

Despite of the fact that modern rice varieties respond well to N fertilisation, the recovery of applied N is very low (Crasswell and De Datta, 1980). It is between 25 and 40 per cent in many situations (Rajendra Prasad *et al.*, 1971; De Datta *et al.*, 1974; Pillai, 1978; Crasswell and Vlek, 1979a and Mahapatra, 1981). Under the best cultured conditions, the recovery does not exceed 49 per cent (Reddy and Patrick, 1977).

The recovery of applied N from urea by rice crop varied from 19 to 50 per cent under variable soil moisture conditions, timings and methods of fertilizer application (Mahapatra et al., 1981). Bhandyopadhyaya and Biswas (1982) observed that the fertilizer N-use efficiency of rice was 21.6 to 23.0 per cent in the common method of split application. The efficiency of fertiliser N in low land rice was reported to be 30 to 50 per cent (Singh et al., 1982).

2.3 CAUSES FOR LOW RECOVERY

Low recovery of applied N by low land rice crop was attributed to losses through denitrification, leaching, ammonia volatilisation, immobilisation, surface runoff and interlattice fixation of NH_4^+ by clay minerals (Parr, 1967; Rajendra Prasad et al., 1971; Sahrawat, 1979 and De Datta, 1981). The important mechanisms of nitrogen losses are briefly reviewed below.

2.3.1 Denitrification

Rice soils on flooding develop a thin oxidized layer immediately below the water underlying which is the reduced zone. These two are responsible for nitrification-denitrification losses from ammonium or ammonia forming fertilisers when applied to flooded rice soils.

Daftadar (1973) observed that in rice under green house conditions, 7 to 19 per cent of applied urea was lost by denitrification. Nommik (1976) reported that the optimum pH for denitrification was in the range of 7-8. Reddy and Patrick (1978) recorded denitrification losses to a maximum of 63 per cent of added ammonium nitrogen in an intermittantly flooded soil. Studies in Japan indicated that nearly one third of the applied nitrogen was lost due to denitrification alone (Yamada et al., 1979).

Crasswell and Viek (1979b) have stated that nitrification was very sensitive to a number of ecological and environmental factors, while denitrification was regulated by temperature and the amount of organic substrate available to heterotrophic bacteria. Meelu (1980) concluded that N losses due to denitrification could vary from 24.1 to 53.7 per cent depending upon soil type, method and time of fertiliser application and source of fertiliser nitrogen. Mahapatra (1981) reported that nearly 14.4 per cent of N was lost due to denitrification.

2.3.2 Ammonia Volatilisation

It is the gaseous loss of nitrogen in the form of ammonia from the soil into the atmosphere. Ammonia, a nitrogen transformation product found continuously in wet land soils and also following application of ammonium forming fertilisers, is subject to volatilisation considerably. Sahrawat (1979) has explained the mechanism of volatilisation wherein urea, when surface applied, is hydrolysed quickly forming unstable ammonium carbonate and ammonium bicarbonate, resulting in ammonia volatilisation with increased pH.

While reviewing the N losses in rice soils, Sahrawat (1979) and De Datta (1981) have listed the important factors that influence ammonia volatilisation from soils are pH, CEC, texture, temperature, soil moisture, source of ammonium, rate and method of application. Incubation studies conducted by Rao and Lalita Batra (1983) showed that ammonia volatilisation was governed by pH/alkalinity of the system and losses were unchanged with variation in temperature from 20 to 40°C. The volatilisation losses of ammonia were more in light textured soils than in heavy soils (Gandhi and Paliwal, 1976).

Ammonia volatilisation losses may vary from 0.25 to 20.00 per cent depending on the method of nitrogen application (Mikkelsen and De Datta, 1979). They further stated that the potential for ammonia volatilisation depends on the flood water aqueous ammonia concentration which is influenced by fertiliser source and management. Vlek and Stumpe (1978) and Vlek and Crasswell (1979) pointed out that ammonia losses from broadcast urea were likely to be more because on hydrolysis, urea produces alkalinity in flood water. Deep placement and slow release fertilisers produced lower concentration of urea, NH_4^+N in the flood water and therefore, the N was less subjected to loss (Vlek and Crasswell, 1979). Mahapatra (1981) indicated that reduced conditions of flooded.soil favoured continuous production of ammonia and quantity in excess of the absorbing capacity of the flood water was lost through volatilisation, which may ranged from 9.7 to 22.7 per cent under field conditions. Sudhakara and Prasad (1986) observed that about 8.4 per cent of applied N was lost as ammonia during a week after application when prilled urea was broadcasted or blended and incorporated in soil 20 days after sowing and the volatilisation losses were reduced to 3.3 per cent with urea super granules (USG). Chauhan and Mishra (1989) observed that ammonia loss through volatilisation was highest from PU accounting for 19 to 20 per cent and 20 to 24 per cent of the applied N in 1983 and 1984, respectively.

2.3.3 Leaching

In flooded soils, movement of fertiliser N along with percolation water is a major problem. Leaching losses of N occur mainly on coarse textured soils with low CEC (Ten Have, 1971 and De Datta, 1981).

Leaching losses accounted for 69.5 per cent in light soils of Punjab depending upon the source, method and time of application of N (Meelu, 1980). Pillai (1978) stated that soil texture was an important variable determining the leaching losses which significantly influence the choice of a fertiliser for a particular soil type.

Lysimeter studies with rice grown on silty clay loam soils showed greater leaching losses through urea super granules (USG) as compared to prilled urea (PU). Leaching losses through deep placed USG were 17 per cent as compared to broadcasted and incorporated USG (14 per cent) and PU applied in 3 splits (11 per cent). Leaching was mainly through NH_4^+N and accounted for as much as 96 per cent of the total leaching losses (Singh and Singh, 1988).

Velu _et al_. (1988) reported that the leaching losses were 9.1 to 13 kg N ha^{-1} and 5.8 to 6.4 kg N ha^{-1} during Kuruvai (Jun-Sep) and Thaladi (Oct-Feb) seasons, respectively.

2.3.4 Surface Runoff

Nitrogen loss in surface water can be considerable depending on the method, source, time of application and rate of flow of water. However, there is limited information on the quantity of N loss by runoff from low land rice.

Singh _et al_. (1978) reported that the runoff losses of 4 to 16 kg N, 6 kg N, 19 to 30 kg N ha^{-1} under normal fertiliser management practices in Japan, Philippines and California, respectively. The loss of N fertiliser due to runoff can be minimised by holding the irrigation or rain on the field for 5 days after fertiliser application (De Datta, 1981).

2.3.5 Nitrogen Immobilisation

Jannson (1958) demonstrated that N in soils was subjected to concurrent mineralisation and immobilisation as the heterotrophic microflora consumed and excreted inorganic N during the decomposition of soil organic matter. Fertiliser N entering the inorganic N pool is, therefore, subject to biological interchange with soil organic fraction. Some amount of inorganic nitrogen applied to soil is subjected to interchange with soil organic fraction. Broadbent and Mikkelsen (1968) noticed more than half of the added 15_N in soil organic fraction and rice roots at the end of the pot experiment with paddy soils. Studies conducted at IRRI suggested that immobilisation of N was about 20 per cent of the nitrogen added for a Maahas clay soil (Yoshida and Padre, 1975).

2.3.6 Ammonium Fixation

Ammonium fixation in soils can take place under wet conditions and can be considered as beneficial phenomenon since it decreases nitrogen loss through denitrification, volatalisation, percolation and runoff. No clearcut evidence on the magnitude of ammonium fixation in flooded soils are available.

Broadbent (1978) concluded that the line of demarcation between exchangeable and fixed ammonium was somewhat superficial, and some of these discrepancies could be resolved if one realises that plants and microorganisms were able to extract and utilise this fixed ammonium. Crasswell and Vlek (1979a) stated that clay fixed ammonium will be available to plants and nitrifying microorganisms. De Datta (1981) while reviewing the ammonium fixation by clay minerals, concluded that the mechanism of fixation was not clearly understood and research with isotopically labelled nitrogen was needed to assess the importance of ammonium fixation in low land rice.

2.4 EFFECT OF UREA-BASED FERTILISERS

Fertiliser N is considered as the king pin of rice farming. Leaching and denitrification losses of fertiliser N have been most serious in low land rice. Inhibition or retardation of nitrification of applied ammonium and amide N can reduce these losses considerably, thus increasing N use efficiency in rice soils. Use of slow release N fertilisers and modified forms of urea are one of the promising techniques suggested.

The available state of knowledge on various aspects of the use of different N sources for low land rice is briefly reviewed hereunder.

2.4.1 Split Application of Prilled Urea (PU)

Application of nitrogen in split doses, synchronising with phenologically important phases of crop growth, which result in maximum utilisation of applied N is one of the major approaches now being widely practiced for increasing the fertiliser N use efficiency of rice. While reviewing the research work done on N use efficiency of rice, Pillai (1981) stated that the incorporation of basal nitrogen followed by the two top dressings each at tillering and a week before panicle initiation would be ideal for most of the rice growing areas of India. Similarly, application of N in three splits (1/3 basal + 1/3 at tillering + 1/3 at PIS) gave higher grain yield of rice than two splits (½ basal + ½ panicle initiation) or single application (Meelu, 1980).

2.4.1.1 Growth Characters: On sandy loam soils of Tirupati, split application of nitrogen at transplanting, maximum tillering and panicle initiation stages (50 + 25 + 25 kg N ha^{-1}) increased the plant height of Sona rice compared to entire 100 kg N ha^{-1} applied as basal (Ramamohana Rao et al., 1977). Increase in dry matter production of rice with split application of N was reported by Chandrasekhara Reddy (1979). Balasubramaniyan (1984) recorded maximum plant height of ADT 31 and ADT 36 rice with application of urea in three splits viz., 50 per cent as basal, 25 per cent at tillering and remaining 25 per cent at panicle initiation.

Nageswara Rao _et al_. (1985) reported that higher number of effective tillers m^{-2} was observed with nitrogen application in three splits (1/3 each at 10 days after planting, maximum tillering and panicle initiation).

Application of 24 kg N ha^{-1} at transplanting and 24 kg N ha^{-1} each at tillering and panicle initiation increased the plant height and tiller number (Singh and Singh, 1986).

Wagh and Thorat (1987) reported that the crop fertilised with 50 per cent of N eight days after transplanting, 30 per cent at maximum tillering and 10 per cent each at primordial initiation and at flowering stages had highest dry matter.

2.4.1.2 _Yield Attributes and Yield_. Chandrasekhara Reddy _et al_. (1979) and De Datta (1981) stated that split application of nitrogen increased the number of panicles and other yield attributing characters in low land rice.

Choubey _et al_. (1985) reported that application of 60 kg N at seven days after planting, 30 kg N at tillering and 30 kg N at booting stage in the form of urea gave significantly higher grain yield at Jabalpur.

More number of panicles (256 m^{-2}) and spikelets (147 $panicle^{-1}$) and tillers (297 m^{-2}) at harvest was observed when nitrogen was applied in three splits i.e. 20 kg at basal, 40 kg at active tillering and 20 kg at panicle initiation (Akanda et al.,1986).

Wagh and Thorat (1987) reported split application of N (50 per cent at eight days after transplanting, 30 per cent at tillering and 10 per cent each at primordial initiation and flowering stages) gave significantly higher number of panicles compared to basal application of entire nitrogen in IR 64 rice.

From fertiliser trials, Patel (1982) concluded that application of 100 kg N ha^{-1} in four equal splits at transplanting, active tillering, maximum tillering and panicle initiation stage produced higher grain and straw yield on medium textured soils of Kaira.

Nageswara Rao et al. (1985) recorded the higher grain yield of 6.3 t ha^{-1} with 1/3 N applied at 10 days after planting, 1/3 at maximum tillering and 1/3 at panicle initiation.

Experiments conducted by Purushothan et al. (1987) indicated that yield components and grain yield of low land rice were increased significantly with the application of 33 per cent nitrogen after last puddling and the remaining nitrogen in two equal splits at tillering and panicle initiation.

Highest grain yield of 3.3 t ha^{-1} was obtained with 50 + 30 + 10 + 10 kg N ha^{-1} applied at eight days after transplanting, maximum tillering, primordial initiation and flowering stages, respectively (Wagh and Thorat, 1987).

2.4.1.3 Uptake and Recovery of Applied Nitrogen. Pillai and Rajat De (1979) recorded 65 per cent recovery of nitrogen when it was applied in three splits i.e., 50 per cent of N at transplanting and the rest top dressed in two equal applications at panicle initiation and boot stage as against 51 per cent when entire nitrogen was applied basally on sandy loam soils of Delhi.

Sahrawat (1980) obtained 3.5 and 18.5 per cent increase in nitrogen uptake and apparent recovery of applied nitrogen, respectively with IR 8 rice due to two splits ($\frac{1}{2}$ at transplanting + $\frac{1}{2}$ at panicle initiation) when compared to basal application of entire nitrogen.

Maximum N uptake (86.5 kg ha^{-1} and 90.2 kg ha^{-1} in 1981 and 1982, respectively) was noted where urea was applied in four splits i.e., $\frac{1}{4}$ basal and $\frac{1}{4}$ each at 20, 40 and 60 days of transplanting (Singh, 1987).

2.4.2. Large Granule Urea (LGU)

Granules of LGU are of the size 6 to 8 mm whereas, USG are of the size 10 to 15 mm and both are substantially larger than the conventionally used prilled urea. The advantage of LGU is that it will facilitate more uniform application in the field compared to USG. Very limited research work has been carried out with LGU and few available research findings are presented.

Fertiliser trials conducted in Netherlands showed that with penetration of LGU in to the mud, a significant decrease of ammonia volatilisation was observed when compared to prilled urea (Koole, 1987).

Factors affecting penetration as indicated in the model study of Prins and Raats (1989), include size of granule, rate of fall, water film on the puddled soil and penetrability of the soil.

Experiments showed that the efficiency of broadcasted urea may be increased by using LGU instead of PU, at least if conditions are favourable for penetration into the soil (Prins and Rauw, 1989).

2.4.2.1 Growth Characters. Fertiliser trials conducted at Regional Agricultural Research Station, Nandyal, Andhra Pradesh indicated that highest plant height of 101 cm was with LGU at 120 kg N ha^{-1} applied in three splits (½ basal + ¼ at tillering + ¼ at panicle initiation) and it was on par with prilled urea applied in three splits, LGU applied as all basal or LGU applied in two splits (½ basal + ½ at tillering) at 120 kg N ha^{-1} (RARS, Nandyal, 1987).

Studies conducted at Agricultural Research Station, Nellore, Andhra Pradesh revealed that the highest plant height was with basal application of LGU and this was on par with two equal splits of LGU (½ basal + ½ panicle initiation) and three equal splits of PU (1/3 basal + 1/3 at tillering + 1/3 at panicle initiation) (ARS, 1987).

2.4.2.2 Yield Attributes and Yield. Darvesh Saheb (1987) reported the application of 100 kg N ha^{-1} as LGU in three equal splits (1/3 at planting + 1/3 at tillering + 1/3 at panicle initiation) was on par with three splits of PU in panicles m^{-2} and number of filled grains panicle^{-1} and was superior to basal application of LGU.

Govindu (1988) and Karuna Sagar (1989) obtained increase in panicle number, number of productive tillers hill^{-1}, panicle weight, panicle length and test weight with LGU over PU. However, significant increase in yield components was not observed due to basal application of LGU over split application of PU (Balaswamy, 1988).

In Food and Agriculture Organisation supported project, 4 to 6 mm sized urea granules were compared with prilled urea. The granular urea gave 11 per cent increase in grain yield compared to prilled urea (FAO, 1980). Travis (1980) reported eight per cent higher grain yield of rice with urea granules of 4 to 6 mm size over prilled urea, when both were broadcasted. This was attributed to a possible deeper penetration of granular urea into the puddled soil of rice field thereby the ammonia volatilisation losses were minimised.

Saleem et al. (1983) recorded the highest grain yield (6.58 t ha^{-1}) with LGU split application (½ basal + ½ top dressed at panicle initiation) when compared to basal application of LGU (5.89 t ha^{-1}). Field experiments from Malong, Indonesia showed that when broadcasted, urea granules (6 to 8 mm) gave 20 per cent increase in grain yield over urea split application at 46 kg N ha^{-1} (Prins et al., 1984).

At Maruteru, LGU applied either as basal or in three splits (1/3 basal + 1/3 at maximum tillering + 1/3 panicle initiation) gave significantly higher grain yield than similar application through PU (DRR, 1987).

Darvesh Saheb (1987) recorded the highest grain and straw yield with LGU in three splits (1/3 at planting + 1/3 at tillering + 1/3 at PIS) and this was significantly superior to PU in three splits (1/3 at planting + 1/3 at tillering + 1/3 at PIS) or basal application of entire LGU.

Studies conducted at Nellore, Andhra Pradesh revealed that grain yield obtained with two splits of LGU (½ basal + ½ at panicle initiation) was on par with three splits of PU i.e., 1/3 each at basal, tillering and panicle initiation stages (ARS, 1987).

Govindu (1988) obtained significant increase in grain and straw yield with application of LGU over PU. The increase in grain and straw yield due to LGU over no nitrogen were 78.9 and 83.2 per cent, respectively and 10.4 and 8.8 per cent increase in grain and straw yield over PU, respectively.

Balaswamy (1988) observed significant increase in grain and straw yield due to split application of PU (½ basal + ¼ at tillering + ¼ at panicle initiation) over basal application of LGU.

2.4.2.3 <u>Uptake and Recovery of Applied Nitrogen</u>. At Maruteru, LGU application in three splits (1/3 basal + 1/3 at maximum tillering + 1/3 at panicle initiation) recorded the highest nitrogen uptake of 100.6 kg ha^{-1} which was superior to PU basal (96 kg N ha^{-1}) but was on par with similar split application of PU (DRR, 1987).

Govindu (1988) recorded a total nitrogen uptake of 89.4 kg ha^{-1} with LGU as against 78.2 kg ha^{-1} with PU. The per cent increase in nitrogen uptake due to LGU over PU was 14.4.

Rabindra *et al* (1989) observed the application of LGU in two splits (66 per cent at transplanting + 33 per cent at tillering) appeared to be the best practice in uptake of N and lower loss of fertiliser N through volatilisation and leaching compared to the recommended practice of urea (50 per cent as basal, 25 per cent at tillering and 25 per cent at panicle initiation).

Prins and Rauw (1989) stated that the LGU placed at 1 cm and 4 cm depth resulted significantly higher N uptake by grain and straw than PU placed at 0 cm depth, LGU placed at 0 cm depth, LGU dropped and LGU shot with force in the puddled soil. The apparent recovery of N in grain and straw increased from 61 to 85 per cent in the order PU + 0 cm, LGU + 0 cm, LGU dropped, LGU-1 cm, LGU shot and LGU-4 cm.

2.4.3 Rock Phosphate Coated Urea (RPCU) and Gypsum Coated (GCU)

Recently, Madras fertilisers Ltd., have come out with two indegenous products viz., rock phosphate coated urea (RPCU) and gypsum coated urea (GCU). The information available on these two coated urea fertilisers are reviewed below.

Budhar *et al.* (1987) observed that the grain yield obtained with USG (60.75 q ha^{-1}) was comparable with GCU (56.25 q ha^{-1}).

A field experiment conducted during wet season of 1985-86 at the Regional Research Station, Mandya revealed that RPCU, PU (three splits) and PU (two splits) were at par with respect to grain yield (Setty *et al.*, 1987).

