FATE AND EFFICIENCY OF UREA BASED FERTILIZER N FOR RICE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Fate and efficiency of urea-based fertilizer N for rice" is a bonafide record of research work done by me during the period of my P.G. course and and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of this or any other University or Society.

P. Babu Mathew

Vellayani
24-3-1987

BABU MATHEW, P.

CERTIFICATE

Certified that this thesis entitled "Fate and efficiency of urea-based fertilizer N for rice" is a bonafide record of research work done independently by Sri. Babu Mathew, P. under my guidance and supervision and that this has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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C O N T E N T S

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LIST OF TABLES

LIST OF APPENDICES

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

AICRIP	All India Co-ordinated Rice Improvement Project
@	At the rate of
cm	Centimetre
cm^2	Square centimetre
CSRC	Cropping Systems Research Centre
CV	Cultivar
DAT	Days after transplanting
DMP	Dry matter production
g	gram
HI	Harvest index
na	hectare
kg	kilogram
KAU	Kerala Agricultural University
m^2	Square metre

INTRODUCTION

INTRODUCTION

Increased productivity, enhanced cropping intensity and effective fertilizer use are the major ways to improve agricultural production. Approximately 8.7 million tons of fertilizers are being consumed annually in India of which the nitrogenous fertilizers amounts to 5.8 million tons and of this 70 per cent is in the form of urea (Anon., 1986a).

Nitrogen, the key element in plant nutrition is the most deficient in soils and is one of the costliest elements. The recovery of nitrogen by the rice plant seldom exceeds 40 per cent (Craswell and De Datta, 1980). Normally it ranges from 25 to 40 per cent with an average of 30 per cent (Craswell and Vlek, 1979). About 40 per cent of applied nitrogen is lost from the soil through run off, leaching, volatalization and denitrification. This situation warrants economisation of this costly input. The efficiency of applied nitrogen can be improved by several means, which include the use of coated fertilizers, nitrification inhibitors, urease inhibitors, placement

of urea super granules and split application of urea. The State of Kerala receives an average annual rainfall of 304 cm, and this leads to loss of a lot of applied nitrogen from the soil by leaching. Despite this, very little study has been undertaken to find out ways and means to increase the efficacy of applied urea in the soils of Kerala, especially in the sandy loam soils of the Trivandrum District. In 1985, the Cropping Systems Research Centre, Karamana, Trivandrum has been selected as one of the 12 bench mark centres in India to study the efficiency of urea-based nitrogen fertilizers under the PL 480 scheme entitled "Fate and efficiency of urea based nitrogen fertilizers in India". This project has been approved by the Kerala Agricultural University as a post-graduate research programme. Thus the present study was undertaken with the following objectives.

(1) To compare the efficacy of urea-modified materials compared to prilled urea on rice yield.

(2) To fix up the optimum dose of nitrogen for the variety Jaya.

(3) To study the interaction effect between levels of nitrogen and modified urea materials on rice.

(4) To study the uptake of nitrogen by rice as influenced by modified urea materials and levels of nitrogen and their interaction.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The use of slow-release nitrogen fertilizers has been one of the methods being followed to increase the efficiency of nitrogen in paddy fields. This chapter is a brief review of research work done on the effect of different modified materials of urea, levels of nitrogen and their interactions on the growth, yield, quality and nutrient uptake of rice.

A. Effect of Urea modified materials on growth, uptake of nutrients and yield of rice.

1. Prilled Urea

The superiority of split application of prilled urea to rice over single basal application has been brought out by many workers. (Ten Havo, 1971; Singh *et al.*, 1972; Muralidharan *et al.*, 1972; Pande *et al.*, 1977; and Ram *et al.*, 1984).

2. Urea Super granules

The efficiency of applied urea can be increased by using large sized urea super granules (USG) (Anon., 1977). Prasad (1979) reported that use of USG gave higher fertilizer N efficiency than the ordinary urea in the case of rice, maize, sugarcane and other crops. Horn (1979) observed that USG (1 g size) exposed lesser surface area (41 cm^2/g) than prilled urea (237 cm^2/g) and therefore it may have slow release properties. Bandyopadhyay and Biswas (1982) reported that the fertilizer use efficiency was higher when USG and urea briquettes were placed at depth in coastal saline soils of West Bengal under deep water-logged conditions. In Tamil Nadu on an average, point placement of USG resulted in higher grain yield (41.5 Q/ha) compared to split application of urea (22.2 Q/ha) and over broadcast method of USG application (Anon., 1982).

Apparao (1983) observed significant increase in paddy yields with USG application compared to urea applied in splits or in a single dose basaly.

Rambabu et al. (1983) reported that under flooded conditions, placement of N as USG in rootzone was most effective in increasing dry matter production, paddy yields, total N uptake and apparent recovery of applied

nitrogen. Cao and De Datta (1983) reported that placement of USG resulted in a production of 51 kg rough rice per kg of applied N. Results of the study conducted at the Tamil Nadu Agricultural University, Coimbatore with modified urea materials revealed that USG is the best source of N for getting increased number of tillers, more plant height, more number of grains per panicle and higher grain and straw yield. Urease inhibited urea ranked second with respect to the above parameters (Anon., 1984 a). Similar results were reported by Rajagopalan and Palaniswamy (1985). Reddy and Mittra (1985) observed an increased nitrogen uptake and grain yield with USG under intermediate deep water conditions.

3. Urease inhibited urea.

Trials conducted by Byrnes et al. (1983) revealed that dry matter production in rice was higher when urea was treated with phenyl derivatives. A comparison of different urea modified materials revealed that yield levels obtained by the applicatioh of urease inhibited urea was higher than other forms of nitrogen like NCU and prilled urea (Anon., 1985 a).

4. Neem cake coated urea

Treatment of urea with neem seed extract could

increase the grain yield and efficiency of applied N, and there was significant increase in effective tillers per hill, number of filled grains per panicle and the thousand grain weight. The efficiency of urea coated with neem seed extract has been attributed to the effect of nimbidine, an alkaloid which inhibits nitrification (Bains et al., 1971). The trials conducted by AICRIP showed that the productive efficiency of nitrogen was increased by treating urea with neem cake. Similar results were reported by Jadhav et al. (1983) and Anon. (1972). Arunachalam and Morachan (1974) found that neem cake extract treated urea enhanced crude protein content of grain.

5. Sulphur coated urea

Trials conducted by the AICRIP during 1972 proved that sulphur coated urea (SCU) is a better source of nitrogen for basal dressings. It gave an increased yield of 25 per cent over prilled urea (Anon., 1972). Venkat Reddy and Freeman (1973) found that sulphur coated urea produced higher grain yield under good management. Subbaiah and Morachan (1974) observed that among the different types of urea tried, sulphur coated urea ranked first in increasing grain yield.