While working with medium duration varieties, Subbaiah and Sharma (1987) reported that USG at 90 kg N ha^{-1} gave significantly superior grain yield followed by RPCU and GCU, where the latter two were at par.

Subbaian *et al.* (1988) reported that basal application of RPCU and USG recorded highest grain yield of 6570 and 6575 kg ha^{-1}, respectively which were on par with recommended urea split application (6553 kg ha^{-1}). Significant increase in grain yield due to RPCU over GCU and PU was reported by Ananda Rao (1988).

A field experiment conducted in Meghalaya and Manipur with rice varieties 'R-292-5258' and Prasad concluded that RPCU was a better source of N on Haplaquent soil of Meghalaya, whereas RPCU and GCU were suitable N sources on clay soil (Histisols of Manipur). RPCU found superior to all the sources of N at both the locations. It was further observed that under high-rainfall area of north-eastern hills region, particularly in Meghalaya, RPCU applied 50 per cent as basal and 50 per cent at panicle initiation further increased the grain yield (Patel and Singh, 1990).

2.4.4 Neemcake Blended Urea (NBU)

Denitrification loss of fertiliser N has been most serious in low land rice. Inhibition or retardation of nitrification of applied ammonium and amide N can reduce these losses considerably. Santhi et al. (1986) reported that the application of neem products like neem leaf and neem cake to wetland soil did not have any adverse effect on the population of heterotrophic microflora, nitrifying bacteria, on the other hand, decreased significantly due to addition of neem cake and fresh and dried neem leaf with urea.

Sarkunan and Biddappa (1980) reported that NBU(urea blended with neem cake @ 30 per cent by weight) application favoured the production of NH_3 and NO_2, whereas nitrate formation was significantly inhibited.

Thomas and Prasad (1982) observed that there was a progressive increase in the ammonium retained in the soil as the amount of neem cake for mixing was increased.

Bains et al. (1971) obtained significant increase in number of panicles per unit area, 1000 grain weight and number of filled grains panicle^{-1} due to neem seed crush mixed urea over ordinary urea. Yield increase of 369 kg ha^{-1} was obtained by Ketkar (1974) with NBU (urea blended with neem cake @ 20% by weight) over untreated urea in acid soils and 397 kg increased yield ha^{-1} in neutral soils at 100 kg N ha^{-1} level.

Harishankar <u>et</u> <u>al</u>. (1976) reported that grain yield was increased when neem cake was blended with urea (@ 20% of the weight of urea) over untreated urea in transplanted rice.

Katti <u>et</u> <u>al</u>. (1976) obtained significant higher grain yield of rice (53.3 q ha^{-1}) with the application of 100 kg N as urea + 33 kg neem cake than the application of 100 kg N ha^{-1} as urea alone (50.6 q ha^{-1}).

There was 22 per cent increase in grain yield of rice due to the application of NBU (urea was blended with 25 kg of neem cake per hectare). This has been mainly attributed to increased number of productive tillers hill^{-1}, number of grains panicle^{-1} and lowest spikelet sterility (Subramanian <u>et</u> <u>al</u>., 1979).

Nayak <u>et</u> <u>al</u>. (1981) reported that NBU (Urea mixed with neem cake powder at 10 per cent by weight) gave the highest grain yield of low land rice at Bidhan Chandra Krishi Viswa Vidhyalaya, Nadia, West Bengal. Rabindra and Rajappa (1981) concluded that NBU (urea mixed with neem cake @ 30%

by weight) saved nitrogen fertiliser to the extent of 20 per cent and increased the yield upto 15 per cent over PU. Similar results were obtained by Singh and Vijay Kumar (1982).

Ravikumar et al. (1986) observed increased yield of direct seeded rice with 80 kg N ha^{-1} as NBU (urea mixed with neem cake @ 10% by weight) over untreated urea. Patil et al. (1987) obtained maximum grain yield with NBU (urea mixed with neem cake powder@ 20% by weight) and lack coated urea and higher N uptake with NBU than with conventional urea.

Darvesh Saheb (1987) reported that grain yield and N uptake was significantly increased with NBU (1:1 proportion) split application (three equal splits at planting, tillering and panicle initiation) compared to similar split application of PU.

2.4.5 Combined Application of Green Leaf Manure + Prilled Urea (Glm + PU)

As a measure against unforseen losses of nitrogen, integrated use of nitrogen through organic and inorganic sources would bring better stability in nitrogen use (De Datta, 1981). Combined application of organic and inorganic sources of nitrogen has been suggested as a measure of minimising the loss and increasing the efficiency of applied nitrogen under flooded conditions (Ten Have, 1971).

Application of 90 kg N ha^{-1} of which 50 per cent was supplemented with green leaf manure was found highly beneficial (Saravanan et al., 1987).

Dhane et al. (1989) obtained increased yield from 3.0 t ha^{-1} when PU (two equal splits broadcast at tillering and top dressed at panicle initiation) was applied alone to 3.5 t ha^{-1} when PU was applied in combination with gliricidia @ 2.5 t ha^{-1}.

It has been found that on lateritic soil, out of the present requirement of fertiliser N (100 kg ha^{-1}) for low land rice, 50 per cent can be supplemented through green leaf manure. This was possible by application of 5 tonnes of fresh gliricidia leaf (one tonne dry matter) supplying 27 kg nitrogen as basal application just before transplanting of rice and 50 kg fertiliser N (Urea 46 per cent N) in two equal splits along with 50 kg P_2O_5 ha^{-1} as basal. It was also noteworthy that increasing the rate of gliricidia alone from 5 to 10 t ha^{-1} was not effective in increasing the yield of rice substantially (Patil, 1989).

Padalia et al. (1989) reported that sesbania green leaf manure along with inorganic nitrogen fertiliser on 50:50 N basis has been found to improve considerably the N-use efficiency.

Approximately the above review indicates that 50 per cent of the fertiliser N required for low land rice can be supplemented through the application of green leaf manure.

2.4.6 Combined Application of Farm Yard Manure and Prilled Urea (FYM + PU)

Experiments conducted by Meelu and Rekhi (1981) indicated that combined use of 12 t FYM and 80 kg N ha^{-1} as PU gave as much rice yield as with the application of 120 kg N ha^{-1}, thus effecting a saving of 40 kg N ha^{-1}.

The efficiency of urea and urea-based fertilisers with respect to grain yield and nitrogen transformation in soil was studied under field conditions. USG, NCU and FYM + urea gave comparable grain yield, but production efficiency of N was higher with NCU and FYM + urea (Mohapatra *et al*.,1983).

In a long term fertiliser cum manurial experiment on paddy - wheat cropping sequence, application of N and FYM increased the yield of crops and response was observed upto 120 kg N ha^{-1} both in absence and in presence of FYM, though the yields were higher in presence of FYM (Kaushik *et al*., 1984).

Field experiments conducted to study the effect of combined use of FYM and urea revealed that the application of 30 kg N ha^{-1} in the form of FYM at puddling and 30 kg N ha^{-1} as urea at planting gave grain yield comparable to that of 60 kg N ha^{-1} as urea applied in 3 splits (Khan *et al*., 1986).

In field experiments conducted during the rainy seasons of 1985 and 1986 at Khargpur, India, the growth and yield of low land rice cv. IR 20 and Ratna was increased significantly with combined use of FYM and N fertiliser in an acid lateritic soil (Sharma and Mitra, 1988).

Highest N uptake (110 kg ha^{-1}) of rice was recorded on red loamy soils of Hyderabad with 100 per cent N (dose based on soil test) in conjunction with 10 t FYM ha^{-1} against the N uptake of 77 kg ha^{-1} with 100 per cent N dose applied (AICRPLTFE, 1984). Thus, FYM seemed to be superior to chemical fertiliser over a period of time.

Apparant N utilisation efficiency of rice under continuous use of N alone and NPK plus FYM was studied on red loamy soils of Hyderabad (AICRPLTFE, 1984). The results indicated that N use efficiency of rice with N alone treatment was 26 per cent and the corresponding figure with N plus FYM was 52 per cent.

From the foregoing review, it could be inferred that for rice crop grown under submergence, split application of N, in general was superior to basal application. Possibility of combining organic and inorganic N sources for successful and profitable rice production is well established. Split application of large granule urea (LGU) was found beneficial over all other modified forms of urea in increasing the total N uptake and N use efficiency. Neem cake blended urea (NBU) was found superior to prilled urea in increasing the fertiliser N use efficiency.

There is a lacuna in the current state of knowledge regarding the use of different modified urea fertilisers viz., GCU, RPCU which are being tried recently in India on low land rice. It is in this context the present investigation was taken up to study the effect of different urea-based fertilisers on lowland rice.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

In this chapter, the materials used and the methods followed during the course of the present investigation are briefly described.

3.1 DETAILS OF THE EXPERIMENTAL SITE

3.1.1 Location

The present experiment entitled "Effect of urea-based fertilisers on growth and yield of rice" was conducted during Kharif season of 1989 at the Tirupati Campus of Andhra Pradesh Agricultural University which is situated at an altitude of 189.2 m above mean sea level on 79°E longitude and 13°N latitude.

3.1.2 Soil Properties

The experiment was conducted on a sandy loam soil. The field was uniform in level and fertility. The physico-chemical properties of the top 20 cm soil was furnished in Table 1. The soil was low in available N and medium in phosphorus and potassium.

Table 1. Physico-chemical properties of the soil of the experimental field

Particulars	Values	Method adopted
MECHANICAL ANALYSIS		
Coarse sand (%)	19.2	Bouyoucos Hydrometer (Piper, 1950)
Fine sand (%)	45.3	
Silt (%)	21.1	
Clay (%)	14.4	
Soil texture	Sandy loam	
CHEMICAL ANALYSIS		
Soil p^H (1:2 soil water suspension)	7.9	p^H meter (Jackson, 1967)
EC (m mhos cm^{-1} at 25°C)	0.23	Solubridge method (Piper, 1950)
Available N (kg ha^{-1})	214	Macro kjeldahl method (Subbaiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	23	Olsen's method (Olsen *et al.*, 1954)
Available K_2O (kg ha^{-1})	144	Flame photometry (Jackson, 1967)

3.1.3 Cropping History of the Experimental Plot

Details of cropping pattern during the preceding years are given below.

Year	Kharif	Rabi	Summer
1987-88	Groundnut	-	-
1988-89	Groundnut	-	-
1989-90	Present Experiment		

3.2 WEATHER DURING THE CROP PERIOD

The weather data pertaining to the crop period recorded at S.V. Agricultural College Meteorological Observatory, Tirupati are presented in Table 2 and depicted in Fig. 1.

During the crop period a total amount of 267.6 mm rainfall was received in 20 rainy days. The weekly mean maximum and minimum temperatures during the crop growth period ranged from 31.7°C to 37.4°C and 20.2°C to 25.6°C with an average of 34.6°C and 23.5°C, respectively. The weekly mean wind velocity ranged from 4.4 kmph to 17.6 kmph with an average of 11.6 kmph. The weekly mean relatively humidity ranged from 40 per cent to 74.5 per cent with an average of 57.8 per cent. The weekly mean bright sunshine hours ranged from 2.8 to 9.3 with an average of 6.3 per day. During the crop period the evaporation from the USWB class A

Table 2. Weather during the crop period (24.06.89 to 19.10.89)

Standard week	Date	Mean weekly temp. (°C)		Rain RH (%)	Wind velocity (kmph)	Sunshine hrs per day	Rainfall (mm)	Rainy days	Evaporation mm day^{-1}
		Max.	Min.						
25	18.6-24.6	37.4	25.3	43.0	14.7	7.4	5.4	1	8.7
26	25.6-1.7	36.9	25.1	40.0	16.7	6.2	-	0	9.8
27	2.7-8.7	36.8	24.0	45.5	16.8	6.0	6.4	1	7.3
28	9.7-15.7	34.9	23.1	64.5	11.1	7.8	42.4	2	7.4
29	16.7-22.7	31.7	23.7	65.5	14.2	4.1	45.6	3	5.8
30	23.7-29.7	32.5	23.2	61.0	13.4	3.7	2.0	0	5.0
31	30.7-5.8	34.7	24.5	53.5	14.0	9.3	4.9	1	8.2
32	6.8-12.8	35.2	25.6	48.5	16.8	7.2	0.0	0	9.6
33	13.8-19.8	33.7	24.0	57.5	17.6	2.8	2.8	1	7.2
34	20.8-26.8	35.3	25.6	51.5	16.6	3.9	0.0	0	8.9
35	27.8-2.9	36.1	25.2	51.0	11.9	6.9	0.0	0	8.9
36	3.9-9.9	36.4	24.4	51.5	8.5	8.0	0.0	0	8.0
37	10.9-16.9	35.6	25.5	54.5	14.0	6.1	0.0	0	10.0
38	17.9-23.9	33.5	22.9	73.5	5.7	5.8	95.6	3	5.1
39	24.9-30.9	32.4	22.1	74.5	6.1	3.9	43.9	5	3.8
40	1.10-7.10	32.2	21.5	71.0	6.2	6.5	9.8	2	3.9
41	8.10-14.10	33.3	21.2	73.5	4.4	6.2	8.8	1	4.8
42	15.10-21.10	35.0	20.2	56.5	4.8	9.3	0.0	0	5.3
43	22.10-28.10	33.0	20.2	61.0	7.0	7.7	0.0	0	5.8

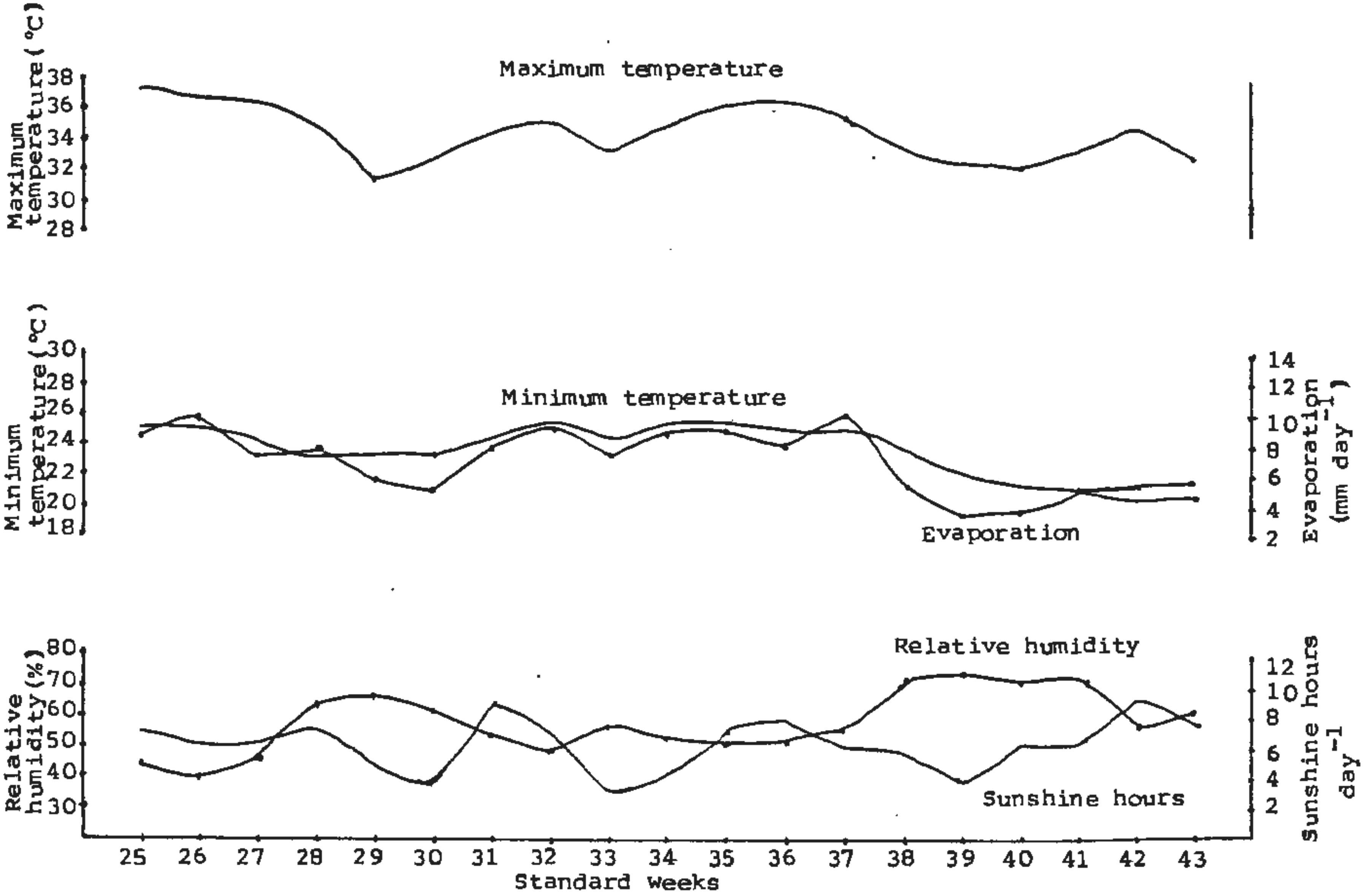


Fig.1 Weekly Meteorological Data During Crop Period

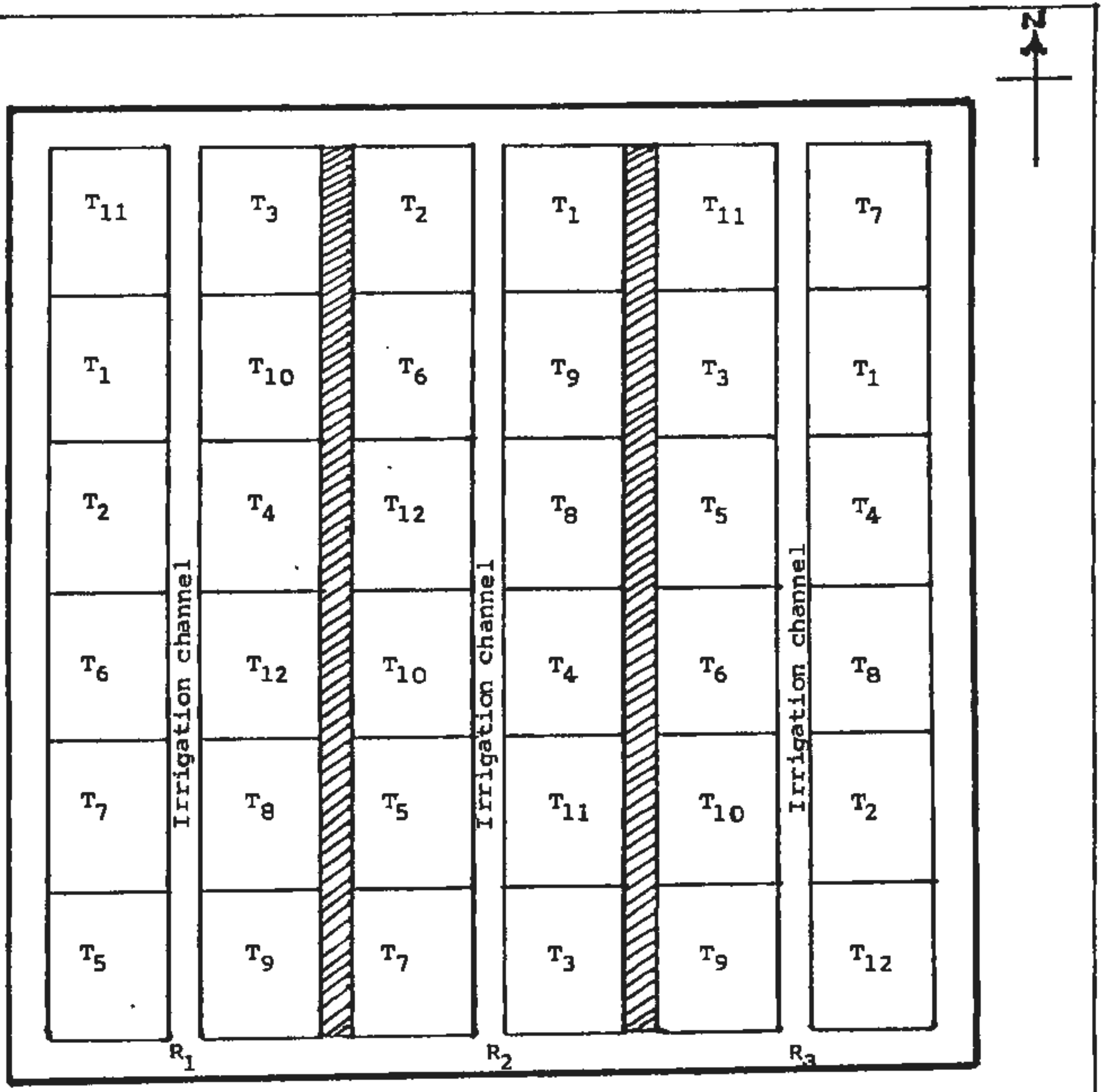
pan evaporimeter ranged from 3.9 mm to 10.0 mm with an average of 7.0 mm per day.

Weather conditions during the crop period were favourable for growth and development.

3.3 EXPERIMENTAL DETAILS

3.3.1 Design and Layout

The experiment was laid out in a Randomised Block Design with twelve treatments and replicated thrice. The gross and net plot sizes were 3.5 x 4.2 m (14.7 m^2) and 2.9 x 3.5 m (10.0 m^2), respectively. Layout plan is given in Fig. 2.



TREATMENTS

T_1 : Control (no nitrogen)
T_2 : PU split (½ basal + ¼ AT + ¼ PIS)
T_3 : FYM (½ N) Basal + PU (½N) ¼ AT + ¼ PIS)
T_4 : Glm (½N) Basal + PU (½N) ¼ AT + ¼ PIS
T_5 : RPCU basal
T_6 : LGU basal

T_7 : NBU basal
T_8 : GCU basal
T_9 : RPCU split (½ basal + ½ PIS)
T_{10} : LGU split (½ basal + ½ PIS)
T_{11} : NBU split (½ basal + ½ PIS)
T_{12} : GCU split (½ basal + ½ PIS)

Design : RBD
Replications : 3
Plot size : Gross : 3.5 x 4.2 m
Net : 2.9 x 3.5 m
Spacing : 15 x 10 cm

Variety : NLR 13969
N dose : 100 kg N ha^{-1} to all N applied treatments

Fig 2. LAYOUT OF THE EXPERIMENTAL FIELD

3.3.2 Treatments

T_1 Control (no nitrogen)

T_2 Prilled Urea (PU) split application ($\frac{1}{2}$ basal + $\frac{1}{4}$ at active tillering + $\frac{1}{4}$ at panicle initiation)

T_3 Farm yard manure (FYM) + PU -($\frac{1}{2}$ N through FYM as basal + $\frac{1}{2}$ N through PU in two equal splits at active tillering and panicle initiation).

T_4 Green leaf manure (Glm) + PU - $\frac{1}{2}$ N through Glm as basal + $\frac{1}{2}$ N through PU in two equal splits at active tillering and panicle initiation.

T_5 Rock phosphate Coated Urea (RPCU) - basal.

T_6 Large Granule Urea (LGU) - basal.

T_7 Neem cake Blended Urea (NBU) - basal.

T_8 Gypsum Coated Urea (GCU) - basal.

T_9 RPCU - split ($\frac{1}{2}$ basal + $\frac{1}{2}$ at panicle initiation).

T_{10} LGU - split ($\frac{1}{2}$ basal + $\frac{1}{2}$ at panicle initiation).

T_{11} NBU - split ($\frac{1}{2}$ basal + $\frac{1}{2}$ at panicle initiation).

T_{12} GCU - split ($\frac{1}{2}$ basal + $\frac{1}{2}$ at panicle initiation).

A recommended dose of 100 kg N ha^{-1} was uniformly adopted in all the treatments except control.

FYM (0.48% N) and fresh leaves of gliricidia (*Gliricidia maculata*) containing 0.49 per cent N on wet basis were incorporated one week before transplanting as per treatments T_3 and T_4 respectively.

The prilled urea and LGU contain 46 per cent N, gypsum coated urea contain 36.8 per cent N, 4.6 per cent Ca and 3.6 per cent S and rock phosphate coated urea contain 36.5 per cent N and 5.1 per cent P_2O_5.

Neemcake blended urea (NBU) was prepared by mixing the urea and finely powdered neem cake in 1:1 ratio in a plastic bucket. The contents were shade dried for 24 hours before the application. Neem cake had 2 per cent N and the amount of N present in neem cake was not deducted in the fertiliser NBU.

All different forms of urea including PU were applied by broadcasting and time of application was as per the treatments.

A common dose of 60 kg P_2O_5 ha^{-1} in the form of single super phosphate, 40 kg K_2O ha^{-1} in the form of muriate of potash and 25 kg $ZnSO_4$ ha^{-1} were applied for all the treatments at the time of planting. As rock phosphate coated urea contained 5.1 per cent P_2O_5 and where this form of urea was used, the level of P was adjusted to give only 60 kg P_2O_5 to these plots also including the 5.1 per cent P_2O_5.

3.3.3 Variety

NLR 13969 was used as a test variety which was released by the Agricultural Research Station, Nellore, Andhra Pradesh. It is a short duration variety (105 days) with an yield potential of 6 t ha^{-1}. It is suitable for both wet and dry seasons. It is resistant to blast, bacterial leaf blight and leaf spot. It is a fine quality variety with medium slender grain.

3.4 CULTIVATION DETAILS

3.4.1 Preparatory Cultivation

3.4.1.1 Nursery. The nursery area was thoroughly puddled and levelled. The seeds of NLR 13969 were soaked in water for 24 hours and incubated for 36 hours in moist gunny bag for germination. The sprouted seeds were broadcasted uniformly over the well prepared seed bed.

3.4.1.2 Main Field Preparation. The main field was ploughed twice with mould board plough. Then the field was flooded and puddled with a country plough thrice. Later by using a wooden plank levelling was done. Individual plots were levelled with spade. Twenty eight day old seedlings were transplanted in the main field at two to three seedlings per hill adopting a spacing of 15 x 10 cm.

3.4.2 After Cultivation

The calender of operations was presented in appendix A. The following after cultivation operations were adopted to the rice crop.

3.4.2.1 Irrigation. A thin film of 2-3 cm water was maintained constantly till the establishment of seedlings. Thereafter water level in the field was maintained at a depth of 5 ± 2 cm during the entire crop period except at the time of fertiliser application. Water was gradually drained out near maturity.

3.4.2.2 Weed and Pest Management. Hand weeding was done once at 20 days after transplanting. There was no incidence of any major pest or disease during the crop growth period.

3.4.2.3 Harvesting and Threshing. The border rows were harvested first and treated as bulk. Later, the crop from net plot was separately harvested treatment wise and threshed. The grain was dried, cleaned and weighed separately for each net plot. The straw from each net plot was dried in the sun and weights recorded.

3.5 OBSERVATIONS

For recording plant height, total tillers per hill, five hills were randomly selected and labelled with tags.

3.5.1 Pre-harvest Observations

3.5.1.1 Plant Height (cm). Plant height was measured in cm from ground level to the tip of the tallest leaf (before flowering) and upto the tip of the tallest panicle (from flowering) of the hill.

3.5.1.2 Number of Green Leaves per Hill. Five hills were uprooted carefully from the destructive sampling area and these plants were utilised for studying leaf number, dry matter production&leaf area. Number of green leaves per hill was counted at tillering, panicle initiation, flowering and maturity.

3.5.1.3 Total Tiller Production (m^{-2}). Number of tillers was counted from 5 randomly selected sample hills at tillering, panicle initiation and flowering stages and were converted into number of total tillers m^{-2}.

3.5.1.4 Dry matter Production ($g\ m^{-2}$). The five hills uprooted were partitioned into culm, leaf sheath, leaf blade and panicle at tillering, panicle initiation, flowering and maturity. Individual plant components were dried in hot air oven at $60^{\circ}C$ till constant weight was obtained and their weights were recorded.

3.5.1.5 Leaf Area Index (LAI). The leaf area index was calculated by dividing the total leaf area with corresponding land area with the help of the following formula.

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Unit land area}}$$

3.5.1.6 Net Assimilation Rate (NAR). The mean net assimilation rate during crop growth period of the plant in different treatments was calculated according to Enyi (1962).

$$\text{NAR} = \frac{(W_2-W_1) - (\log_e L_2 - \log_e L_1)}{(t_2-t_1)\ (L_2-L_1)}\ \text{g cm}^{-2}\ \text{day}^{-1}$$

Where W_1 and W_2 represent dry weights and L_1 and L_2 represent leaf areas of plants at times t_1 and t_2, respectively.

3.5.1.7 Crop Growth Rate (CGR). The crop growth rate was calculated as suggested by Buttery (1970).

$$\text{CGR} = \frac{W_2-W_1}{t_2-t_1}\ \text{g m}^{-2}\ \text{day}^{-1}$$

Where W_1 and W_2 represent dry weights at times t_1 and t_2, respectively.

3.5.1.8 Relative Growth Rate (RGR). The relative growth rate was calculated as suggested by Enyi (1962).

$$\text{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2-t_1}\ \text{mg g}^{-1}\ \text{day}^{-1}$$

Where W_1 and W_2 represent dry weights at times t_1 and t_2, respectively.

3.5.1.9 Days to 50 per cent Flowering. The number of days taken from sowing to time when 50 per cent of the plants show anthesis recorded as 50 per cent to flowering.

3.5.1.10 Days to Maturity. The crop was considered mature when the grains in the lower rachis of the panicle have passed soft dough stage and when the straw turned yellow. Number of days taken from sowing to this stage was considered as days to maturity.

3.5.1.11 Panicles m^{-2}. The number of panicles from five randomly selected hills was recorded at the time of maturity and panicle density m^{-2} was computed.

3.5.2 Post Harvest Observations

Ten panicles were randomly selected for recording panicle length, panicle weight, filled grains per panicle and spikelet sterility.

3.5.2.1 Panicle Length (cm). The length from the last node to the tip of panicle was recorded as length of the panicle and expressed in cm.

3.5.2.2 Panicle Weight (g). The ten panicles collected from ten randomly selected hills from each treatment were weighed and the average panicle weight was recorded in grams.

3.5.2.3 Number of Filled Grains Panicle^{-1}. The number of filled grains on ten randomly selected panicles was counted and expressed as number of filled grains per panicle.

3.5.2.4 Spikelet Sterility. The number of unfilled grains of ten randomly selected panicles was counted. The spikelet sterility was calculated by using the following formula.

$$\text{Spikelet sterility (\%)} = \frac{\text{Total number of unfilled grains}}{\text{Total number of grains}} \times 100$$

3.5.2.5 1000-grain Weight (g). Three composite samples of each 1000 grains were drawn from the produce of each treatment and weights of these samples were recorded. The average was calculated and expressed as 1000-grain weight in grams.

3.5.2.6 Grain Yield (kg ha^{-1}). Grain from the net plot was thoroughly sun dried, weighed and expressed in kg ha^{-1}.

3.5.2.7 Straw Yield (kg ha^{-1}). Straw obtained from the net plot was thoroughly sun dried, weighed and expressed as straw yield in kg ha^{-1}.

3.5.2.8 Harvest Index (HI). The relationship of economic yield to the total biological yield was estimated by dividing the economic yield (grain yield) by the biological yield (grain + straw) and expressed in percentage as 'Harvest Index'.

3.6 CHEMICAL ANALYSIS

3.6.1 Ammonia Volatilisation Losses

Ammonia volatilisation losses under field conditions were estimated in a closed chamber with polythene sheet (0.5 x 0.5 x 0.5 m). In the chamber a petridish containing 100 ml of 0.1NH_2SO_4 was kept. Care was taken that the petridish was kept well above the water surface. The ammonia absorbed in H_2SO_4 was determined by micro-kjeldahl method. The contents of the petridish were analysed for N. The cumulative loss of N as ammonia volatilisation was computed upto 15 days after fertiliser application.

3.6.2 Plant Analysis

The plant samples collected for dry matter estimation at tillering, panicle initiation, flowering and maturity were ground into fine powder and used for chemical analysis. For calculating nutrient uptake at harvest, nutrient content of grain and straw (analysed separately) was multiplied with respective dry weights of grain and straw and summed up.

The N content of plant samples was estimated by micro kjeldahl method (Humphries, 1956) and uptake was estimated by multiplying the nutrient content with dry matter yield and expressed as kg ha^{-1}. Phosphorus and potassium were estimated by Vanadomolybdate and flame photometer methods, respectively (Jackson, 1967) and uptake was expressed as kg ha^{-1}.

3.6.3 Apparant N Recovery

Apparant recovery of applied N (%) was calculated by using the formula given below.

$$\frac{\text{N uptake in particular treatment (kg ha}^{-1}\text{)} - \text{N uptake in control (kg ha}^{-1}\text{)}}{\text{Amount of N (kg ha}^{-1}\text{) applied as per the treatment}} \times 100$$

3.6.4 Response to N

Response to nitrogen (increase in grain yield per kg of nitrogen applied) was worked out by using the following formula.

$$\text{Response} = \frac{yt - yo}{At}$$

Where yt and yo are grain yields of treatment and control, respectively and At is the amount of nitrogen applied in treatment 't'.

3.7 ECONOMICS

Gross returns, net returns and net returns per rupee invested on nitrogen fertiliser were calculated based on cost of cultivation details and the input purchase and produce sale records available at the S.V. Agricultural College Farm, Tirupati.

3.8 STATISTICAL ANALYSIS

The experimental data were analysed by method of analysis variance outlined by Panse and Sukhatme (1978). The level of significance used in 'F' test was at 5 per cent level of probability. The results were diagrammatically presented for clarity wherever necessary.

RESULTS

CHAPTER IV

RESULTS

The results of the experiment entitled "Effect of urea-based fertilisers on growth and yield of rice" are presented in this chapter. The normal practice of the farmer is the split application of prilled urea in three equal splits at basal, tillering and panicle initiation stages. Since the losses are more with prilled urea, it is modified into different forms like rock phosphate coated urea (RPCU), large granule urea (LGU), neem cake blended urea (NBU), gypsum coated urea (GCU) and in combination with organic forms like farm yard manure (FYM) and green leaf manure (Glm) in order to increase the nitrogen use efficiency (NUE). A uniform dose of 100 kg N ha^{-1} was applied in all the treatments except control. Generally, the modified forms are applied as basal. But in the experiment, these modified forms were also applied in split doses so as to increase NUE.

4.1 GROWTH CHARACTERS

4.1.1 Plant Height (Table 3 and Fig. 3)

The mean plant height varies from 34.9 cm to 81.5 cm from tillering to maturity. Plant height differed significantly due to various treatments at all stages of crop growth.

Table 3. Plant height (cm) of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	Tillering	Panicle initiation	Flowering	Maturity
T_1	26.8	44.2	60.1	65.5
T_2	34.9	57.8	77.0	81.7
T_3	32.5	53.2	73.2	78.7
T_4	33.5	54.7	77.8	84.2
T_5	38.0	58.1	78.5	83.2
T_6	36.8	61.7	79.1	85.7
T_7	40.5	57.4	75.4	79.8
T_8	37.2	57.7	77.1	83.1
T_9	35.2	54.9	76.5	82.7
T_{10}	34.2	56.7	80.8	87.1
T_{11}	33.9	62.4	77.1	84.2
T_{12}	34.9	55.1	76.2	82.1
Mean	34.9	56.2	75.7	81.5
SEm ±	1.0	1.5	0.7	1.2
CD 5%	2.8	4.3	1.9	3.5

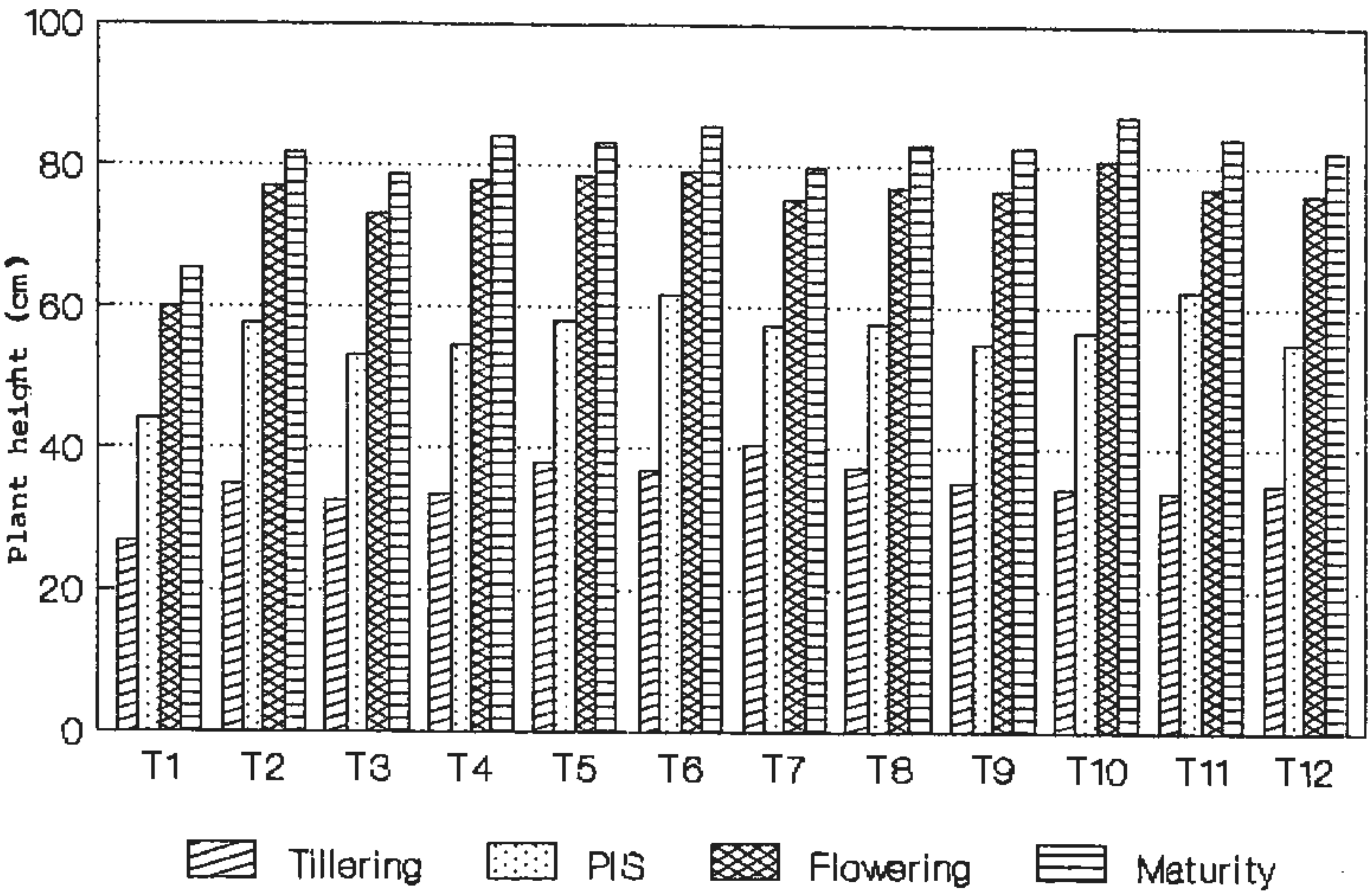


Fig. 3 .Plant height (cm) of rice as influenced by urea-based fertilisers at various crop growth stages.