Sanchez et al., (1973) found that SCU increased panicle production. At AICRIP, application of nitrogen as SCU resulted in highest number of panicle and panicle weight (Anon., 1975).

Bandyopadhyay and Biswas (1982) observed substantial improvement in plant growth characters and fertilizer use efficiency with SCU in farmers' field experiments. Mellu and Rekhi (1983) reported that SCU produced highest mean grain yield of 6.36 t/ha. Dry matter production and N uptake also followed a similar trend. Rana et al. (1984) observed a linear increase in grain yield due to the application of SCU. Sulphur coated urea was observed to be the best source of nitrogen in increasing the DMP, productive tillers, grain weight per hill and grain yield in both the seasons at the Agricultural Research station, Mangalore (Anon., 1985 b). Further, at the Gujarat Agricultural University, SCU was noticed to be significantly superior to PU and USG in increasing the dry matter production, grain yield, straw yield and total nitrogen uptake at harvest (Anon., 1985 c). However, Singh et al. (1985) reported that SCU can reduce the grain yield at higher N levels due to the higher percentage of unfilled grain.

6. Rock phosphate coated urea

Saravana (1979) reported that Rock phosphate coated

urea (RCU) increased the N availability at all stages of crop growth. Jayaramamoorthy (1982) observed the highest grain yield, straw yield and N uptake in plots applied with RCU. Subbian (1983) reported that RCU was Superior to Prilled urea in their direct effect on paddy yield in Kharif season. There was a site to site variability due to differences in water management and cation exchange of soils (Benette and Subramony, 1983). In the Orissa University of Agriculture and Technology, highest average grain yield was obtained with RCU which was on par with prilled urea (Anon., 1986 b).

B. Effect of levels of nitrogen.

(a) Growth characters of rice

Increase in plant height with increase in the levels of applied nitrogen has been reported by many workers (Sadayappan and Kolandaiswamy, 1974; Sushama-kumari, 1981; Anon., 1984 a; Surendran, 1985). The effect of this nutrient on tiller production has been observed to be positive (Lenka and Behera, 1967; Gunasena et al., 1979; De Datta and Surjith, 1981; Anon., 1985 c; Ajithkumar, 1984).

Dry matter production has been reported to increase with increase in nitrogen application (Ramanujam and

Rao, 1971; Sushamakumari, 1981). According to Nagre and Mahajan (1981), dry matter accumulation at 100 DAT was more when the dose of nitrogen was enhanced from 50 to 150 kg/ha. Increase in DMP upto 150 kg/ha was noticed at all stages of plant growth (Anon., 1985c). Studies at the BRSA Agricultural University, Ranchi revealed that dry matter production increased only upto 112.5 kg/ha (Anon., 1986b).

(b) Yield attributes and yield

Number of panicles per hill increases with increase in the amount of nitrogen upto 94 kg/ha (Koyama and Niamsrichand, 1973), while Sushamakumari (1981) observed positive effect of nitrogen upto 90 kgN/ha. Balasubramoniyan (1984) observed this effect upto 120 kgN/ha. Experiments at the Jawaharlal Nehru Krishi Vishwa Vidyalaya indicated that the number of productive tillers in rice increased upto 112.5 kg/ha and thereafter it decreased (Anon, 1984 b).

Sushamakumari (1981) observed that levels of nitrogen significantly influenced the number of spikelets per panicle when Jaya was grown with varying levels of nitrogen. Similar findings are reported by Anon. (1984 b) and Alexander et al. (1974).

The percentage of filled grains was not altered beyond 60 kgN/ha (Ramanujam and Rao 1971). De Detta and Surjit (1981) and Sobhana (1983) have reported that the number of filled grains per panicle increases with increase in levels of Nitrogen.

Kalyanikutty and Morachan (1974) obtained the highest thousand grain weight at 120 kgN/ha, in Co-30, a dwarf indica rice variety. Nair, (1976) observed significant increase in the test weight when the level of nitrogen was enhanced from 50 to 70 kg/ha. Studies at the Jawaharlal Nehru Krishi Viswa Vidyalaya indicated an increased test weight upto 75 kgN/ha and thereafter it declined (Anon., 1984 b).

(i) Grain yield

Rethinam et al (1975) observed steady increase in yield with enhanced doses of nitrogen and the highest yield was obtained with 160 kg N/ha. Pillai et al. (1976) suggested that more than 100 kgN/ha need not be applied for realising the yield potential and maximum profits in dwarf varieties of rice, whereas Sharma and De (1976) found that increase of nitrogen rates from zero to 150 kg/ha increased average yield from 3.76 - 5.56 t/ha and further increase in nitrogen rates contributed to no additional

yield. Singh and Modgal (1978) observed that the optimum rates for the dwarf Cv. Jaya and IR-20 were 158 and 116 kg N/ha respectively. Singh et al. (1978) reported that with Cv. Jaya, application of 100 kg N/ha in the split doses gave the highest yield of 7.5 tons of rough paddy per hectare. Singh et al. (1979) opined that the most profitable nitrogen rates calculated for saket - 3, Retna and Jaya were 75, 100 and 140 kg/ha. respectively. However Le and Aleshin (1970) found that the application of high nitrogen rates to rice plants decreased paddy yields. Experiments at the Agricultural Research Station, Kankanady, Mangalore indicated an increased trend of grain yield due to increase in N levels upto 112.5 kg N/ha and a decline thereafter. Application of nitrogen at higher levels than 112.5 kg/ha has been reported to induce more of vegetative growth, and resulted in more of chaffy grains and thereby lower grain (Anon., 1985 b).

(ii) Straw yield

Rao and Ramanujam (1971) reported that increase of nitrogen levels from zero to 180 kg/ha increased straw yield. Raj et al. (1974) pointed out that straw yield was increased by the applied nitrogen from 0-250 kg/ha.

Venkateswarlu (1978) stated that straw yields increased with nitrogen levels upto 200 kg/ha only and beyond which it declined. Linear increase in straw yield was observed upto 150 kgN/ha in trials at the Agricultural Research Station, Kankanady (Anon., 1985 b).

Prasad (1981) reported a decrease in the harvest index with an increase in the level of nitrogen from 0 - 100 Kg/ha. Sreekumaran (1981) observed significant reduction in grain to straw ratio with increase in the levels of nitrogen; the highest level of 120 kg N/ha recorded the lowest ratio.