At tillering, application of NBU as basal gave higher plant height of 40.5 cm which was significantly superior to rest of the treatments but on par with basal application of RPCU (38.0 cm). At PIS, NBU split application resulted higher plant height of 62.4 cm which was on par with basal application of LGU (61.7 cm) and RPCU (58.1 cm) but significantly superior to the rest of the treatments. At flowering, maximum plant height of 80.8 cm was with LGU split application which was on par with LGU basal (79.1 cm), but significantly superior to the rest of the treatments. At maturity, maximum plant height of 87.1 cm was with the split application of LGU and it was significantly superior to the rest of the treatments but on par with LGU basal (85.7 cm),Glm + PU (84.2 cm) and NBU split (84.2 cm). Minimum plant height was with control (no nitrogen) at all stages of crop growth.

4.1.2 Total Tillers

The production of tillers of rice at various crop growth stages as influenced by different treatments was significant (Table 4 and Fig. 4).

At tillering, NBU basal application gave significantly higher number of tillers (349 m^{-2}) compared to rest of the treatments but comparable with LGU basal (338 m^{-2}). At PIS, total tiller production was significantly higher

Table 4. Total tiller production m^{-2} of rice as influenced by urea-based fertilisers at different crop growth stages

Treatment	Tillering	Panicle initiation	Flowering
T_1	198	251	271
T_2	309	385	425
T_3	239	330	354
T_4	293	423	438
T_5	311	355	381
T_6	338	381	406
T_7	349	363	386
T_8	268	349	379
T_9	282	407	467
T_{10}	306	457	497
T_{11}	327	435	479
T_{12}	295	398	445
Mean	293	378	411
SEm ±	5	6	6
CD 5%	14	18	17

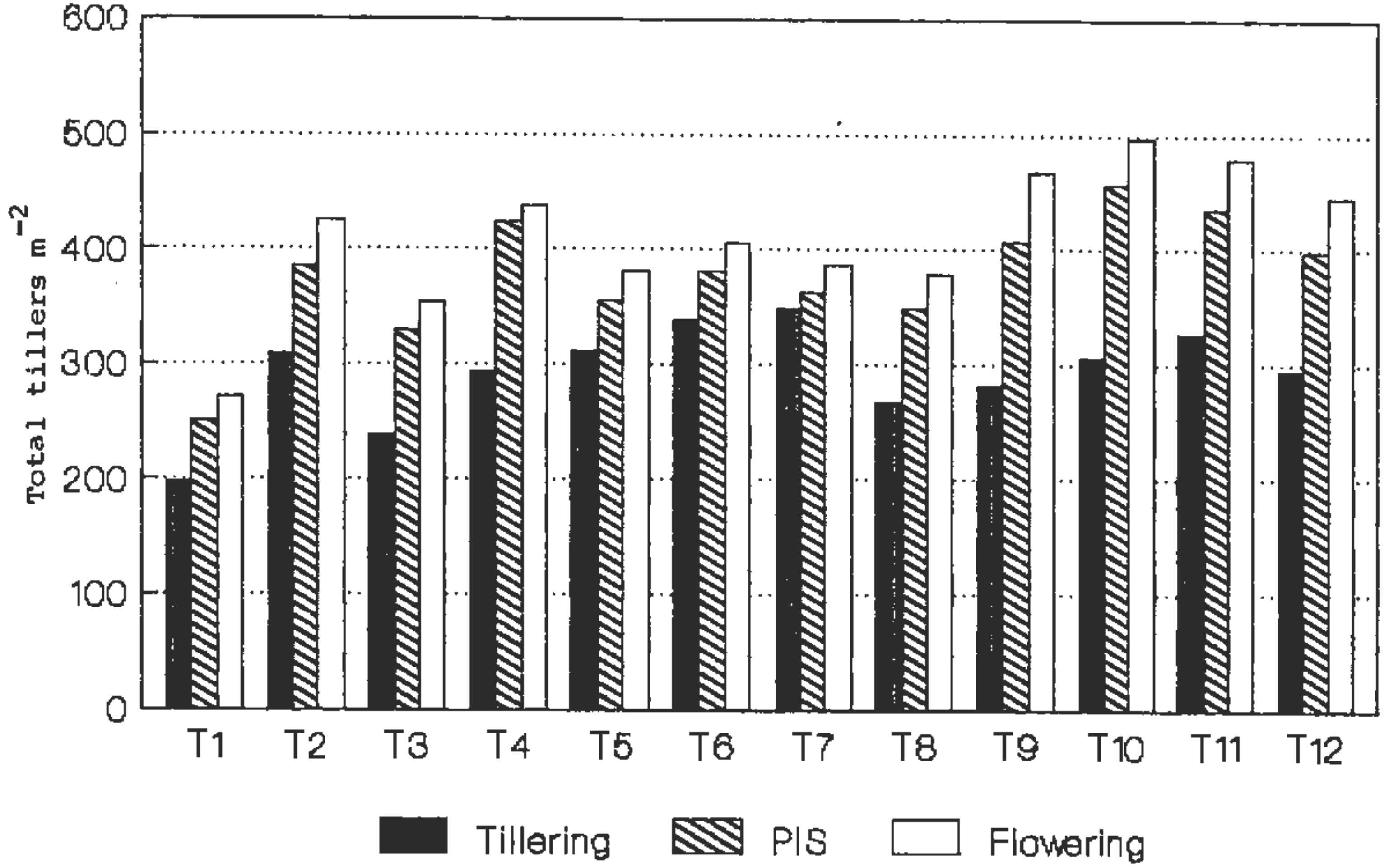


Fig.4 .Total tillers (m^{-2}) of rice as influenced by urea-based fertilisers at crop growth stages.

($457\ m^{-2}$) with LGU split application than that of others. At flowering, LGU split application showed significant superiority to the rest of the treatments and recorded 497 tillers m^{-2}. Number of tillers recorded with NBU split application ($479\ m^{-2}$) and RPCU split application ($467\ m^{-2}$) was on par and both were significantly superior to the rest of the treatments. Tiller production due to split application of GCU ($445\ m^{-2}$) was on par with Glm + PU ($438\ m^{-2}$) but significantly superior to the rest of the treatments. PU split application was significantly superior to basal application of all urea based fertilisers (UBF) and FYM + PU only. But it was not comparable with the split applications of UBF with regard to tiller production. Lower number of tillers were with control (no nitrogen) at all stages of crop growth.

4.1.3 Leaf Area Index (LAI)

Data recorded on LAI at various crop growth stages were significant (Table 5 and Fig. 5).

Rapid increase in LAI was observed from tillering (1.21) to panicle initiation (2.19) followed by gradual increase (2.97) upto flowering and thereafter declined till maturity (1.75). Rate of increase in LAI was maximum (0.065 day^{-1}) between tillering and PIS followed by PIS and flowering (0.052 day^{-1}) and decreased (0.041 day^{-1}) from flowering to maturity.

Table 5. Leaf Area Index (LAI) of rice as influenced by urea based-fertilisers at various crop growth stages

Treatment	Tillering	Panicle initiation	Flowering	Maturity
T_1	0.51	1.15	1.98	0.89
PU T_2	1.11	2.11	3.10	1.87
FYM T_3	0.65	1.75	2.41	1.42
GN T_4	1.05	2.15	2.69	1.98
T_5	1.53	2.31	3.17	1.66
LCU T_6	1.54	2.27	2.89	1.81
NCU T_7 ✓	1.75	2.36	3.06	1.59
T_8	1.50	2.01	2.77	1.57
T_9	1.22	2.52	3.22	1.88
T_{10}	1.37	2.82	3.73	2.47
T_{11}	1.18	2.59	3.43	2.12
T_{12}	1.21	2.29	3.21	1.79
Mean	1.21	2.19	2.97	1.75
SEm ±	0.05	0.06	0.05	0.03
CD 5%	0.14	0.16	0.14	0.07

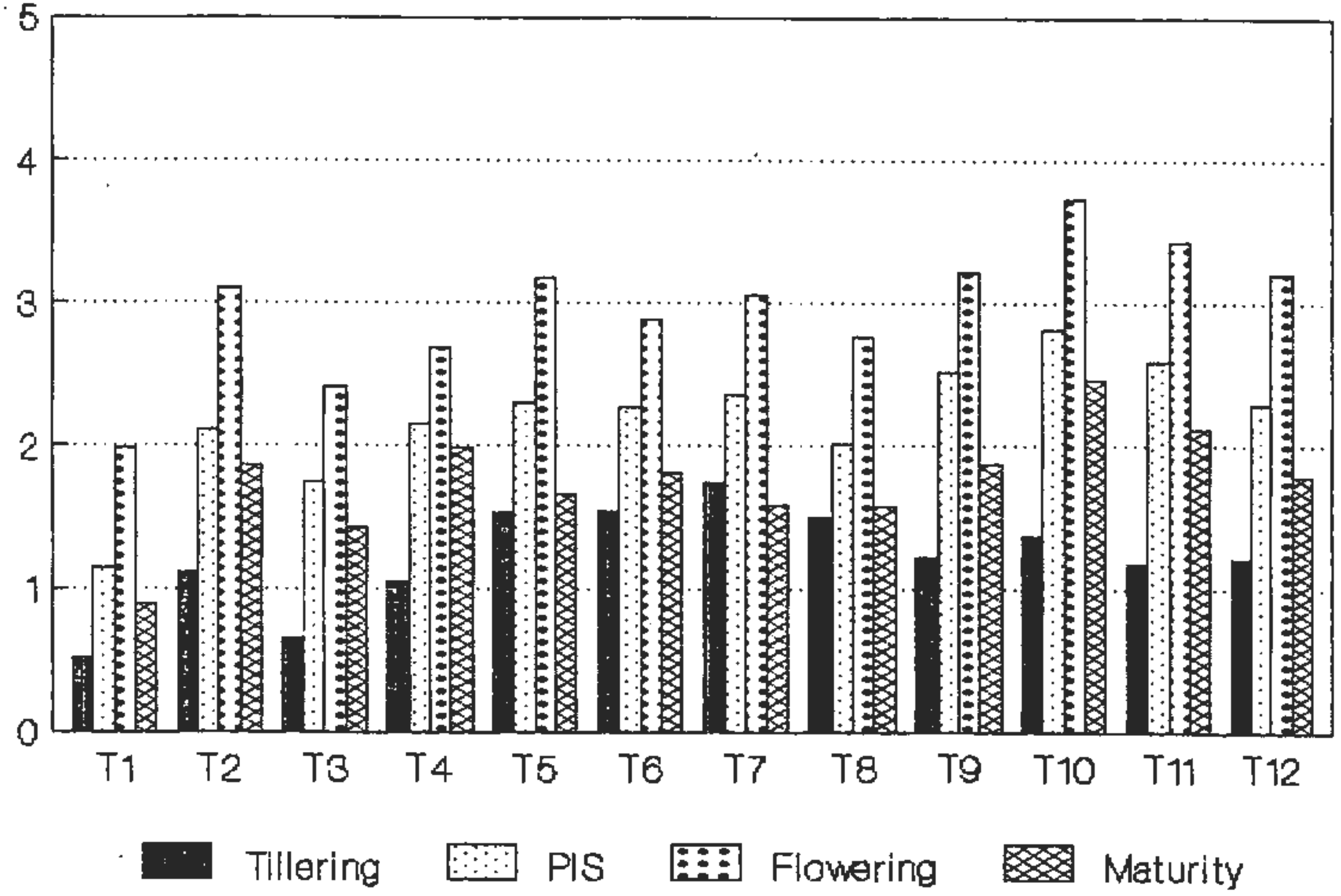


Fig.5 .Leaf Area Index (LAI) of rice as influenced by urea-based fertilisers at various crop growth stages.

At tillering, higher LAI (1.75) was with NBU basal application which was superior to the rest of the treatments. Higher LAI was obtained with LGU basal (1.54) which was significantly superior to the rest but on par with RPCU basal (1.53) and GCU basal (1.50), whereas at remaining crop growth stages, LGU split application resulted in higher LAI compared to rest of the treatments. The LAI with LGU split was 2.82, 3.73 and 2.47 at PIS, flowering and maturity, respectively. Lower LAI of 0.51 at tillering and 1.98 at flowering was with control (no nitrogen).

4.1.4 Dry Matter Production

The data pertaining to dry matter production were significantly influenced by various treatments at different growth stages (Table 6 and Fig. 6).

At tillering, higher dry matter (116 g m^{-2}) was obtained with NBU basal application compared to other urea based fertilisers followed by LGU basal (109 g m^{-2}) and NBU split application (87 g m^{-2}). At PIS, LGU split application produced higher dry matter (320 g m^{-2}) which was significantly superior to all other forms but on par with NBU split application (314 g m^{-2}). RPCU split application resulted in higher dry matter (300 g m^{-2}) which was on par with PU split application (294 g m^{-2}) but significantly superior to the rest of the treatments. Dry matter production at flowering

Table 6. Dry matter production (g m^{-2}) of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	Tillering	Panicle initiation	Flowering	Maturity
T_1	42	170	376	543
T_2	82	294	591	983
T_3	56	229	496	727
T_4	69	268	601	987
T_5	81	257	561	863
T_6	109	263	589	930
T_7	116	273	565	798
T_8	78	247	557	821
T_9	61	300	606	1018
T_{10}	82	320	673	1193
T_{11}	87	314	623	1046
T_{12}	67	293	599	998
Mean	78	269	570	909
SEm ±	1	4	7	14
CD 5%	4.0	13	20	41

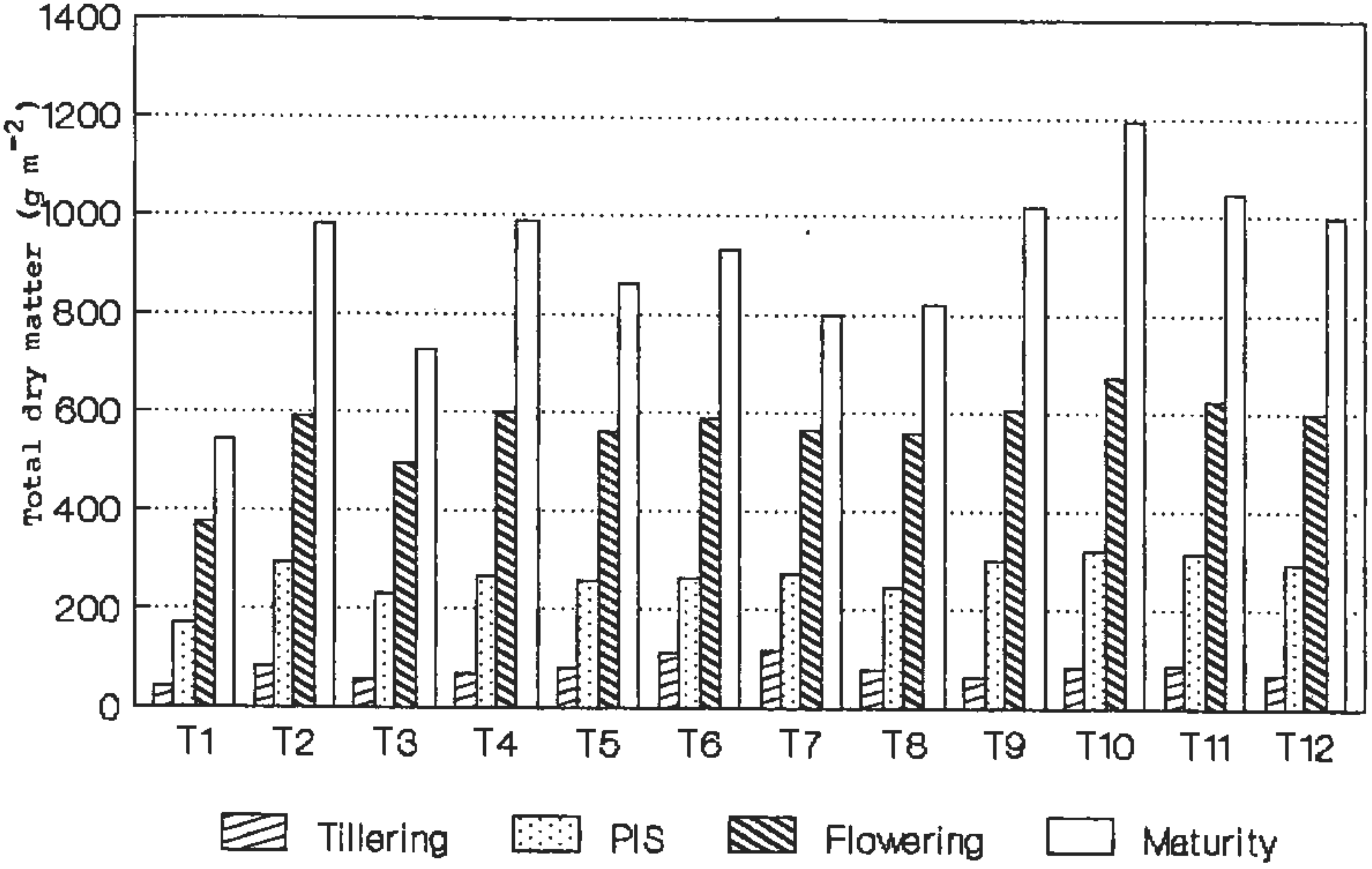


Fig.6 .Total dry matter (gm^{-2}) of rice as influenced by urea-based fertilisers at various crop growth stages.

and maturity confirmed the significant superiority due to the LGU split application over rest of the treatments and recorded 673 and 1193 g m^{-2} at flowering and maturity, respectively. At maturity, split application of LGU, NBU and RPCU recorded 54.5, 48.1 and 46.7 per cent increase in dry matter over control, respectively whereas 17.6, 6.0 and 3.4 per cent over PU split application. Split application of all UBF significantly increased the dry matter over basal application of corresponding UBF. The per cent increase in dry matter due to split application of LGU, NBU, RPCU and GCU were 22.0, 23.7, 15.2 and 17.7 over basal application of corresponding UBF, respectively. Glm + PU recorded higher dry matter (987 g m^{-2}) which was on par with PU split application (983 g m^{-2}) but significantly superior to basal application of all UBF and FYM + PU. Lower dry matter was recorded at all stages of crop growth in control.