(c) Content and uptake of nitrogen

Sadanandan et al. (1969) reported that the nitrogen percentage in the plant decreased with advancement of growth. It remained at a comparatively higher level upto tillering phase, and thereafter declined steeply. It was observed by Sivappah et al. (1969) that nitrogen content in grain was influenced by nitrogen fertilization.

Gopalaswamy and Raj (1977) reported that increase in the rate of applied nitrogen from 0 to 200 kg/ha produced linear increase in the uptake of nitrogen. Application of nitrogen upto 120 kg/ha increased the N uptake as reported by Agarwal (1978). Significant

increase in nitrogen uptake with N levels upto 80 kg/ha was reported by Rai and Murthy (1979).

d) Protein content of Grain

Abraham et al. (1974) observed highest protein content in grain by the application of 120 Kg.N/ha. Ajithkumar (1984) also obtained significant increase in grain protein content with levels of nitrogen, and recorded highest percentage of 8.41 with 70 kg N/ha. Surendran (1985) observed an increase in protein content of grain with increase in nitrogen levels from 20 to 80 kg N/ha.

C. Interaction effect between types of urea and levels of Nitrogen

a) Effect on growth characters.

Interaction effect between levels of N and types of urea was not considerable on the number of tillers. But significant effect was noticed in plant height, and the highest values were noted when USG was applied @ 112.5 kg N/ha (Anon., 1984 a). Rajagopalan and Palaniswamy (1985) could observe highest plant height with USG at 75 kg N/ha. Highest dry matter accumulation

was observed wheh the crop was supplied with 100 kg N/ha in the form of SCU and its effect was on par with the same level of N in the form of USG and 112.5 Kg N/ha as SCU or USG (Anon., 1985 c). However the interaction effect between levels of N and types of urea on growth characters was absent in trials at the Agricultural Research station, Kankandy Mangalore (Anon., 1985 b).

b) Interaction Effect on Yield and Yield Components

Jadhev et al. (1983) reported that application of 75 kg N/ha as Neem cake coated urea gave higher paddy yields than 100 kg N/ha as prilled urea. Singh et al. (1983) observed higher grain yield with sulphur coated urea applied @ 20 and 40 kg N/ha. Another study by Apparao (1983) indicates that 50 kg N/ha as USG is better for increasing the grain yields. In the Tamil Nadu Agricultural University it was found that highest grain yield was obtained by applying USG @ 112.5 kg N/ha. (Anon., 1984 a). Ali (1985) observed that USG was superior in grain production at a level of 62 kg N/ha. Singh et al. (1985) reported that rice yields with SCU and USG were similar and superior to prilled urea at 29 kg N/ha.

Studies with different forms and levels of nitrogen at the Gujarath Agricultural University indicated that

interaction effect between levels of N and types of urea was pronounced in the case of straw yield. SCU and USG @ 150 kg N/ha gave the highest straw yield over the rest of the treatments (Anon., 1985 c). However, in studies at the Agricultural Research station, Kankanady, Mangalore, yield and its attributes did not differ significantly due to interaction by the levels of nitrogen and types of urea. The results revealed that the yield obtained from SCU or USG at lower levels of N was on par with the yield obtained from the higher levels of N from prilled urea (Anon., 1985 b).

c) Interaction Effect on uptake of nutrients

The interaction effect between types of urea and levels of N differed significantly with respect to N uptake by rice. The highest N uptake at harvest was noticed with USG applied @ 150 kg N/ha which was on par with SCU applied @ 112.5 kg (Anon., 1985 c).

MATERIALS AND METHODS

MATERIALS AND METHODS

Two field experiments were conducted during 1985-86 to study the comparative efficacy of different urea modified materials at various doses on the growth, yield, quality of rice and to study their residual effects in the subsequent rice crop. The materials used and the methods followed for the experiments are presented below.

Materials

(a) Experimental site

The experiments were conducted at the Cropping Systems Research Centre, Karamana, Trivandrum. The experimental site is situated at 8.5° North latitude and 77.9° East longitude at an altitude of 29 m above mean sea level. The experimental area was under bulk crop of rice during the previous seasons.

(b) Soil

The soil of the experimental area is sandy loam

with 156.4 kg available nitrogen, 16.3 kg available P_2O_5 and 124.4 kg available K_2O per hectare. The physico-chemical properties of the soil are presented in table 1.

c) Climate

The experimental site enjoys a humid tropical climate. The data on various weather parameters (monthly rainfall, mean maximum and minimum temperatures and relative humidity) during the cropping periods are given in Appendix I and graphically presented in Fig. 1. The mean maximum and minimum temperature during the cropping periods ranged from 29.7 ^{o}C to 33.3 ^{o}C and 22.6 ^{o}C to 24.2 ^{o}C respectively. The mean relative humidity ranged from 73 to 98 per cent. The monthly rainfall of the cropping period ranged from 2.1 mm to 424.3 mm with a total receipt of 824.1 mm during the first season, and 243 mm during the second season. Weather data recorded during the cropping period revealed that the weather did not vary much from the normal weather conditions enjoyed by the place.

d) Season

The main experiment was conducted during the first crop season (kharif) of 1985-86 from 28-6-1985 to