4.2 DRY MATTER PARTITIONING

At tillering (Table 7) average share of leaf blade and sheath of photosynthates was 52.8 and 47.2 per cent, respectively. The dry matter produced upto tillering was translocated more to leaf blade in all the treatments compared to leaf sheath except in control and FYM + PU where equal share was observed. Comparatively more per cent of dry matter was translocated to leaf blade by basal applica-

Table 7. Dry matter partitioning of rice as influenced by urea-based fertilisers at tillering

Treatment	Dry matter (g m^{-2})	
	Leaf blade	Leaf sheath
T_1	21 (50.0)*	21 (50.0)*
T_2	42 (51.2)	40 (48.8)
T_3	28 (50.0)	28 (50.0)
T_4	35 (50.8)	34 (49.2)
T_5	43 (53.1)	38 (46.9)
T_6	62 (56.9)	47 (43.1)
T_7	65 (56.0)	51 (44.0)
T_8	41 (52.6)	37 (47.4)
T_9	32 (52.5)	29 (47.5)
T_{10}	42 (51.2)	40 (48.8)
T_{11}	48 (55.2)	39 (44.8)
T_{12}	36 (53.7)	31 (46.3)
Mean	41.0(52.8)	36 (47.2)
SEm ±	0.7	0.7
CD 5%	2.0	2.0

*Figures given in parenthesis are percentages of total dry matter tion of UBF than split application. In case of NBU and GCU even with split application, more per cent of dry matter was translocated to leaves compared to leaf sheath.

At PIS (Table 8), culm is new sink which constituted about 7.4 per cent of total dry matter. However, leaf sheath and leaf blade continued to be important sinks with 37.8 and 54.8 per cent, respectively. In all the treatments, the per cent of sheath weight to total dry matter was more than leaf blade and culm.

At flowering (Table 9), on an average dry matter partitioned to each part viz., leaf blade, leaf sheath, culm and panicle was 28.0, 35.3, 19.1 and 17.6 per cent of the total dry matter, respectively. Higher per cent of total dry matter partitioned to panicle with split application of LGU (19.4) followed by NBU split (19.1) and RPCU split (18.7). About 17.6 per cent of total dry matter was partitioned to panicle in case of PU split application.

At maturity (Table 10 and Fig. 7) on an average 13.4, 20.0, 9.6 and 57.0 per cent of the total dry matter was partitioned to leaf blade, leaf sheath, culm and panicle, respectively. LGU split application resulted significantly higher leaf blade (163 g m^{-2}) leaf sheath (246 g m^{-2}), culm (94 g m^{-2}) panicle (662 g m^{-2}) dry matter compared to rest of the treatments.

Table 8. Dry matter partitioning of rice as influenced by urea-based fertilisers at panicle initiation

Treatment	Dry matter (g m^{-2})		
	Leaf blade	Leaf sheath	Culm
T_1	66 (38.8)*	93 (54.7)*	11 (6.5)*
T_2	109 (37.1)	163 (55.4)	22 (7.5)
T_3	84 (36.7)	130 (56.8)	15 (6.5)
T_4	104 (38.8)	144 (53.7)	20 (7.5)
T_5	93 (36.2)	144 (56.0)	20 (7.8)
T_6	98 (37.3)	140 (53.2)	25 (9.5)
T_7	104 (38.1)	148 (54.2)	21 (7.7)
T_8	92 (37.2)	136 (55.1)	19 (7.7)
T_9	117 (39.0)	163 (54.3)	20 (6.7)
T_{10}	122 (38.1)	177 (55.3)	21 (6.6)
T_{11}	118 (37.6)	171 (54.5)	25 (7.9)
T_{12}	112 (38.2)	161 (54.9)	20 (6.9)
Mean	102 (37.8)	148 (54.8)	20 (7.4)
SEm ±	2	2	0.3
CD 5%	7	5	1.0

* Figures in parenthesis are percentages of total dry matter

Table 9. Dry matter partitioning of rice as influenced by urea-based fertilisers at flowering

Treatment	Dry matter (g m^{-2})			
	Leaf blade	Leaf sheath	Culm	Panicle
T_1	110 (29.3)*	135 (35.9)*	72 (19.1)*	59 (15.7)*
T_2	163 (27.6)	208 (35.2)	116 (19.6)	104 (17.6)
T_3	146 (29.4)	173 (34.9)	90 (17.5)	87 (18.2)
T_4	168 (28.0)	220 (36.6)	111 (18.5)	102 (16.9)
T_5	154 (27.5)	204 (36.4)	107 (19.1)	98 (17.0)
T_6	176 (29.9)	204 (34.6)	107 (18.2)	102 (17.3)
T_7	157 (27.8)	194 (34.3)	120 (21.2)	96 (16.7)
T_8	156 (28.0)	199 (35.7)	113 (20.3)	89 (16.0)
T_9	165 (27.2)	213 (35.1)	115 (19.0)	113 (18.7)
T_{10}	184 (27.3)	232 (34.4)	127 (18.9)	130 (19.4)
T_{11}	167 (26.8)	224 (36.0)	113 (18.1)	119 (19.1)
T_{12}	161 (26.9)	208 (34.7)	118 (20.0)	112 (18.4)
Mean	159 (28.0)	201 (35.3)	109 (19.1)	101 (17.6)
SEm ±	2	2	1	1
CD 5%	6	7.0	4.0	4.0

* Figures in parenthesis are percentages of total dry matter

Table 10. Dry matter partitioning of rice as influenced by urea-based fertilisers at maturity

Treatment	Dry matter ($g\ m^{-2}$)			
	Leaf blade	Leaf sheath	Culm	Panicle
T_1	59 (10.9)*	119 (21.9)*	54 (9.9)*	311 (57.3)*
T_2	128 (13.0)	195 (19.8)	95 (9.7)	563 (57.2)
T_3	101 (13.9)	142 (19.5)	66 (9.1)	429 (59.0)
T_4	132 (13.4)	196 (19.9)	94 (9.5)	565 (57.2)
T_5	122 (14.1)	163 (18.9)	85 (9.8)	489 (57.2)
T_6	127 (13.7)	187 (20.1)	88 (9.5)	528 (56.7)
T_7	110 (13.8)	146 (18.3)	73 (9.1)	469 (58.8)
T_8	108 (13.2)	151 (18.4)	77 (9.4)	483 (59.0)
T_9	136 (13.4)	206 (20.2)	99 (9.7)	577 (56.7)
T_{10}	163 (13.7)	246 (20.6)	122 (10.2)	662 (55.5)
T_{11}	145 (13.9)	221 (21.1)	94 (9.0)	582 (56.0)
T_{12}	137 (13.7)	207 (20.7)	96 (9.6)	558 (56.0)
Mean	122 (13.4)	182 (20.0)	87 (9.6)	518 (57.0)
SEm ±	2	2	1	8
CD 5%	6	7	4	24

*Figures in parenthesis are percentages of total dry matter

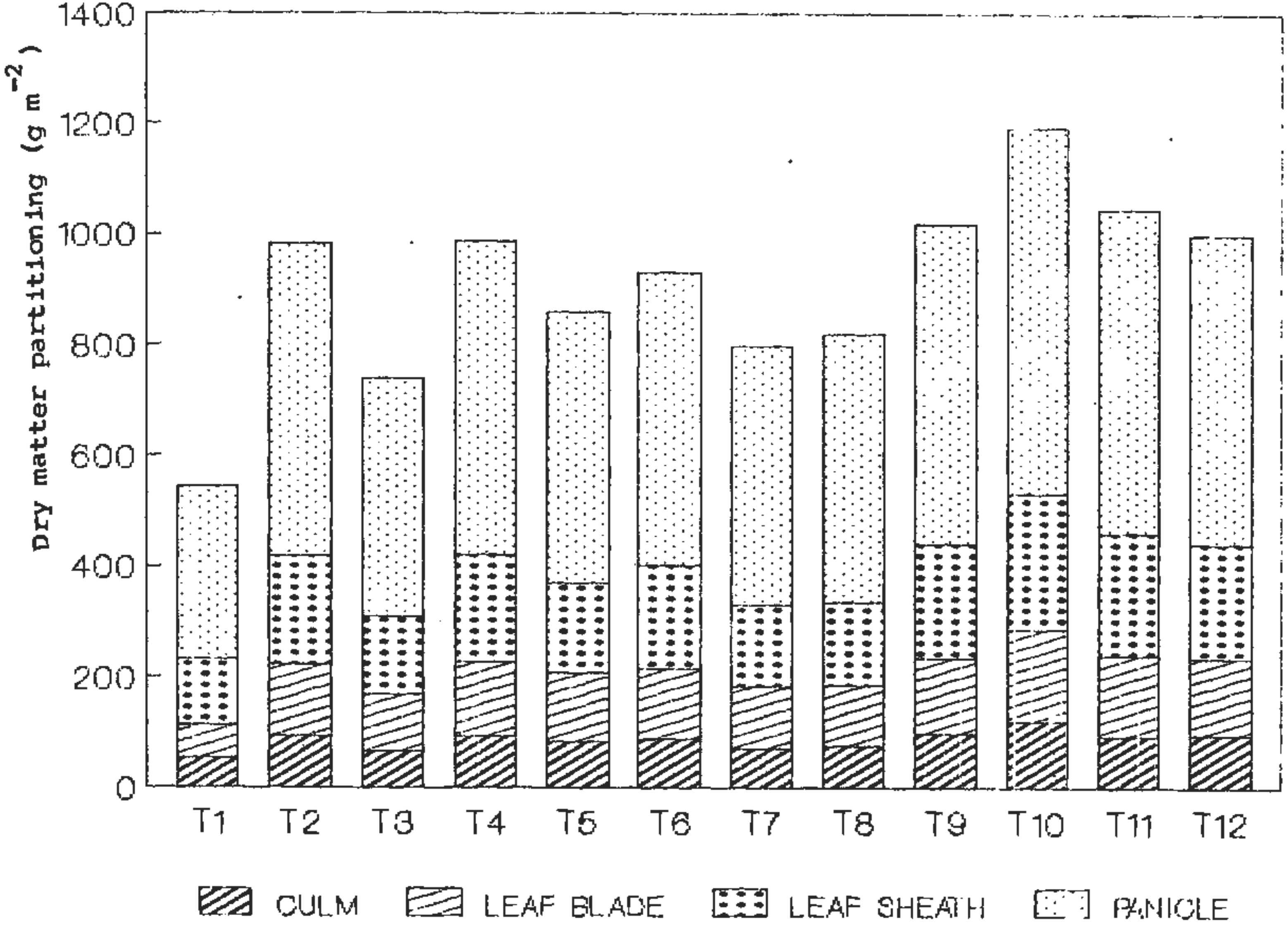


Fig. **7** Dry matter partitioning as influenced by urea-based fertilisers at maturity

In general, NBU basal application gave significantly higher leaf blade and leaf sheath dry matter upto tillering compared to other treatments. At PIS, LGU split application gave significantly higher leaf blade and sheath dry matter compared to other treatments but on par with NBU split application in case of dry matter of leaf blade. At flowering and maturity, LGU split application showed its significant superiority resulting in more leaf blade, sheath, culm and panicle dry matter over the rest.

4.3 GROWTH ANALYSIS

4.3.1 Crop Growth Rate (CGR)

The data indicated that there was conspicuous rise in CGR from PIS to flowering and CGR rates were smaller in between tillering to PIS and flowering to maturity as evident from table 11.

Significant differences due to different treatments were observed at all stages of crop growth. Higher CGR recorded with RPCU split application (15.93 g m^{-2} day^{-1}) which was significantly superior to all treatments but on par with LGU split application (15.86 g m^{-2} day^{-1}) during period between tillering and PIS. Significantly higher CGR was obtained with LGU split application (23.53 g m^{-2} day^{-1}) which was on par with Glm + PU (22.20 g m^{-2} day^{-1}) between

Table 11. CGR (g m^{-2} day^{-1}) of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	T - PIS	PIS - F	F - M
T_1	8.53	13.73	5.57
T_2	14.13	19.80	13.07
T_3	11.53	17.80	7.70
T_4	13.26	22.20	12.87
T_5	11.73	20.26	10.06
T_6	10.26	21.73	11.36
T_7	10.46	19.46	7.76
T_8	11.26	20.66	8.79
T_9	15.93	20.40	13.72
T_{10}	15.86	23.53	17.33
T_{11}	15.13	20.60	14.10
T_{12}	15.06	20.40	13.30
Mean	12.76	20.05	11.30
SEm ±	0.30	0.58	0.31
CD 5%	0.89	1.70	0.90

T : Tillering F : Flowering

PIS : Panicle initiation M : Maturity

PIS and flowering. LGU split application resulted significantly in higher CGR (17.33 g m^{-2} day^{-1}) compared to the rest of the treatments between flowering and maturity. NBU and RPCU split applications were on par and recorded significantly higher CGR values of 14.10 and 13.72 g m^{-2} day^{-1}, respectively compared to the rest of the treatments. CGR was less at all stages of crop growth in control(no nitrogen).

4.3.2 Relative Growth Rate (RGR)

There were significant differences in RGR due to different treatments at all periods (Table 12). The RGR was maximum with RPCU split application (106.1 mg g^{-1} day^{-1}) and superior to all the treatments between tillering and PIS. Between PIS and flowering, GCU basal application recorded significantly higher RGR (54.1 mg g^{-1} day^{-1}) compared to rest of the treatments but on a par with Glm + PU, LGU basal, control, RPCU basal and FYM + PU. Between flowering and maturity, LGU basal application recorded significantly higher RGR (21.2 mg g^{-1} day^{-1}) followed by LGU split (19.0 mg g^{-1} day^{-1}).

4.3.3 Net Assimilation Rate (NAR)

The data on NAR were consistent (Table 13). NAR was higher with control (0.0723 g cm^{-2} day^{-1}) which was on par with FYM + PU (0.0692 g cm^{-2} day^{-1}) and both were significantly superior to other urea-based fertilisers during the period

Table 12. RGR (mg g^{-1} day^{-1}) of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	T - PIS	PIS - F	F - M
T_1	93.2	52.7	12.2
T_2	84.8	46.5	16.9
T_3	94.0	51.3	12.7
T_4	87.3	53.8	16.5
T_5	76.8	53.1	14.3
T_6	58.7	53.7	21.2
T_7	57.0	48.4	11.4
T_8	76.8	54.1	12.9
T_9	106.1	46.8	17.2
T_{10}	91.2	49.4	19.0
T_{11}	85.2	45.6	17.2
T_{12}	98.3	47.6	16.9
Mean	84.1	50.2	15.7
SEm ±	1.7	1.4	0.4
CD 5%	4.9	4.2	1.3

T : Tillering F : Flowering

PIS : Panicle initiation M : Maturity

Table 13. NAR (g cm^{-2} day^{-1}) of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	T-PIS	PIS-F	F-M
T_1	0.0723	0.0599	0.0272
T_2	0.0613	0.0513	0.0358
T_3	0.0692	0.0575	0.0274
T_4	0.0576	0.0614	0.0370
T_5	0.0413	0.0497	0.0287
T_6	0.0364	0.0564	0.0328
T_7	0.0342	0.0481	0.0230
T_8	0.0431	0.0581	0.0277
T_9	0.0593	0.0476	0.0367
T_{10}	0.0526	0.0477	0.0378
T_{11}	0.0562	0.0459	0.0345
T_{12}	0.0593	0.0499	0.0364
Mean	0.0536	0.0528	0.0321
SEm ±	0.0022	0.0018	0.0011
CD 5%	0.0065	0.0054	0.0031

T : Tillering   F : Flowering

PIS : Panicle initiation   M : Maturity

from tillering to PIS. NAR was significantly higher with Glm + PU (0.0614) g cm^{-2} day^{-1}) but comparable with control, FYM + PU and basal application of GCU and LGU between PIS and flowering whereas it was higher with LGU split application (0.0378 g cm^{-2} day^{-1}) which was on par with Glm + PU and split application of RPCU, GCU and PU between flowering and maturity.

4.4 DAYS TO 50 PER CENT FLOWERING

The data on number of days to 50 per cent flowering as influenced by different treatments are presented in table 14. Number of days to 50 per cent flowering ranged from 67.3 to 69.3. Plants grown with Glm + PU, LGU basal and LGU split application took 69.3 days to 50 per cent flowering, whereas PU split took 67.7 days.

4.5 DAYS TO MATURITY

Days to maturity due to different treatments are presented in table 14. Split application of LGU, RPCU, NBU and GCU delayed the maturity by 4 days compared to GCU basal application and PU split and by 3 days compared to Glm + PU and LGU basal. Days to maturity were same (107) with FYM + PU RPCU basal, NBU basal and control.

Table 14. Days to 50 per cent flowering and days to maturity of rice as influenced by urea-based fertilisers

Treatment	Days to 50 per cent flowering	Days to maturity
T_1	67.3	107
T_2	67.7	109
T_3	67.3	107
T_4	69.3	110
T_5	68.3	107
T_6	69.3	110
T_7	68.3	107
T_8	68.7	109
T_9	67.7	113
T_{10}	69.3	113
T_{11}	68.7	113
T_{12}	68.3	113
Mean	68.4	
SEm ±	0.4	
CD 5%	1.2	NA

NA : Not analysed

4.6 YIELD ATTRIBUTES

Number of panicles m^{-2} was significantly influenced by different treatments (Table 15 and Fig.8). Among different UBF, LGU split application produced significantly more number of panicles m^{-2} (421). This was closely followed by NBU split application (404 m^{-2}). RPCU split application recorded significantly higher number of panicles (391 m^{-2}) compared to the rest of the treatments but on par with Glm + PU application (386 m^{-2}). Panicles obtained with PU split (369 m^{-2}), GCU split (365 m^{-2}) and LGU basal applications (360 m^{-2}) were on par with each other. Application of LGU, NBU, RPCU in split and Glm + PU resulted in 12.4, 8.7, 5.6 and 4.4 per cent increase in panicles over PU split application, respectively. Basal application of RPCU, NBU and GCU produced significantly lower number of panicles compared to PU split application. Split application of LGU, NBU, RPCU and GCU recorded 14.5, 19.1, 12.0 and 7.7 per cent increase in panicles over basal application of corresponding UBF, respectively. FYM + PU produced lesser number of panicle m^{-2} (312). Significantly lower number of panicles m^{-2} (268) was obtained with no nitrogen treatment.