FIG. 1. WEATHER CONDITIONS DURING THE CROPPING PERIOD

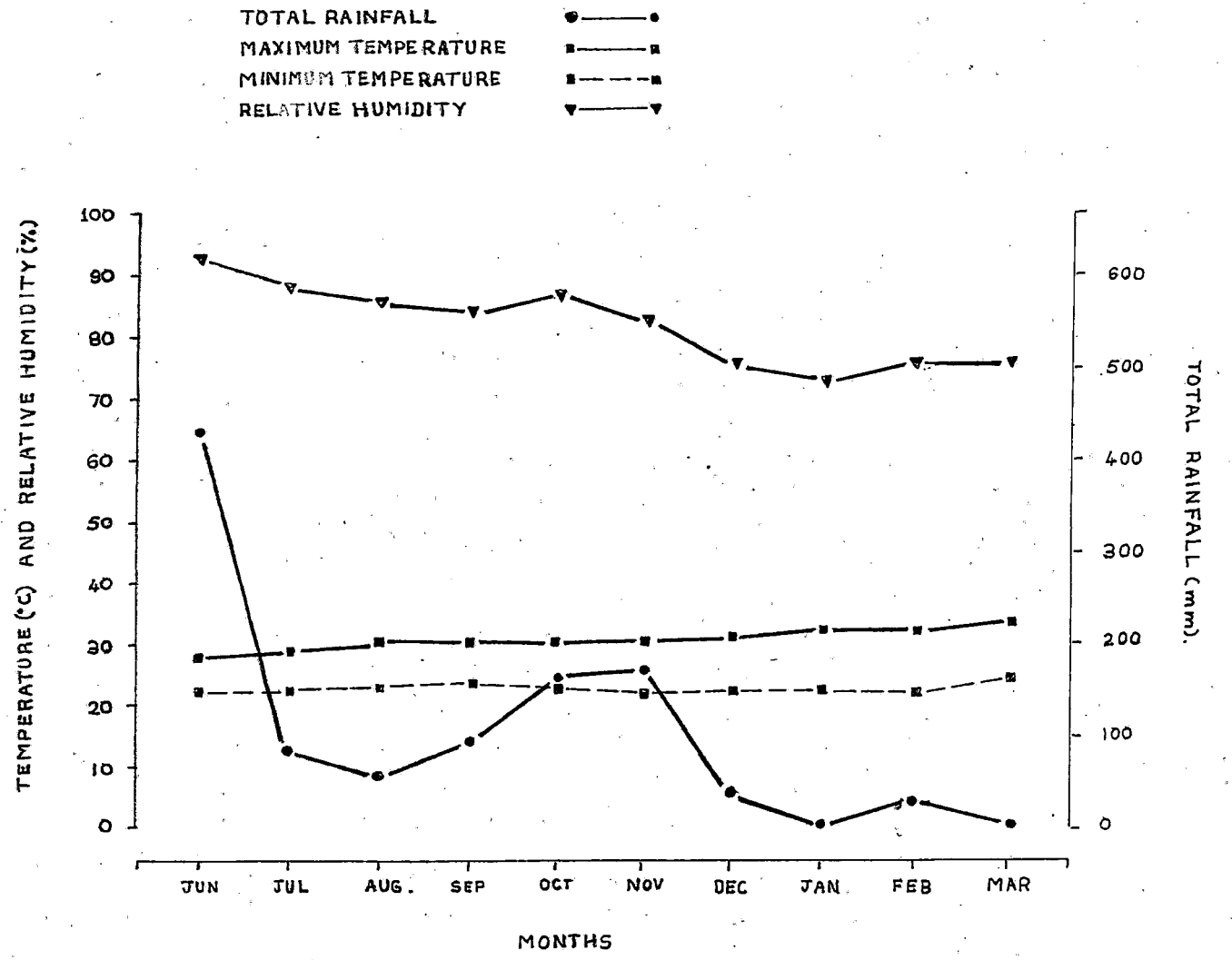


Table 1. Physico-chemical properties of the experimental soil.

Sl. No.	Parameter	Depth in cm		Composite sample	Fertility sample
		0 - 15	15 - 30		
1.	Soil texture	Sandy loam	Sandy loam	Sandy loam	
2.	Sand (%)	-	-	74.28	
3.	Silt (%)	-	-	8.73	
4.	Clay (%)	-	-	17.87	
5.	p^H	4.8	4.8	4.50	
6.	EC (mmhos/cm^2)	0.01	0.02	0.016	(Safe)
7.	CEC(m.eq/100g)	6.82	8.01	7.41	
8.	Organic carbon (%)	1.45	1.53	1.51	High
9.	Available N (Kg/ha)	155.60	158.52	156.39	Low
10.	Available P_2O_5 (,,)	17.08	16.85	16.25	Medium
11.	Available K_2O (,,)	127.57	121.17	124.37	Medium
12.	0.1 N Hcl extractable Zn (ppm)	3.5	3.0	3.3	

5-11-1986. The residual effect was studied in the second crop season (Rabi) of 1985-86 from 22-11-1985 to 22-3-1986.

e) Variety

The variety used for the study was Jaya, a cross between TN-1 from Taiwan and an Indian variety T-141 from Orissa. It is a dwarf photoinsensitive, medium duration (130-140 days) variety, evolved at the All India Co-ordinated Rice Improvement Project, Rajendra Nagar, Hyderabad, India. It has got special features like long bold white grain with high stability in yield. The seeds for the experiment were obtained from the C.S.R.C., Karamana itself.

f) Fertilizers used

The fertilizers used for the experiment were Prilled Urea 46 per cent N, Urea Super granules 45 per cent N, Urease inhibited Urea 45 per cent N, Sulphur coated Urea 38 per cent N, Rock phosphate coated urea 31.2 per cent N, Super phosphate 16.5 percent P_2O_5 and Muriate of Potash 58 per cent K_2O.

Prilled urea manufactured by the F.A.C.T. was used for the experiment. The urea modified materials

such as Urea Super Granules, Urease Inhibited Urea and Sulphur coated urea were obtained from the American embassy, New Delhi, and Rock phosphate coated urea from the Madras Fertilizers Ltd. The neem cake coated urea was prepared by mixing neem cake and prilled urea at the ratio of 1:5 and keeping for 48 hours.

Methods

a) Treatments

Two factors, viz. levels of nitrogen and types of urea modified materials were studied in split plot design with three replications. There were 30 treatment combinations comprising of five main plot treatments (levels of N) and six sub plot treatments (urea modified materials) as detailed below.

i) Main plot

1. N_0 0 kg N/ha
2. N_1 37.5 kg N/ha
3. N_2 75.0 kg N/ha
4. N_3 112.5 kg N/ha
5. N_4 150.0 kg N/ha

ii) Sub plots

1. S_1 Prilled urea (PU)
2. S_2 Urea Super granules (USG)
3. S_3 Urease inhibited urea (UIU)
4. S_4 Neem cake coated urea (NCU)
5. S_5 Sulphur coated urea (SCU)
6. S_6 Rock phosphate coated urea (RCU)

b) Design and Lay out.

The experiments were laid out in a split plot in randomised block design replicating thrice. The lay out plan is presented in Fig.2. The gross plot size was 10.4x3m and in total there were 90 plots. The spacing adopted for planting was 20 x 15 cm.

Six rows of plants were left breadthwise on either side (2 for border, 2 for destructive sampling and again 2 for border). Lengthwise 4 rows of plants were left as border rows on either side. Thus the net plot size was 8 x 1.8 m.

c) Details of cultivation

i) Land preparation

The main field was ploughed and levelled, and plots of 10.4 x 3 m were laid out with bunds of 30 cm width around. Main and sub irrigation channels were provided wherever necessary. Individual plots were again puddled and perfectly levelled. The crop was raised using standard procedures and techniques as per the recommendations of the package of practices of KAU.

ii) Application of fertilizers

Sixty kg P_2O_5/ha and 30 kg K_2O/ha were applied as a single

LAY OUT PLAN OF THE EXPERIMENT IN SPLIT PLOT DESIGN

n_2s_3	n_2s_6	n_1s_4	n_1s_2	n_0s_1	n_0s_3	n_4s_5	n_4s_2	n_3s_3	n_3s_2
n_2s_1	n_2s_2	n_1s_3	n_1s_6	n_0s_5	n_0s_2	n_4s_6	n_4s_1	n_3s_5	n_3s_6
n_2s_5	n_2s_4	n_1s_5	n_1s_1	n_0s_4	n_0s_4	n_4s_4	n_4s_3	n_3s_1	n_3s_4
n_1s_1	n_1s_6	n_2s_3	n_2s_4	n_4s_3	n_4s_4	n_0s_3	n_0s_6	n_3s_4	n_3s_5
n_1s_2	n_1s_5	n_2s_5	n_2s_2	n_4s_5	n_4s_1	n_0s_2	n_0s_4	n_3s_2	n_3s_1
n_1s_4	n_1s_3	n_2s_6	n_2s_1	n_4s_6	n_4s_2	n_0s_5	n_0s_1	n_3s_6	n_3s_3
n_2s_3	n_2s_6	n_4s_3	n_4s_6	n_1s_2	n_1s_6	n_3s_5	n_3s_3	n_0s_1	n_0s_2
n_2s_1	n_2s_4	n_4s_5	n_4s_4	n_1s_3	n_1s_1	n_3s_1	n_3s_2	n_0s_4	n_0s_6
n_2s_2	n_2s_5	n_4s_1	n_4s_2	n_1s_4	n_1s_5	n_3s_6	n_3s_4	n_0s_5	n_0s_3

R_3 R_2 R_1

N

FIG. 2

n_0 - 0 kg N/ha
n_1 - 37.5 kg N/ha
n_2 - 75.0 kg N/ha
n_3 - 112.5 kg N/ha
n_4 - 150.0 kg N/ha

S_1 - PU
S_2 - USG
S_3 - UIU
S_4 - NCU
S_5 - SCU
S_6 - RCU

basal dose as suggested in the report of PL 480 Scheme, a project under which this experiment was envisaged.

Prilled urea and Urease inhibited urea, according to the treatments were applied 50 per cent basally, 25 per cent at 21 DAT and 25 per cent at panicle initiation stage. Sulphur coated urea, Neem cake coated urea and Rock phosphate coated urea were applied entirely as basal dose and incorporated into the soil.

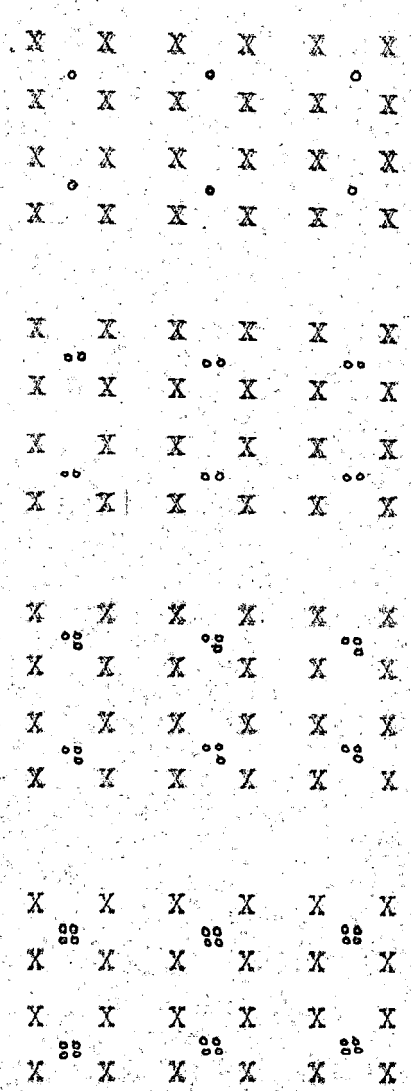
The USG of 1 gm size were placed at 8 - 10 cm depth at the centre of every 4 hills at 6 days after transplanting. Corresponding to the levels of 37.5, 75.0, 112.5 and 150 kg N/ha, 1, 2, 3 and 4 granules were placed at the centre of every 4 hills as per the method of placement shown in Fig. 3.

iii) Transplanting and maintenance

Twenty day-old seedlings were transplanted on 18-7-1985 for the main experiment. Gap filling was done on the 7th day after transplanting. The crop was hand-weeded on the 20th day after transplanting. The general stand of the crop was good. Five centimetre water was maintained in the field continuously, and the water was cut off 10 days prior to harvest.

Two sprayings with Ekalux, Metacid and Dimecron against stem borer and leaf folder during vegetative phase,

FIG. 3 METHOD OF PLACEMENT OF SUPERGRANULES AT GRADED LEVELS OF NITROGEN.



37.5 kg N/ha.

75.0 kg N/ha.

112.5 kg N/ha.

150.0 kg N/ha.

one spraying with Metacid during milky stage against ear head bug, and one spraying with Streptocyclin against bacterial leaf blight at panicle initiation stage were given.

iv) Harvest

The plots in the border rows were harvested separately and thereafter the crop in the net area of the individual plots were harvested, threshed, cleaned, dried winnowed, and yield at 14 per cent moisture was recorded. The weight of the sun-dried straw was also recorded.

Studies on the residual effect of urea modified materials

To study the residual effects of various urea modified materials at different doses, a crop was raised during the subsequent season (Rabi 1985-86) in the same field, retaining the plots as it is. The same rice variety (Jaya) was raised by transplanting 20-day old seedlings on 22-11-1985 using the standard procedures and techniques. A uniform dose of 45 kg N (50 per cent of N recommended for the variety Jaya) and 60 kg P_2O_5 and 30 kg K_2O/ha was received by all the plots. The crop was harvested on 22-3-1986. The grain and straw yields were recorded as mentioned earlier.

Observations

A. Growth characters

Biometric observations were recorded as suggested by Gomez (1972).

(i) Height of plants

At harvest, the plant height was recorded from the base to the tip of the longest panicle from ten plants. The mean height was computed and expressed in centimetres.

(ii) Number of tillers per m^2

The tillers from three 2 x 2 hill sampling units were counted at the maximum tillering stage and the number of tillers per m^2 was calculated.

(iii) Dry matter production

Random samples of 10 hills were collected from the rows for destructive sampling at 20, 40 and 70 DAT and at harvest. The weight of the oven-dried samples were recorded and the dry matter production was calculated and expressed in kg/ha.

B. Chemical analysis

The chemical analysis was done from the plant

samples collected at different stages of growth (20,40,70 DAT and at harvest). It was then finely ground using a Wileey mill, and sieved through 2 mm sieve. A known weight of the sample was then digested, and the digest was chemically analysed. The nitrogen content of plants at different stages and of grain and straw at harvest were determined separately. The total N content of the digest of each sample was analysed by modified microk-jeldal method (Jackson, 1967).