Number of filled grains $panicle^{-1}$ differed significantly due to different treatments (Table 15 and Fig. 9). Split application of RPCU (78.3) and GCU (77.9) resulted in similar number of filled grains $panicle^{-1}$ which was signifi-

Table 15. Number of panicles m^{-2}, filled grains panicle^{-1}, 1000 grain weight (g) and spikelet sterility (%) of rice as influenced by urea-based fertilisers

Treatment	Number of panicles m^{-2}	Number of filled grains panicle^{-1}	1000 grain weight (g)	Spikelet sterility (%)
T_1	268	60.3	20.330	7.6
T_2	369	73.5	20.585	13.3
T_3	312	68.6	20.729	8.7
T_4	386	72.4	20.928	12.9
T_5	344	72.6	20.846	9.4
T_6	360	73.5	20.857	11.8
T_7	327	71.2	20.512	10.5
T_8	337	71.7	20.425	8.3
T_9	391	78.3	20.772	11.6
T_{10}	421	74.9	20.641	13.6
T_{11}	404	76.1	20.692	13.9
T_{12}	365	77.9	20.489	12.7
Mean	357	72.6	20.65	11.2
SEm ±	4.1	0.7	0.17	0.1
CD 5%	12.0	2.1	NS	0.4

NS : Not significant

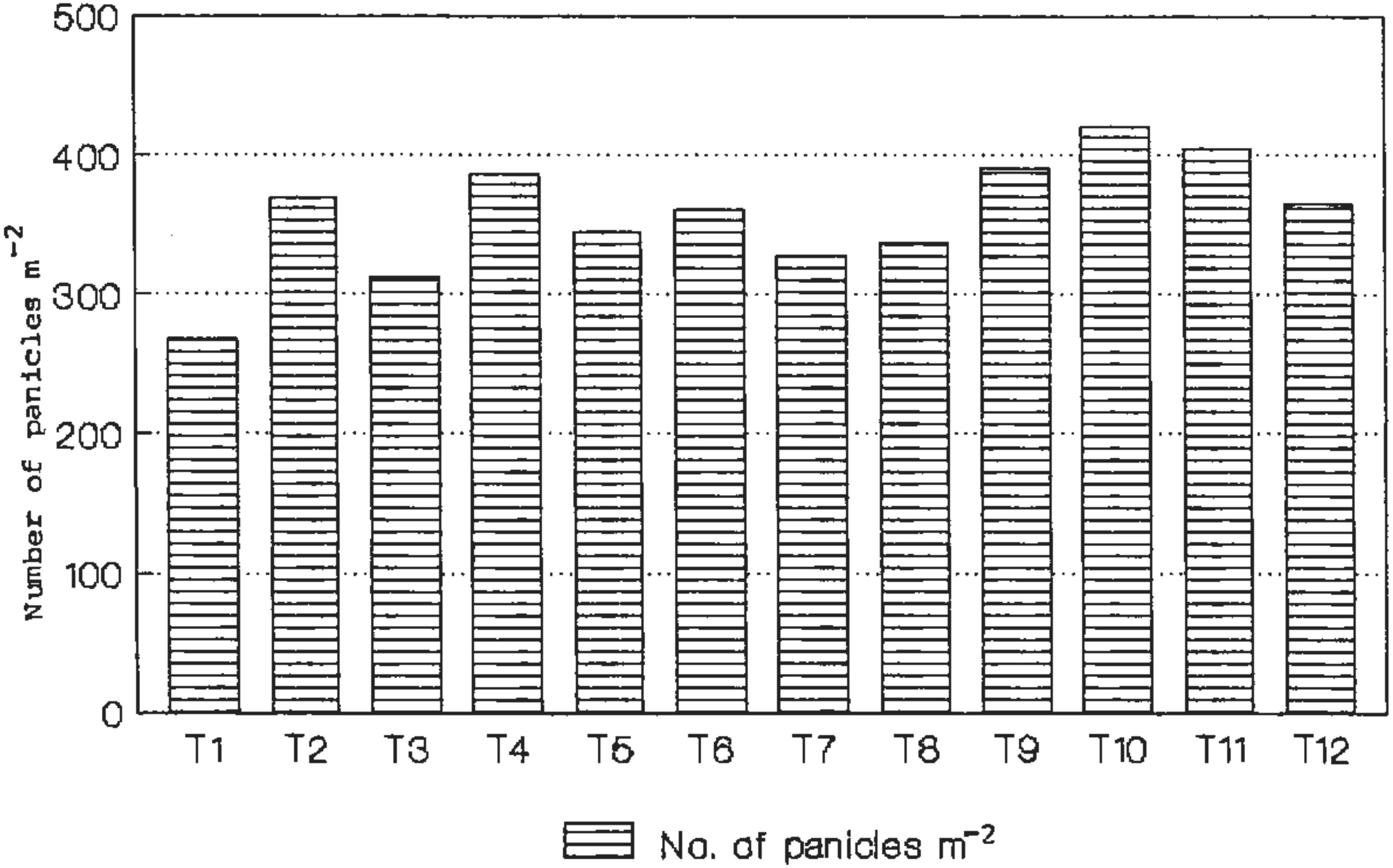


Fig.8 .Number of panicles per square metre of rice as influenced by urea-based fertilisers

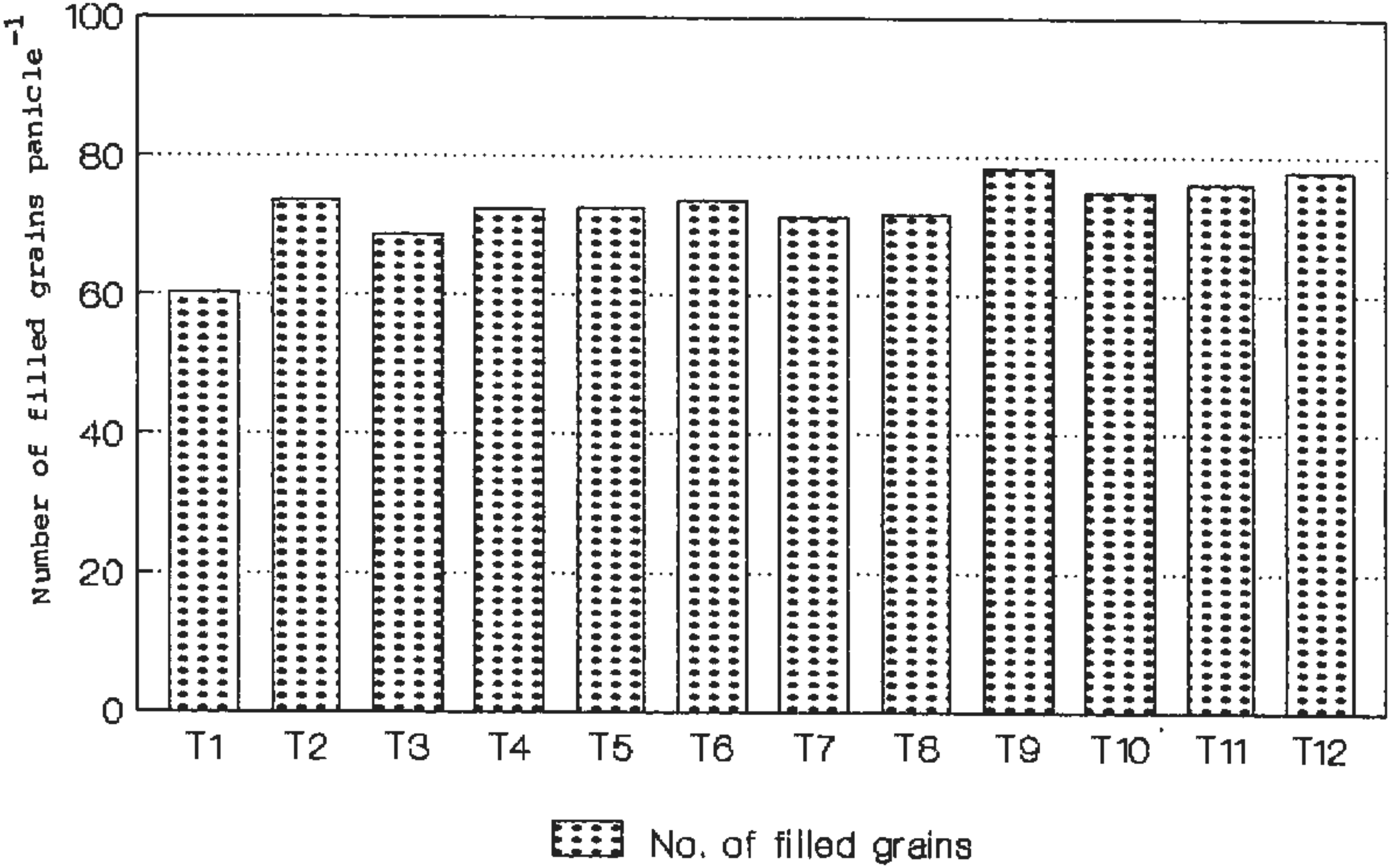


Fig.9.No. of filled grains per panicle of rice as influenced by urea-based fertilisers

cantly superior to all the other treatments. Number of filled grains panicle^{-1} obtained with NBU split (76.1) was higher than the rest of the treatments but on par with LGU split application (74.9). Filled grains panicle^{-1} recorded with LGU basal (73.5) PU split application (73.5) Glm + PU (72.4) and GCU basal (71.7) were comparable with each other. Application of FYM + PU gave lesser number of filled grains panicle^{-1} (68.6). Significantly lower number of filled grains panicle^{-1} was with no nitrogen treatment (60.3).

Thousand grain weight was not influenced by different urea based fertilisers. The test weight ranged from 20.33 g in control to 20.93 g in Glm + PU. There were significant differences in spikelet sterility percentage due to various treatments. NBU split application recorded higher spikelet sterility percentage (13.9) than the rest of the treatments, but it was on par with LGU split application (13.6). Sterility percentage recorded with PU split application (13.3) was comparable with Glm + PU (12.9). Significantly lower sterility percentage (7.6) was recorded in control.

Panicle weight and panicle length were significantly influenced by different treatments (Table 16). RPCU split application recorded significantly higher panicle weight (2.29 g) than all the other treatments. Panicle weight observed with LGU split (2.21 g) and NBU split (2.19 g) was

Table 16. Panicle weight (g) and panicle length (cm) of rice as influenced by urea-based fertilisers

Treatment	Panicle weight (g)	Panicle length (cm)
T_1	1.55	17.5
T_2	2.04	19.3
T_3	1.78	18.5
T_4	2.05	19.8
T_5	1.86	18.8
T_6	1.92	19.3
T_7	1.82	18.6
T_8	1.83	18.6
T_9	2.29	19.4
T_{10}	2.21	20.4
T_{11}	2.19	21.0
T_{12}	1.92	19.2
Mean	1.96	19.2
SEm ±	0.01	0.1
CD 5%	0.04	0.4

on par with each other but significantly higher compared to rest of the treatments. Glm + PU and PU split application recorded similar panicle weight. Lower panicle weight (1.55 g) was with control. Significantly more panicle length was with NBU split application (21.0 cm) followed by LGU split application (20.4 cm). Panicle length with Glm + PU and RPCU split application was on par and recorded 19.8 and 19.4 cm, respectively. Panicle length with PU split application was 19.3 cm. Panicle length was lesser with control (17.5 cm).

4.7 GRAIN YIELD

The data pertaining to grain yield was significantly influenced by different urea-based fertilisers (Table 17 and Fig. 10).

The higher grain yield of 5793 kg ha^{-1} was obtained with the LGU split application which was significantly superior to rest of the treatments. It was followed by NBU split application (5573 kg ha^{-1}). Grain yield obtained with RPCU split application (5346 kg ha^{-1}) was similar with Glm + PU (5276 kg ha^{-1}) but both were better than the rest of the treatments. The difference in grain yield due to split application of PU (5190 kg ha^{-1}), GCU split application (5170 kg ha^{-1}) and LGU basal (5090 kg ha^{-1}) was not significant but significantly higher over RPCU basal (4876 kg ha^{-1}), GCU

Table 17. Grain yield and straw yield (kg ha^{-1}) and harvest index (%) of rice as influenced by urea-based fertilisers

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)
T_1	2936	3010	49.3
T_2	5190	4790	52.0
T_3	4133	4276	49.1
T_4	5276	5293	49.9
T_5	4876	4686	50.9
T_6	5090	4713	51.9
T_7	4610	4733	49.3
T_8	4766	4866	49.4
T_9	5346	5743	48.2
T_{10}	5793	6103	48.6
T_{11}	5573	5916	48.4
T_{12}	5170	5486	48.5
Mean	4897	4968	49.6
SEm ±	53	26	0.4
CD 5%	154	77	1.2

basal (4766 kg ha^{-1}), NBU basal (4610 kg ha^{-1}) and FYM + PU (4133 kg ha^{-1}). The per cent increase in grain yield due to split application of LGU, NBU, RPCU and Glm + PU were 49.3, 47.3, 45.1 and 44.4 over control, respectively whereas it was 10.4, 6.9, 2.9 and 1.6 per cent over PU split application, respectively. Split application of LGU, NBU, RPCU and GCU resulted in 12.1, 17.3, 8.8 and 7.8 per cent increase in grain yield over their basal application. Lower grain yield of 2936 kg ha^{-1} was with no nitrogen.

4.8 STRAW YIELD

Significant difference in straw yield was observed due to different UBF (Table 17 and Fig. 6). Higher straw yield was with split application of LGU (6103 kg ha^{-1}) which was significantly superior to all other treatments. This was followed by NBU split (5916 kg ha^{-1}), RPCU split (5743 kg ha^{-1}), GCU split (5486 kg ha^{-1}) and Glm + PU (5293 kg ha^{-1}). The difference in straw yield due to PU split, basal application of NBU and LGU was not significant. Significantly lower straw yield (3010 kg ha^{-1}) was with control.

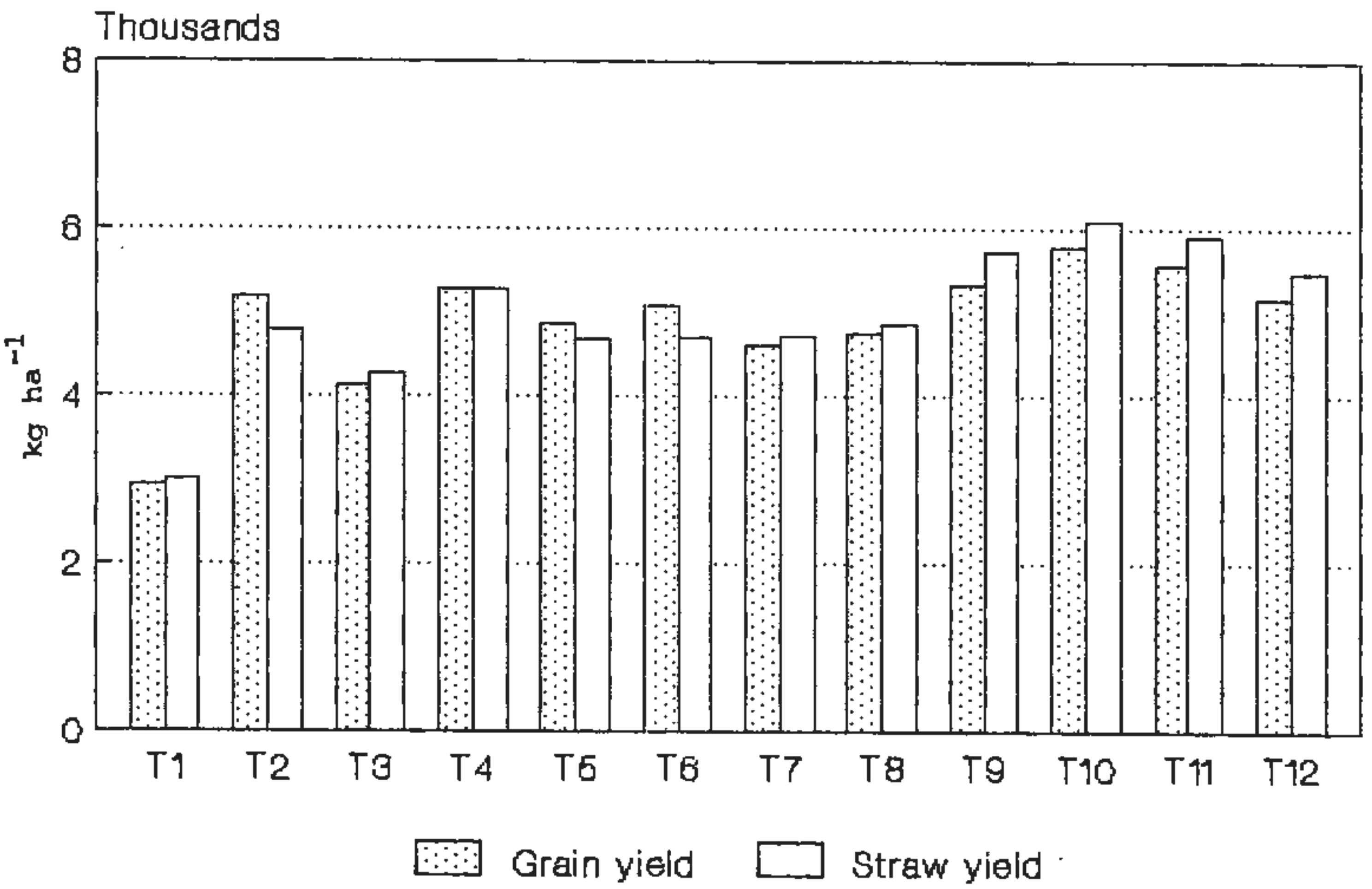


Fig10. Grain and straw yield (kg ha^{-1}) of rice as influenced by urea-based fertilisers

4.9 HARVEST INDEX (HI)

HI was significantly influenced by different treatments (Table 17). PU split application gave higher HI (52.0 per cent) which was on par with basal application of LGU (51.9 per cent) and RPCU (50.9 per cent) but significantly higher than the rest of the treatment. Lower HI was with RPCU split (48.2 per cent) followed by NBU split application (48.4 per cent).

4.10 AMMONIA VOLATILISATION LOSSES

Ammonia volatilisation loss from the time of fertiliser application to two weeks after their application was estimated (Table 18). Loss was in the range of 5.84 per cent in control to 13.46 per cent in prilled urea split application. Application of UBF in splits reduced the volatilisation losses considerably. Glm + PU resulted in less volatilisation loss (9.35 per cent) followed by FYM + PU (10.32 per cent) and LGU split application (10.99 per cent).

4.11 N CONTENT (%)

The shoot samples were analysed for nitrogen content at tillering, panicle initiation, flowering and grain and straw samples at harvest by micro kjeldahl method.

Data in table 19 indicated that significant differences were noticed in N content of plants due to application of different UBF at all stages of crop growth. N content at

Table 18. Ammonia volatilisation losses as influenced by urea-based fertilisers

Treatment	Ammonia volatilisation losses (per cent) upto two weeks after fertiliser application
T_1	5.84
T_2	13.46
T_3	10.32
T_4	9.35
T_5	12.91
T_6	11.27
T_7	13.02
T_8	12.12
T_9	11.87
T_{10}	10.99
T_{11}	12.03
T_{12}	11.47
	NA

NA : Not analysed

Table 19. Nitrogen content (%) of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	Tillering	Panicle initiation	Flowering
T_1	1.66	1.10	0.89
T_2	2.33	1.24	0.97
T_3	2.64	1.27	0.97
T_4	2.68	1.30	1.00
T_5	2.24	1.27	0.97
T_6	2.14	1.37	1.02
T_7	2.00	1.33	0.92
T_8	2.26	1.34	0.95
T_9	2.91	1.23	1.01
T_{10}	2.25	1.24	0.99
T_{11}	2.14	1.28	0.99
T_{12}	2.70	1.21	0.96
Mean	2.33	1.27	0.97
SEm ±	0.07	0.04	0.01
CD 5%	0.21	0.12	0.03

tillering was higher with RPCU split (2.91) which was significantly superior to all the treatments except GCU split application (2.70). N content with PU split, FYM + PU and Glm + PU were 2.33, 2.64 and 2.68 per cent, respectively. At PIS, it was higher with LGU basal (1.37) which was equal to that recorded with GCU basal, NBU basal, Glm + PU, FYM + PU and NBU split application. N content at flowering was higher with LGU basal (1.02) which was on par with that of RPCU split, Glm + PU, LGU split and NBU split application. Least N content was with control at all stages of crop growth.

N content in grain varied from 0.98 in control to 1.11 in Glm + PU, RPCU basal and RPCU split application whereas in straw it ranged from 0.32 in control to 0.42 in GCU split application (Table 20).

4.12 N UPTAKE

Table 21 indicated that treatments differed significantly with regard to N uptake at different stages of crop growth.