The N uptake at different stages was calculated as the product of the percentage content of the nutrient in the plant sample and the respective dry weights. At harvest, the value of total uptake of nitrogen was obtained as the sum of the products of the percentage content of nitrogen in the grain and straw at harvest and their respective dry weights. The N uptake values are expressed in kg/ha.

The protein percentage of the grain was computed by multiplying the N percentage with a factor 6.25 (Simpson et al., 1965).

C. Soil analysis

Soil samples collected from the experimental area before the experiment were analysed for available nitrogen,

P_2O_5 and K_2O. After the experiment, the soil was analysed for total nitrogen by modified microkjeldal method. The available nitrogen content in the soil was determined by alkaline permanganate method (Subbiah and Asija, 1956), available P_2O_5 by Bray's method (Jackson, 1967) and available K_2O by amonium acetate method.

In addition to the above, the soil was analysed for pH, EC and mechanical composition.

D. Yield attributes and yield

The following observations were recorded as suggested by Gomez (1972).

(i) Number of panicles/m^2.

The total number of panicles from the 12 hills selected was counted and number of panicles/m^2 computed.

(ii) Number of filled spikelet per panicle

The main culm panicles from the 12 hills were threshed and the number of filled grains (f) and the weight of filled grains (w) were determined. The rest of the panicles from all the 12 hills were also threshed and the weight of unfilled grains (W) was assessed.

From these data, the number of filled grains per panicle was calculated using the following formula suggested by Gomez (1972).

$$\text{Number of filled grains per panicle} = \frac{f}{w} \times \frac{W + w}{p}$$

where p is the total number of panicles from all the hills.

iii) Thousand grain weight

From the values obtained for calculating the number of filled grains per panicle, thousand grain weight was calculated, and adjusted to 14 per cent moisture using the following formula proposed by Gomez (1972).

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

M = the moisture content of filled grains

iv) Percentage of filled grains

The total filled and unfilled grains from the panicles were separately counted and the percentage of filled grains was recorded.

v) Grain yield

Grain yield was recorded from the net area, weight adjusted to 14 per cent moisture and expressed in kg/ha.

vi) Straw yield

Straw obtained from the net plot was uniformly sundried, weighed and expressed in kg/ha.

vii) Harvest index

This is the percentage of grain weight to the total plant weight. This is calculated from grain and straw weight of the respective plots.

Harvest index was calculated by dividing the weight of grains with the total weight of grain and straw.

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

E. Nitrogen use efficiency

The biological nitrogen use efficiency (N response), chemical nitrogen use efficiency (Apparent N recovery) and the productive efficiency were computed by the following formulae.

(a) $$\text{N response} = \frac{\text{Grain yield in treatment} - \text{Grain yield in control}}{\text{Quantity of N applied}}$$

(b) $$\text{Apparent N recovery} = \frac{\text{N uptake in treatment} - \text{N uptake in control}}{\text{Quantity of N applied}} \times 100$$

$$\text{(c) Productive efficiency} = \frac{\text{Grain yield in treatment} - \text{Grain yield in control}}{\text{N uptake in treatment} - \text{N uptake in control}}$$

F. Statistical analysis

The data collected were statistically analysed following the Analysis of variance technique suggested by Snedecor and Cocheran (1967). Important correlations were also worked out.

RESULTS

R E S U L T S

The experimental data were subjected to statistical scrutiny to bring out the main effect of N, types of urea and their interactions. The results obtained in the study are presented in the following section.

A. Growth characters

1) Plant height (Table 2)

Plant height increased with increase in levels of nitrogen upto 112.5 kg/ha. However, the effect at this level was on par with 150/kg nitrogen/ha. Neither the types of urea nor their interaction with N levels influenced plant height.

2) Number of tillers/m^2 (Table 2)

Number of tillers/m^2 at maximum tillering stage was influenced by levels of N, and the highest value

Table 2. Plant height and number of tillers/m^2 as influenced by levels of N and types of urea

Levels of N kg/ha. \ Types of urea	Plant height (cm) at harvest							Number of tillers/m^2 at 40 DAT						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	87.42	83.50	84.75	81.92	83.08	88.58	84.88	193.33	203.33	192.33	183.33	200.00	196.00	194.61
37.5	81.92	90.17	86.67	86.00	84.85	85.00	85.77	256.33	233.33	229.00	237.67	277.00	270.00	250.89
75.0	87.33	87.08	91.17	84.67	83.17	84.08	86.25	317.67	329.00	290.67	229.00	317.33	236.00	286.61
112.5	87.58	99.08	96.42	87.67	93.42	94.42	92.93	234.00	318.67	282.67	262.00	310.00	274.67	280.33
150.0	87.92	92.33	91.50	93.58	95.75	94.08	92.53	264.67	357.67	312.67	312.33	300.33	328.33	313.67
Mean	86.43	90.43	89.90	86.77	88.05	89.23	-	253.20	288.80	262.67	244.67	280.93	261.07	-

For comparing	CD at 5%	SEm ±	CD at 5%	SEM ±
1. Levels of nitrogen	3.50	1.07	35.18	10.78
2. Types of urea	NS	-	25.25	8.88
3. Types of urea at a fixed level of nitrogen	NS	-	56.47	19.86
4. Levels of N at a fixed type or different types of urea	NS	-	62.29	21.10

(313.67) was observed with 150 kg N/ha. This was on par with 112.5 and 75 kg.N/ha. The effects of types of urea and their interaction with N levels were also pronounced. The highest tiller count (288.86) was obtained with USG, and its effect was on par with SCU. The UIU ranked next, and its effect was on par with RCU, NCU and prilled urea. Among the interactions, USG at 150 kg per ha produced highest number of tillers.

3) Dry matter production (Table 3a and 3b)

The dry matter production recorded at 20, 40 and 70 DAT and at harvest revealed that there was considerable difference in the biomass production due to change in levels of N at all stages of growth. An overview of the data on dry matter production indicates that the dry matter production attained its peak at a level of 112.5 kg.N/ha. The data further revealed that increasing N beyond this level results in a decrease in dry matter production.

The types of urea did not influence the dry matter production at early stages. But the effect was marked at later stages (70 DAT and at harvest). During these stages, application of SCU resulted in highest dry matter production.

Table 3a. Dry matter production (kg/ha) stagewise

Levels of N kg/ha	20 DAT	40 DAT	70 DAT	Harvest
0.0	318	1062	2434	4564
37.5	315	1395	2850	5850
75.0	366	1568	3355	7243
112.5	501	1689	4950	8303
150.00	468	1944	5210	7711
CD	34.92	150.35	264.70	243.11
SEM ±	10.70	46.10	81.16	74.54
Types of Urea				
PU	382	1433	3399	6617
USG	426	1558	3916	6954
UIU	409	1599	3832	6957
NCU	385	1495	3521	6766
SCU	375	1586	4111	7176
RCU	384	1520	3900	6653
CD	NS	NS	200.88	283.16
SEM ±	NS	NS	70.67	82.02

Table 3b. Drymatter production (Kg/ha) as influenced by levels of N and types of urea stage-wise

	20 DAT	40 DAT	70 DAT	Harvest
N_0S_1	343	1166	2399	4464
N_0S_2	349	1088	2539	4704
N_0S_3	280	1011	2465	4521
N_0S_4	301	1049	2399	4517
N_0S_5	292	1049	2472	4454
N_0S_6	341	1010	2333	4724
N_1S_1	295	1220	2732	5453
N_1S_2	291	1399	3012	5523
N_1S_3	291	1383	2899	5799
N_1S_4	372	1376	2645	5963
N_1S_5	310	1477	3645	6243
N_1S_6	329	1518	2769	6120
N_2S_1	326	1477	2819	6914
N_2S_2	401	1673	3232	7139
N_2S_3	403	1788	3385	7242
N_2S_4	404	1360	3325	7324
N_2S_5	350	1711	3832	8154
N_2S_6	317	1399	3539	6684
N_3S_1	488	1477	3939	7938
N_3S_2	539	1776	4765	9551
N_3S_3	606	1710	5132	9088
N_3S_4	413	1671	4639	8668
N_3S_5	497	1749	5792	9613
N_3S_6	466	1805	5372	8558
N_4S_1	481	1827	5045	8318
N_4S_2	550	1905	6032	7852
N_4S_3	464	2101	5279	5138
N_4S_4	438	2021	4599	7359
N_4S_5	427	1944	5412	7415
N_4S_6	466	1867	5492	7182
CD_1	NS	NS	449.19	521.37
CD_2	NS	NS	487.17	533.68
SEM_1	-	-	158.02	153.41
SEM_2	-	-	165.52	169.09

CD_1 and SEM_1 - for comparing types of urea at a fixed level of nitrogen.

CD_2 and SEM_2 - For comparing levels of N at a fixed type or different types of urea.

The interaction effect between levels of N and types of urea on dry matter production was seen at 70 DAT and at harvest, and the highest values were noted with USG 150 kg N/ha (at 70 DAT) and SCU at 112.5 Kg.N/ha (at harvest).

B. Chemical Analysis

1) Content of N in plant parts

N content of plant parts recorded at 20, 40 and 70 DAT and of grain and straw at harvest are presented in table (4a & 4b).

The effect of N levels on the N concentration of plant parts was marked at all stages of plant growth. The N content of plant parts went on increasing with increase in the levels of applied nitrogen. However, the increase in N concentration beyond the level of 112.5 kg N/ha was negligible, and this trend was observed at all the stages of plant growth.

The effect of types of urea on percentage content of N in plant parts was considerable at 20, 40 and 70 DAT, but this effect was not seen at harvest. The beneficial influence of SCU and NCU to maintain a high N concentration

Table 4a. N concentration in plant (%) stagewise

Levels of N (Kg/ha)	20 DAT	40 DAT	70 DAT	Harvest
0.0	2.45	1.46	1.06	0.62
37.5	2.97	1.74	1.47	0.78
75.0	3.02	1.74	1.64	0.79
112.5	3.29	1.79	1.83	0.82
150.0	3.31	1.84	1.79	0.80
CD	0.07	0.07	0.65	0.05
SEM ±	0.02	0.02	0.45	0.01
Types of urea				
PU	3.03	1.68	1.47	0.75
USG	2.99	1.69	1.62	0.73
UIU	2.97	1.71	1.60	0.76
NCU	3.00	1.77	1.48	0.80
SCU	3.06	1.74	1.61	0.80
RCU	3.01	1.73	1.62	0.75
CD	0.04	0.05	0.11	0.05
SEM ±	0.01	0.02	0.04	0.02

Table 4b. N concentration in plant (%) as influenced by levels of N and types of urea stage-wise

	20 DAT	40 DAT	70DAT	Harvest
N_0S_1	2.48	1.47	0.99	0.65
N_0S_2	2.41	1.41	0.99	0.61
N_0S_3	2.46	1.47	1.09	0.60
N_0S_4	2.37	1.64	1.17	0.57
N_0S_5	2.50	1.45	1.09	0.74
N_0S_6	2.49	1.35	1.11	0.61
N_1S_1	2.99	1.64	1.33	0.73
N_1S_2	2.99	1.60	1.49	0.72
N_1S_3	2.83	1.74	1.47	0.81
N_1S_4	2.94	1.84	1.37	0.94
N_1S_5	3.03	1.84	1.52	0.79
N_1S_6	3.05	1.80	1.68	0.72
N_3S_1	3.03	1.70	1.49	0.76
N_2S_2	3.05	1.62	1.84	0.73
N_2S_3	2.97	1.76	1.72	0.74
N_2S_4	2.99	1.78	1.47	0.89
N_2S_5	3.05	1.80	1.62	0.86
N_3S_6	3.03	1.86	1.74	0.81
N_3S_1	3.27	1.68	1.74	0.79
N_3S_2	3.29	1.88	1.88	0.79
N_3S_3	3.37	1.84	1.92	0.82
N_3S_4	3.28	1.82	1.72	0.84
N_3S_5	3.35	1.76	1.40	0.88
N_3S_6	3.19	1.80	1.88	0.84
N_4S_1	3.39	1.90	1.78	0.83
N_4S_2	3.21	1.94	1.88	0.83
N_4S_3	3.21	1.80	1.88	0.84
N_4S_4	3.41	1.76	1.66	0.79
N_4S_5	3.37	1.86	1.94	0.76
N_4S_6	3.29	1.84	1.66	0.79
CD_1	0.10	0.13	NS	NS
CD_2	0.12	0.14	NS	NS
SEM_1	0.03	0.04	-	-
SEM_2	0.04	0.04	-	-

CD_1 and SEM_1 – for comparing types of urea at a fixed level of nitrogen

CD_2 and SEM_2 – for comparing levels of N at a fixed type or different types of urea.

in plant parts was generally observable at different stages of plant growth.

The interaction between the types of urea and the levels of N was seen upto 40 DAT, and the highest N concentration was noticed with SCU, NCU and USG at the higher levels of N.

2) Nitrogen uptake

The total N uptake at 20, 40 and 70 DAT and at harvest are presented in tables 5a and 5b.