At tillering, higher N uptake was with LGU basal (23.3 kg ha^{-1}) which was significantly superior to all other UBF except NBU basal application (22.9 kg ha^{-1}) with which it was on par. N uptake at PIS was more with LGU split

Table 20. Nitrogen content (%) in grain and straw of rice as influenced by urea-based fertilisers

Treatment	Grain	Straw
T_1	0.98	0.32
T_2	1.08	0.41
T_3	1.09	0.37
T_4	1.11	0.41
T_5	1.11	0.39
T_6	1.10	0.38
T_7	1.03	0.40
T_8	1.07	0.38
T_9	1.11	0.40
T_{10}	1.06	0.41
T_{11}	1.08	0.41
T_{12}	1.03	0.42
Mean	1.07	0.39
SEm ±	0.01	0.01
CD 5%	0.03	0.03

Table 21. Nitrogen uptake (kg ha^{-1}) of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	Tillering	Panicle initiation	Flowering
T_1	7.0	18.7	33.5
T_2	19.1	36.5	57.3
T_3	14.8	29.1	48.1
T_4	18.5	34.8	60.1
T_5	18.1	32.6	54.4
T_6	23.3	36.0	60.1
T_7	22.9	36.3	52.0
T_8	17.6	33.1	52.9
T_9	17.7	36.9	61.8
T_{10}	18.5	40.3	66.7
T_{11}	18.6	39.9	61.7
T_{12}	18.1	35.4	57.5
Mean	17.9	34.1	55.5
SEm ±	0.6	1.2	0.7
CD 5%	1.8	3.4	2.1

application (40.3 kg ha^{-1}) which was comparable with split application of NBU (39.9 kg ha^{-1}) and RPCU (36.9 kg ha^{-1}) but significantly superior to all other treatments. LGU split application recorded maximum N absorption (66.7 kg ha^{-1}) among all the treatments at flowering. N uptake obtained with RPCU split (61.8 kg ha^{-1}) and NBU split, Glm + PU (60.1 kg ha^{-1}) and LGU basal application (60.1 kg ha^{-1}) was comparable but significantly superior to the rest of the treatments.

N uptake in grain as well as in straw (Table 22) was significantly more with LGU split application (61.4 and 25.0 kg ha^{-1}, respectively) but on par with NBU split application (60.2 and 24.3 kg ha^{-1}, respectively).

Maximum total N uptake (86.4 kg ha^{-1}) was with LGU split application which was significantly superior to all treatments but on par with NBU split application (84.5 kg ha^{-1}). Total N uptake resulted with RPCU split application (82.3 kg ha^{-1}) and Glm + PU (80.3 kg ha^{-1}) was on par with each other but significantly higher than all the other treatments. The difference in total N uptake due to the split application of GCU (76.3), PU split (75.7) and LGU basal (73.9) was not significant.

Application of LGU, NBU, RPCU in splits and Glm + PU resulted in 12.4, 10.4, 8.0 and 5.7 per cent increase in N uptake over PU split application, respectively.

Table 22. Nitrogen uptake by grain, straw and total nitrogen uptake (kg ha^{-1}) of rice as influenced by urea-based fertilisers

Treatment	N-uptake in grain	N-uptake in straw	Total N-uptake
T_1	28.8	9.6	38.4
T_2	56.1	19.6	75.7
T_3	45.0	15.8	60.8
T_4	58.6	21.7	80.3
T_5	54.1	18.3	72.4
T_6	56.0	17.9	73.9
T_7	47.5	18.9	66.4
T_8	51.0	18.5	69.5
T_9	58.8	23.5	82.3
T_{10}	61.4	25.0	86.4
T_{11}	60.2	24.3	84.5
T_{12}	53.3	23.0	76.3
Mean	52.6	19.7	72.2
SEm ±	0.8	0.5	1.3
CD 5%	2.4	1.4	3.8

4.13 P AND K UPTAKE AT HARVEST

The amount of P and K present in grain and straw was estimated to compute total uptake of P and K at harvest by the crop. P and K uptake were significantly influenced by different treatments (Table 23).

Split application of all UBF resulted in higher P uptake compared to their basal application. Maximum P uptake was with split application of LGU (19.6 kg ha^{-1}) followed by NBU split (18.2 kg ha^{-1}). Lower P uptake was with control (8.7 kg ha^{-1}) and FYM + PU (12.8 kg ha^{-1}). K uptake was higher with LGU split (70.1 kg ha^{-1}) and it was comparable with RPCU split (69.8 kg ha^{-1}) and NBU split application (69.8 kg ha^{-1}). The K uptake with PU split application was 63.8 kg ha^{-1} and it was least in crop grown with control (36.3 kg ha^{-1}).

4.14 PROTEIN CONTENT (%)

Protein content differed significantly due to various treatments (Table 23). The protein content varied from 6.13 per cent in control to 6.94 in Glm + PU and RPCU basal application. It was 6.75 per cent with PU split application.

4.15 RESPONSE TO N

There was significant response of rice to N due to different treatments (Table 24). LGU split application showed maximum N response (28.57 kg grain kg^{-1} N

Table 23. Phosphorus and potassium uptake and protein content of rice as influenced by urea-based fertilisers

Treatment	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Protein content (%)
T_1	8.7	36.3	6.13
T_2	15.1	63.8	6.75
T_3	12.0	48.4	6.83
T_4	15.8	63.4	6.94
T_5	14.4	55.2	6.94
T_6	15.0	61.3	6.88
T_7	13.9	52.1	6.44
T_8	14.1	53.3	6.69
T_9	17.2	69.8	6.88
T_{10}	19.6	70.1	6.63
T_{11}	18.2	69.8	6.75
T_{12}	16.8	62.0	6.44
Mean	15.1	58.8	6.69
SEm ±	0.2	1.0	0.06
CD 5%	0.7	2.9	0.19

which was superior to all other treatments. This was followed by the NBU split application (26.37 kg grain kg^{-1} N). Significantly higher responses were obtained with RPCU split, Glm + PU and PU split application which were on par and recorded 24.10, 23.40 and 22.54 kg grain kg^{-1}N, respectively. Significantly lower response was observed with FYM + PU (11.97 kg grain kg^{-1}N).

4.16 APPARANT N RECOVERY

The data on apparant recovery of N presented in table 24 revealed that there were significant differences due to different treatments. The trend in N recovery matched the yield response. It was higher with LGU split application (48.0 per cent) which was on par with NBU split application (46.1 per cent) but superior to all other treatments. N recovery obtained with RPCU split application (43.9 per cent) and Glm + PU (41.9 per cent) was on par with each other but significantly higher compared to the rest of the treatments. Split application of GCU, PU and LGU basal application recorded similar apparant N recovery. It was significantly lower with FYM + PU (22.4 per cent).

Table 24. Response to N and apparant N recovery of rice as influenced by urea-based fertilisers

Treatment	Response to N (kg grain kg^{-1} N)	Apparent N recovery (per cent)
T_1	-	-
T_2	22.54	37.3 ✓
T_3	11.97	22.4 ✓
T_4	23.40	41.9 ✓
T_5	19.40	34.0
T_6	21.54	35.5
T_7	16.74	28.0
T_8	18.30	31.1
T_9	24.10	43.9
T_{10}	28.57	48.0
T_{11}	26.37	46.1
T_{12}	23.34	37.9
Mean	21.48	36.9
SEm ±	0.55	1.1
CD 5%	1.62	3.1

4.17 CORRELATIONS

Plant height and total dry matter at all stages of crop growth except at tillering had a positive and significant correlations with grain yield (Table 25). LAI at all stages except at tillering had a positive and significant correlation with grain yield. All the yield components had a positive and significant correlations with grain yield.

Total N uptake at harvest was very closely related to grain yield with a positive correlation ('r' value 0.9951). P and K uptake at harvest were significantly correlated with grain yield.

4.18 ECONOMICS

The data on economics in rice production with different urea based fertilisers are presented in Table 26 and illustrated in Fig. 11.

Net returns were significantly influenced by urea-based fertilisers. Higher net returns were with LGU split application (Rs. 7957 ha^{-1}) compared to all treatments. The net returns obtained with NBU split (Rs.7169 ha^{-1}), RPCU split (Rs.6921 ha^{-1}) and Glm + PU (Rs.6841 ha^{-1}) were at par. Split application of GCU, PU and basal application of LGU resulted similar net returns but superior to basal application of RPCU, GCU and NBU. Lower net returns were recorded with control (Rs.2304 ha^{-1}). Net returns per rupee invested on N fertiliser was highest

Table 25. Correlation coefficients ('r' values) between growth characters and yield attributes with grain yield

Character	'r' values	
Grain yield vs Plant height at T	0.5037	NS
Grain yield vs Plant height at PIS	0.7735	**
Grain yield vs Plant height at F	0.8484	**
Grain yield vs Plant height at M	0.9185	**
Grain yield vs Total dry matter at T	0.4546	NS
Grain yield vs Total dry matter at PIS	0.9520	**
Grain yield vs Total dry matter at F	0.9905	**
Grain yield vs Total dry matter at M	0.9664	**
Grain yield vs LAI at T	0.5614	NS
Grain yield vs LAI at PIS	0.9278	**
Grain yield vs LAI at FS	0.8868	**
Grain yield vs Panicles m^{-2}	0.9544	**
Grain yield vs Filled grains $panicle^{-1}$	0.9317	**
Grain yield vs 1000-grain weight	0.8785	**
Grain yield vs Panicle weight	0.7823	**
Grain yield vs Panicle length	0.8373	**
Grain yield vs N uptake at T	0.7212	**
Grain yield vs N uptake at PIS	0.9607	**
Grain yield vs N uptake at F	0.9902	**
Grain yield vs Total N uptake at harvest	0.9951	**
Grain yield vs P uptake at harvest	0.9629	**
Grain yield vs K uptake at harvest	0.9765	**

** Significant at 1% level   NS : Non-significant

Table 26. Gross and net returns and net returns per rupee invested on N fertiliser in rice as influenced by urea-based fertilisers

Treatment	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Net returns per rupee invested on N fertiliser
T_1	4270	6474	2304	-
T_2	4870	11338	6468	6.9
T_3	4970	9121	4151	2.6
T_4	4770	11611	6841	9.1
T_5	4900	10689	5789	5.5
T_6	4830	11123	6293	7.1
T_7	5140	10167	5027	3.1
T_8	4890	10505	5615	5.3
T_9	4920	11841	6921	7.1
T_{10}	4850	12807	7957	9.7
T_{11}	5160	12329	7169	5.5
T_{12}	4910	11437	6527	6.9
Mean			5922	
SEm ±			145	
CD 5%		NA	426	NA

NA : Not analysed

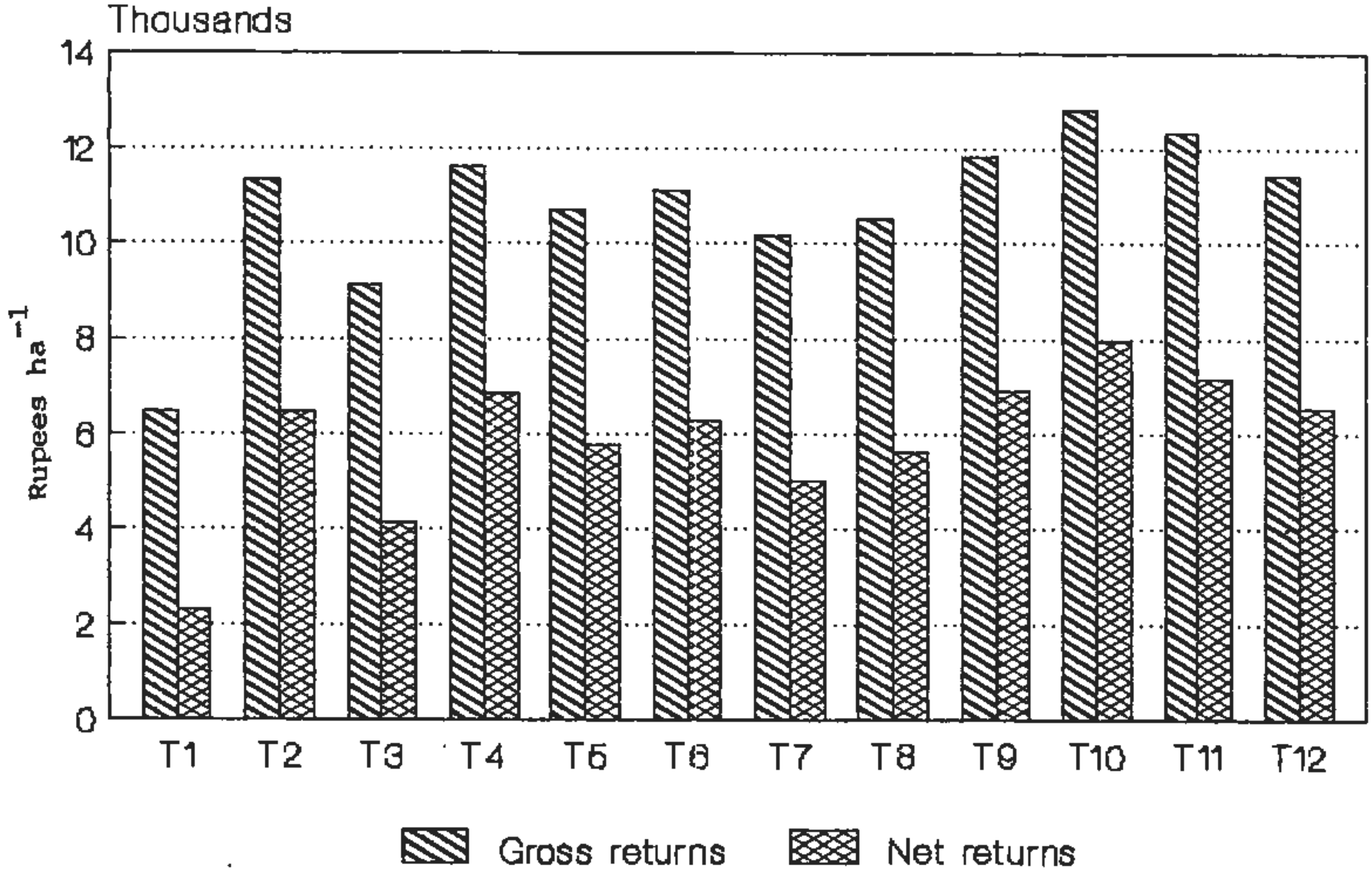


Fig.11.Gross and net returns (Rs ha^{-1}) of rice as influenced by urea-based fertilisers

with LGU split (Rs.9.7) followed by Glm + PU (Rs.9.1), LGU basal and NBU split (Rs.7.1) while it was lowest with FYM + PU (Rs.2.6).

DISCUSSION

CHAPTER V

DISCUSSION

The results obtained from the investigation entitled "Effect of urea-based fertilisers on growth and yield of rice" are discussed hereunder.

The weather conditions during the crop period were favourable for growth and development. In the present study the dose of N (100 kg ha^{-1}) was the same in all treatments except control (no nitrogen).

5.1 GROWTH CHARACTERS

Growth was measured as plant height, number of tillers, LAI and dry matter production. Application of urea-based fertilisers had significant influence on plant height, tiller production, LAI and dry matter production.

At tillering, significantly higher plant height was obtained with NBU basal application compared to rest of the treatments but on par with RPCU basal application (Table 3). It might be due to higher N availability as entire dose of N was applied as basal. Maximum plant height due to NBU basal application at tillering was reported by Darvesh Saheb (1987). At PIS, NBU split application found significantly superior to the rest of the treatments but comparable with basal application of LGU and RPCU. At flowering taller plants were with LGU split application compared to rest of the treatments but on par with LGU basal. LGU split application continued to produce taller plants at maturity which was comparable with LGU basal, Glm + PU and NBU split application. The nutrient release from granular form of urea (LGU) might have been continuous and this could have resulted in more plant height. Increased plant height due to LGU over PU was reported by Govindu (1988) and Karuna Sagar (1989) and highest plant height due to LGU applied in three splits was reported by RARS, Nandyal, Andhra Pradesh (1987).

Higher tiller production was with NBU basal application which was on par with LGU basal application, but superior to the rest of the treatments at tillering (Table 4). At PIS and flowering stages, LGU split application was superior to the rest of the treatments and resulted in production of 457 and 497 tillers m^{-2}, respectively. The enhanced availability of N due to reduced losses through LGU split application might have increased the tiller production as supported by Madhusudhana Reddy (1987).

It is generally accepted that the leaf area represents the measure of photosynthetic efficiency. Data recorded on LAI (Table 5) at various crop growth stages indicated that rate of increase in LAI was maximum (0.065 day^{-1}) between tillering and PIS followed by PIS and flowering (0.052 day^{-1}) and there after decreased (0.041 day^{-1}) from flowering to maturity which was due to decrease in leaf number (Appendix B). At tillering, application of NBU as basal resulted in higher LAI (1.75). LAI obtained with LGU basal (1.54), RPCU basal (1.53) and GCU basal (1.50) was comparable whereas at remaining crop growth stages, LGU split application showed its superiority in increasing the LAI. The more LAI due to LGU split application compared to other UBF was attributed to more number of tillers (Table 4) and leaves $hill^{-1}$ (Appendix B).

Higher dry matter production was with NBU basal application (Table 6) at tillering. At PIS, higher dry matter obtained with LGU split application was comparable with NBU split application. The effect of RPCU split, PU split and GCU split application on dry matter production was same at PIS. At flowering and maturity, LGU split application showed significant increase in dry matter production (673 and 1193 g m^{-2} respectively). The reduced N losses with split application of LGU might have enhanced better utilisation of applied N for higher dry matter production (Madhusudhana Reddy, 1987 and Govindu, 1988). The dry matter production obtained with NBU split application (1046 g m^{-2}) was more or less equal to that of RPCU split (1018 g m^{-2}) but superior to the rest of the treatments. The per cent increase in dry matter due to split application of LGU, NBU and RPCU was 54.5, 48.1 and 46.7, respectively over the control whereas 17.6, 6.0 and 3.4 per cent over PU split application. The dry matter production due to split application of LGU, NBU, RPCU and GCU increased by 22.0, 23.7, 15.2 and 17.7 per cent over their basal application, respectively.

Split application of UBF recorded higher tiller production, dry matter and LAI over their basal application at all stages of growth except at early stage. Basal application of entire dose of N as UBF should have higher N in the soil compared to split application. Therefore, it was natural to expect more growth with basal application of UBF at tillering. At later stages, application of entire dose of N as basal might have resulted in higher leaching losses compared to split application. In addition, due to split application, there might be sustained availability of N. Application of FYM + PU did not show appreciable effect in increasing total tillers, LAI and dry matter at all stages of crop growth among all the UBF.

5.2 DRY MATTER PARTITIONING

Translocation of photosynthates for partitioning of dry matter depends on the demand of the plant components like leaf blade, sheath, culm and panicle. Supply is controlled by net photosynthesis, whereas its actual allocation depends on several factors including fertiliser application. Total dry matter production during the growing season and partition of dry matter to the panicle are the major determinants of grain yield of rice (Yoshida, 1972). In the present study, dry matter was partitioned into leaf blade, leaf sheath at tillering; leaf blade, leaf sheath and culm at PIS; leaf blade, sheath, culm and panicle at flowering and maturity. During tillering, leaf blade and sheath contained equal amounts of dry matter (Table 7). NBU split application produced higher amount of leaf blade and leaf sheath dry matter followed by LGU basal application. At PIS, more dry matter was partitioned to sheath over leaf blade (Table 8). Split application of UBF produced more leaf blade and leaf sheath dry matter compared to basal application of UBF. Culm dry matter due to split and basal application was more or less equal. Dry matter alloted to culm at flowering (Table 9) was increased substantially indicating the culm development. There was a considerable fall in blade and sheath dry matter as panicle started developing. This shows the redistribution of assimilates to panicle during the reproductive stage. Comparatively reduction in leaf dry weight was more in basal applied LGU and NBU indicating the significance of redistribution of accumulated photosynthates to grain. All UBF when applied in split, produced more panicle dry matter along with PU split and Glm + PU split (Table 10).

5.3 GROWTH ANALYSIS

Between tillering and PIS (Table 11) the differences in CGR due to split application of RPCU, LGU, NBU and GCU were comparable with each other but significantly superior to the rest of the treatments. CGR was higher with RPCU split (15.93 g m^{-2} day^{-1}) and LGU split application (15.86 g m^{-2} day^{-1}). Between PIS and flowering, CGR was more with LGU split (23.53 g m^{-2} day^{-1}) followed by Glm + PU application (22.20 g m^{-2} day^{-1}). Evenafter PIS, LGU split application continued to result in higher CGR (17.33g m^{-2} day^{-1}) compared to other treatments. The important losses of N under low land conditions are leaching and denitrification. Higher CGR maintained by LGU might be due to reduction in leaching losses because of its less solubility and application in splits.

The RGR between tillering and PIS (Table 12) was higher with split application of RPCU, GCU, LGU and NBU compared to their basal application and PU split. RGR was maximum with RPCU split application (106.1 mg g^{-1} day^{-1}). The higher RGR due to split application of LGU compared to PU split application might be due to reduction in volatilisation losses (Table 18) and leaching losses which might have increased the availability of N to the crop. RGR during PIS to flowering was higher with GCU basal followed by Glm + PU and LGU basal application. During flowering to maturity, RGR was higher with LGU basal followed by LGU split application.

The data on NAR (Table 13) were inconsistent. However, during flowering to maturity split application of UBF resulted in higher NAR compared to their basal application.

5.4 YIELD ATTRIBUTES

Data on number of panicles m^{-2} (Table 15) revealed that LGU split application recorded higher number of panicles (421 m^{-2}) closely followed by NBU split application (404 panicles m^{-2}). It might be due to higher tiller production. Number of panicles obtained through RPCU split application and Glm + PU was comparable and significantly superior compared to the rest of the treatments. Application of LGU, NBU, RPCU in split application and Glm + PU increased the panicles by 12.4, 8.7, 5.6 and 4.4 per cent over PU split application, respectively. The per cent increase in panicles due to split application of LGU, NBU, RPCU and GCU was 14.5, 19.1, 12.0 and 7.7, respectively over basal application of corresponding UBF. Higher number of panicles due to split application of UBF may be due to continuous availability of N for longer time. Increase in panicles due to LGU over PU was reported by Madhusudhana Reddy (1987), Govindu (1988) and Karuna Sagar (1989).

Filled grains panicle^{-1} obtained through the split application of all UBF were comparatively higher than their application. RPCU and GCU split application more or less recorded similar number of grains panicle^{-1} (78.3 and 77.9, respectively). The number of filled grains panicle^{-1} recorded with NBU split application (76.1) was comparable with LGU split application (74.9). The number of spikelets in rice reflects the sink capacity for grain production and it is fairly well established that split application of N at PIS could be quite beneficial for improving the spikelet production per unit area (Murata, 1969). In the present study, prolonged sustained availability of N under split application might be more beneficial in increasing the number of filled grains panicle^{-1}. Increase in filled grains panicle^{-1} due to RPCU over PU was reported by Anand Rao (1988), due to NBU split application by Darvesh Saheb (1987). Madhusudhana Reddy (1987), Govindu (1988) and Karuna Sagar (1989) reported the trend of increase in number of filled grains panicle^{-1} due to LGU over PU.

Thousand grain weight is a more stable character mainly influenced by genetic factors than management practices. In the present study, different UBF did not influence this character.

Split application of all UBF significantly increased the panicle weight and panicle length as compared to their basal application (Table 16). However, LGU basal application was comparable with GCU split application in panicle weight. Maximum panicle weight (2.29 g) was recorded with RPCU split followed by LGU split (2.21 g) and NBU split (2.19 g) whereas, maximum panicle length was observed with NBU split (21.0 cm) followed by LGU split (20.4 cm).

The significant increase in the yield attributing characters with split application of UBF might be due to greater photosynthetic ability of rice crop by continued availability of N. Similar increase in the yield components was recorded with the application of LGU over PU (Madhusudhana Reddy, 1987 and DRR, 1987).

5.5 GRAIN YIELD

From Table 17, it was clear that among the urea-based fertilisers, application of LGU in split gave higher grain yield (5793 kg ha^{-1}). This was followed by NBU split application (5573 kg ha^{-1}). Grain yield obtained with

RPCU split (5346 kg ha^{-1}) and Glm + PU (5276 kg ha^{-1}) was comparable. Application of LGU, NBU, RPCU in split application and Glm + PU increased the grain yield to a tune of 10.4, 6.9, 2.9 and 1.6 per cent over PU split application, respectively, whereas it was 49.3, 47.3, 45.1 and 44.4 over control, respectively. Higher grain yield due to split application of LGU was due to higher number of panicles m^{-2} and more number of filled grains panicle^{-1}. Grain yield due to urea granules increased by 11 per cent over PU was reported by FAO (1980) whereas 8 per cent by Travis (1980) and 20 per cent by Prins _et al_. (1984). Madhusudhana Reddy (1987), Govindu(1988) and Karuna Sagar (1989) reported increased grain yield due to LGU over PU. Application of urea briquetts is possible only with row transplanted crop and the placement possess a problem. To overcome this problem, broadcast application of LGU is one of the alternatives to low land rice. If large sized urea granules (1 to 2 g) broadcasted, the distribution will be uneven. So, LGU with an average weight of 0.17 g were tried and the results are promising when applied in splits. Higher grain yield with NBU in split application was due to superior yield attributing characters as reported by Darvesh Saheb (1987). The beneficial effect of green leaf manure might be due to continued and slow release of N to the crop as reported by Saravanan _et al_. (1987).

5.6 STRAW YIELD

Straw yield was also higher with LGU split (6103 kg ha^{-1}) followed by split application of NBU, RPCU, GCU and Glm + PU. This was because of prolonged vegetative growth even during grain filling period due to slow release nature of UBF.

5.7 HARVEST INDEX (HI)

HI represents the increased physiological capacity (often termed as sink capacity) to mobilise photosynthates and translocate it to organs having economic value. It was more with PU split application (52.0 per cent) and LGU basal (51.9 per cent) showing effective utilisation of assimilates. Similar results were also reported by Darvesh Saheb (1987).

5.8 VOLATILISATION LOSSES

Higher volatilisation loss was noted in PU split application and it was minimum in Glm + PU. This might be higher content of NH_4^+N in flood water in former than in the later which had slow mineralisation. Similar findings were also noted with PU split application by Saravanan et al. (1988). Application of LGU, GCU, RPCU and NBU reduced the volatilisation losses compared to PU split application.

5.9 N CONTENT

N content of plants was maximum at tillering and showed a decline thereafter (Table 19). N is absorbed vigorously at early stages of crop growth due to greater cell division. N content decreased as the crop age increased due to dilution effect caused by higher dry matter production in comparison to absorption and mobilisation of N towards developing grain (Dubey and Bisen, 1989).

5.10 N UPTAKE

From table 21 it was clear that at tillering, N uptake was maximum with LGU basal (23.3 kg ha^{-1}) followed by NBU basal application. At PIS, N uptake was higher with LGU split (40.3 kg ha^{-1}) and comparable with NBU split and RPCU split. At flowering, LGU split application recorded significant increase in N uptake (66.7 kg ha^{-1}) compared to all the treatments.

Total N uptake (Table 22) was more with LGU split (86.4 kg ha^{-1}) and on par with NBU split (84.5 kg ha^{-1}). Total N uptake observed with RPCU split and Glm + PU was comparable but significantly higher compared to all treatments. Total N uptake was similar with split application of GCU, PU and LGU basal application. The increased N uptake at all stages of crop growth might be due to its influence on dry matter production. Increased N uptake due to LGU over PU was also reported by Rabindra et al. (1989). The trend of increase in N uptake in grain and straw due to NBU over split application of PU might be attributed to the inhibition of nitrification by neem cake and resulted decrease in loss of N through leaching as nitrate and denitrification (Thomas and Prasad, 1982).

5.11 P AND K UPTAKE AT HARVEST

From Table 23, it was clear that LGU split application recorded significantly higher phosphorus uptake (19.6 kg ha^{-1}) followed by NBU split application (18.2 kg ha^{-1}). Increased N absorption might have favoured P uptake. Potassium uptake with LGU split (70.1 kg ha^{-1}) and NBU split (69.8 kg ha^{-1}) was comparable but both were superior to the rest of the treatments. The increase in nutrient uptake was due to its efficiency in absorption of more nutrients from the soil and converting it into dry matter. Increased uptake of N and P due to NBU was reported by Subbaiah et al. (1979) and Darvesh Saheb (1987). Maximum P and K uptake with LGU over PU was reported by Govindu (1988) and Karuna Sagar (1989).

5.12 RESPONSE TO N

N response (Table 24) was higher with LGU split application (28.57 kg grain kg^{-1}N) followed by NBU split (26.37 kg grain kg^{-1}N). Slow release of N from LGU and NBU might have increased the availability of N throughout the crop growth. This has led to high response of rice to nitrogen in terms of grain yield. N response obtained with RPCU split, Glm + PU and PU split was comparable. LGU basal application was on par with PU split but superior to basal application of other UBF. Higher response due to LGU over PU was reported by Govindu (1988) and Karuna Sagar (1989). Higher grain production kg^{-1} N due to RPCU was reported by Singh and Patel (1990).

5.13 APPARANT N RECOVERY

LGU split application recorded significantly higher apparant recovery of N (48.0 per cent) compared to all treatments (table 24) but comparable with NBU split application (14.1 per cent). It may be noted that total N uptake was maximum due to split application of LGU and NBU leading to maximum apparant N recovery against PU split (37.3 per cent). Apparant recovery of N with the application of Glm + PU was higher (41.9 per cent) than that of PU split application. This may be due to greater uptake of N due to less volatilisation of N in Glm + PU compared to PU split application (Table 18). Madhusudhana Reddy (1987), Govindu (1988) and Karuna Sagar (1989) reported an increase in apparant recovery in LGU over PU.

From the present study, it can be concluded that the application of large granule urea in two equal splits (½ basal + ½ at panicle initiation) was the best for low land rice. Neem cake blended urea application in two equal splits (½ basal + ½ at panicle initiation) was the next best among different urea-based fertilisers. Application of green leaf manure one week before transplanting to supply 50 kg N and the remaining 50 kg N through prilled urea in two equal splits at active tillering and panicle initiation was found equal to the application of 100 kg N ha^{-1} through prilled urea in three splits (½ N basal + ¼ at active tillering + ¼ at panicle initiation). Application of large granule urea in two equal splits (½ basal + ½ at panicle initiation) is recommended for getting higher yield of low land rice.

SUMMARY

CHAPTER VI

SUMMARY

Nitrogen is the king pin of the rice production. Paradoxically N is the only element subjected to major losses such as denitrification, volatilisation, leaching and runoff. Efficient N management using urea-based fertilisers in minimising the losses will result in higher N use efficiency and increased grain yield. Hence, an experiment was conducted on sandy loam soil of S.V. Agricultural College Farm, Tirupati during Kharif, 1989 to study the effect of urea-based fertilisers on growth and yield of NLR 13969 rice. There were 12 treatments consisting of prilled urea (PU) applied in three splits (½ basal + ¼ at active tillering + ¼ at PIS) large granule urea (LGU), rock phosphate coated urea (RPCU), neem cake blended urea (NBU), gypsum coated urea (GCU) applied basal and two equal splits (½ at transplanting + ½ at PIS), farm yard manure + prilled urea, green leaf manure + prilled urea and control (no nitrogen). The N dose applied was 100 kg ha^{-1} in all the treatments except control. The experiment was conducted in a randomised block design with three replications. The salient findings are summarised below.

There were significant differences in plant height, tiller production, LAI and dry matter production at all stages of crop growth due to different urea based fertilisers. Basal application of urea based fertilisers performed better on all growth attributes during early stages of crop growth whereas split application of UBF took over the advantage along with GLM + PU during later stages of crop growth.

During tillering stage, plants grew taller with higher LAI and produced more tillers and dry matter when the crop was grown with basal application of NBU. All other UBF favoured the growth differently when applied basal. The Plant height was higher in RPCU basal and GCU basal and more tillers recorded with basal application of LGU.

At panicle initiation, taller plants were with split application of NBU. However, comparable effects on plant height were recorded with basal application of LGU and RPCU. LGU split application performed better in increasing the LAI and tiller production which was superior to their other UBF. Higher dry matter was obtained through LGU split application which was comparable with NBU split application.

During flowering stage, higher plant height was with LGU split application but on par with LGU basal application. Significant increase in tiller production, LAI and dry matter was obtained due to split application of LGU.

At maturity, plants were taller in LGU split, LGU basal, GLM + PU and NBU split application. LGU split application showed its superiority in increasing LAI (2.47) and dry matter production (1193 g m^{-2}).

The distribution of photosynthates to various plant parts viz., leaf blade, sheath, culm and panicle varied considerably with different UBF and stages of crop growth. During early stages of crop growth, leaf blade and sheath contained equal amounts of dry matter. At PIS, leaf blade had more dry matter followed by leaf sheath and culm. At flowering, the leaf blade dry matter decreased considerably while leaf sheath and culm dry matter increased. More dry matter was accumulated in panicle followed by leaf sheath at harvest. LGU split application had higher leaf blade, sheath, culm and panicle dry matter as compared to rest of the treatments.

Number of panicles m^{-2} was higher with LGU split application (421) followed by NBU split application (404). Split application of PU was equal with basal application of LGU in producing panicles m^{-2}. Maximum number of filled grains $panicle^{-1}$ was with RPCU split application (78.3) which was on par with GCU split application (77.9). Filled grains $panicle^{-1}$ obtained with split application of NBU and LGU was at par. Thousand grain weight was not influenced by different UBF. NBU split application recorded higher spikelet sterility percentage (13.9) which was comparable with LGU split application. Higher panicle weight (2.29 g) was recorded with RPCU split application whereas panicle length (21.0 cm) with NBU split application. Lower number of panicles m^{-2}, filled grains $panicle^{-1}$ and spikelet sterility percentage was with control.

Grain yield was significantly higher with LGU split application (5793 kg ha^{-1}) followed by NBU split application (5593 kg ha^{-1}). Grain yield obtained with Glm + PU (5276 kg ha^{-1}) and split application of PU (5190 kg ha^{-1}) was comparable. The lower grain yield was with control (2936 kg ha^{-1}).

LGU split application resulted in higher straw yield (6103 kg ha^{-1}). Lower straw yield (3010 kg ha^{-1}) was obtained with control (no nitrogen). Straw yield obtained with Glm + PU (5293 kg ha^{-1}) was higher than that of PU split application (4790 kg ha^{-1}).

PU split application gave significantly higher HI (52.0 per cent) which was comparable with basal application of LGU and RPCU.

Volatilisation loss of N was reduced considerably due to split application of UBF as compared to their basal application. Lower volatilisation loss was observed with

GLM + PU (9.35 per cent) whereas it was higher with PU split application (13.46 per cent).

N uptake increased as the crop age advanced. At tillering, significantly more N uptake (23.3 kg ha^{-1}) was observed with LGU basal application. At PIS, split application of LGU resulted in higher N uptake (40.3 kg ha^{-1}) which was comparable with split application of NBU. N uptake was higher (66.7 kg ha^{-1}) with LGU split application at flowering. N uptake in grain as well as straw was higher with LGU split application but comparable with NBU split application. Maximum total N uptake was with LGU split application (86.4 kg ha^{-1}). The higher uptake of N by crop was recorded in Glm + PU as compared to PU split application. Lower N uptake (38.4 kg ha^{-1}) was with control.

P uptake was significantly more with LGU split application (19.6 kg ha^{-1}). The K uptake recorded with LGU split (70.1 kg ha^{-1}) and NBU split application (69.8 kg ha^{-1}) was comparable but significantly superior to the rest of the treatments.

The protein content varied from 6.13 per cent in control to 6.94 in Glm + PU and RPCU basal application.

Significantly higher response of rice to N was observed with LGU split (28.57 kg grain kg^{-1} N) followed by NBU split (26.37 kg grain kg^{-1}N). Lower response to N was recorded in FYM + PU (11.97 kg grain kg^{-1}N).

Apparent N recovery was higher with LGU split (48.0 per cent) but on par with NBU split application (46.1 per cent). Recovery of N was lower with FYM + PU (22.4 per cent).

There were significant and positive correlations between grain yield and growth characters like plant height, LAI and total dry matter at all stages of crop growth except at tillering where positive and non significant correlations were observed.

Grain yield was positively and significantly correlated with all yield components and N uptake at all stages of crop growth. P and K uptake at harvest were positively correlated with grain yield.

Net returns were significantly higher with LGU split application (₨.7957 ha^{-1}). Net returns obtained with NBU split, RPCU split and Glm + PU were comparable. Net returns per rupee invested on N fertiliser was highest with LGU split (₨.9.70) followed by Glm + PU (₨.9.10). Lower net returns were recorded with control.

From the present study, it can be inferred that split application (½ basal + ½ at panicle initiation) of urea based fertilisers like large granule urea (LGU), neem cake blended urea (NBU) and rock phosphate coated urea (RPCU) were advantageous over prilled urea (PU) split application(½ basal + ¼ at active tillering + ¼ at panicle initiation). Green leaf manure in combination with prilled urea was found beneficial in minimising N losses and saving 50 per cent N through inorganic N fertiliser. Application of large granule urea in two equal splits (½ basal + ½ at panicle initiation) was the best for increasing the grain yield and net returns in lowland rice.

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* Original not seen

APPENDICES

APPENDIX A

List of Calender of operations (Kharif, 1989)

Date	Operation
24.06.89 to 27.06.89	Nursery bed preparation
28.06.89	Broadcasting of sprouted seeds
16.07.89 to 22.07.89	Main field preparation and incorporation of green leaf manure and farm yard manure as per treatments
23.07.89	Fertiliser application and Transplanting
11.08.89	Hand weeding
13.08.89	Fertiliser application
29.08.89	Fertiliser application
12.10.89 to 19.10.89	Harvesting

APPENDIX B

Number of leaves hill^{-1} of rice as influenced by urea-based fertilisers at various crop growth stages

Treatment	Tillering	Panicle initiation	Flowering	Maturity
T_1	12.1	16.1	17.6	14.7
T_2	17.3	24.2	28.3	21.4
T_3	15.1	21.4	23.4	17.7
T_4	17.0	24.4	27.4	23.5
T_5	19.9	24.6	27.7	20.0
T_6	19.4	23.5	26.8	21.0
T_7	20.5	24.6	25.9	19.4
T_8	18.4	23.0	25.5	19.7
T_9	17.6	25.1	28.7	22.5
T_{10}	18.0	28.7	32.4	24.7
T_{11}	17.8	26.1	31.2	24.0
T_{12}	17.9	24.3	28.5	23.2
Mean	17.6	23.8	27.0	21.0
SEm ±	0.2	0.2	0.4	0.3
CD 5%	0.7	0.7	1.1	0.9