The effect of N levels on uptake of N was pronounced at all stages of growth (Fig. 4). The uptake of N showed an increasing trend with increased levels of N. However, N uptake beyond 112.5 kg N/ha was negligible at all stages of growth except at 40 DAT.

The N uptake was influenced by types of urea (Fig.5) and this was seen at 40 and 70 DAT and at harvest. But at all these stages the highest N uptake values were observed with SCU.

The interaction effect between the urea modified materials and levels of N was noticed at 70 DAT and at harvest. Application of USG either at 112.5 kg/ha or 150 kg N/ha resulted in the highest N uptake.

Table 5a. Uptake of N (kg/ha) stage-wise

Levels of N (kg/ha.)	20 DAT	40 DAT	70 DAT	Harvest
0.0	7.83	15.53	26.01	34.72
37.5	9.14	24.45	42.26	57.28
75.0	11.12	27.41	53.69	74.15
112.5	20.00	30.39	91.93	98.42
150.0	16.42	35.95	96.72	78.74
CD	5.53	3.92	5.03	4.25
SEM ±	1.69	0.89	1.54	1.30
Types of Urea				
PU	15.95	24.26	53.03	64.31
USG	13.00	27.01	64.40	68.59
UIU	13.65	28.05	64.82	68.94
NCU	11.46	26.56	53.89	69.84
SCU	11.76	28.08	70.25	71.97
RCU	11.68	26.54	66.36	68.34
CD	NS	2.42	4.08	3.81
SEM±	NS	0.85	1.43	1.34

Table 5b. N uptake (Kg/ha) as influenced by levels of N and types of urea stagewise

	20 DAT	40 DAT	70 DAT	Harvest
N_0S_1	8.58	17.14	23.96	37.12
N_0S_2	8.46	15.31	25.37	34.73
N_0S_3	6.99	14.82	25.20	33.50
N_0S_4	7.16	17.05	28.18	33.35
N_0S_5	7.38	15.22	27.16	33.89
N_0S_6	8.42	13.67	26.20	35.77
N_1S_1	8.87	20.01	36.41	53.15
N_1S_2	8.76	22.52	44.85	52.33
N_1S_3	8.30	24.20	42.64	56.33
N_1S_4	9.42	25.39	36.36	62.28
N_1S_5	9.44	27.23	46.48	62.10
N_1S_6	10.09	27.38	26.82	57.49
N_2S_1	9.94	25.17	41.87	65.64
N_2S_3	12.29	27.27	48.58	66.60
N_2S_3	12.03	30.82	58.37	72.43
N_2S_4	12.11	24.28	48.94	76.92
N_2S_5	10.75	30.98	62.46	82.84
N_2S_6	9.64	25.99	61.96	81.01
N_3S_1	36.71	25.01	72.81	82.02
N_3S_2	17.77	32.47	89.58	108.80
N_3S_3	20.50	31.28	98.50	98.74
N_3S_4	13.53	30.43	79.66	95.74
N_3S_5	16.65	31.55	109.96	107.09
N_3S_6	14.90	31.63	101.10	98.20
N_4S_1	15.65	34.00	90.12	82.63
N_4S_2	17.72	37.48	113.60	81.05
N_4S_3	20.44	39.13	99.38	83.70
N_4S_4	15.08	35.64	76.34	80.80
N_4S_5	14.31	35.44	105.21	73.94
N_4S_6	15.35	34.03	95.74	69.21
CD_1	NS	NS	9.13	8.53
CD_2	NS	NS	9.72	8.86
SEM_1	-	-	3.21	3.00
SEM_2	-	-	3.31	3.03

CD_1 and SEM_1 - for comparing types of urea at a fixed level of nitrogen.

CD_2 and SEM_2 - for comparing levels of N at a fixed types or different types of urea.

3) Apparent N recovery (Table 6)

Nitrogen recovery decreased with increase in the levels of applied nitrogen. The highest N recovery (60.17%) was noticed with application of 37.5 Kg N/ha, and the lowest (29.9%) with the highest level of applied N (150 kg N/ha).

There was considerable difference between types of urea on the apparent recovery of applied N. The highest percentage recovery (56.91%) was noted with SCU (Fig. 6) and its effect was on par with NCU. The lowest N recovery (41.2%) was observed with prilled urea. The N recovery from USG, UIU & RCU were more or less the same.

The interaction between levels of N and types of urea were also considerable on the recovery percentage of applied N. The highest recovery of N was observed either with NCU or SCU both at lowest level of applied N (37.5 kg).

4) Protein content of grain (Table 6)

The protein content of grain was changed by levels of Nitrogen. The protein content was highest (9.34%) with the treatments receiving 112.5 kg N/ha. The effect of types of urea on protein content of grain was not considerable.

The interaction effect between levels of N and types of urea was marked, and application of USG at 112.5 kg/ha

Table 6. Protein content of grain (%) and Apparent N recovery (%) of rice as influenced by levels of N and types of urea.

Levels of N kg/ha. \ Types of urea	Protein content of grain							Apparent N recovery %						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	6.21	5.73	5.38	5.73	5.48	7.42	5.98	-	-	-	-	-	-	-
37.5	7.44	7.19	6.94	7.19	7.56	7.31	7.27	49.13	46.95	57.71	73.02	73.01	60.71	60.17
75.0	7.31	7.19	8.06	7.81	7.81	9.90	8.01	41.23	41.79	50.27	56.26	64.16	61.72	52.57
112.5	8.44	9.90	9.17	9.17	9.29	8.94	9.14	42.03	65.85	57.11	54.23	64.33	56.42	56.66
150.0	8.33	8.06	8.06	8.81	7.94	7.44	8.10	32.60	30.88	32.65	34.15	26.14	22.99	29.90
Mean	7.55	7.61	7.52	7.74	7.62	8.20	-	41.25	49.37	49.44	54.54	56.91	50.46	-

For comparing	CD	SEM±	CD at 5%	SEM ±
1. Levels of nitrogen	0.36	0.11	6.68	2.73
2. Types of urea	NS	-	5.51	2.44
3. Types of urea at a fixed level of nitrogen	1.30	0.45	11.03	5.45
4. Levels of N at a fixed type or different type of urea	1.24	0.43	12.04	4.01

resulted in the production of better quality grains in terms of protein percentage.

C. Yield components and yield

1) Number of panicles/m^2 (Table 7)

Number of panicles/m^2 increased with increase in the rate of nitrogen upto 112.5 kg N/ha, and after which it declined. The different types of urea did not bring about appreciable change in this yield component. The interaction effect between levels of N and types of urea was marked, and SCU at 112.5 kg N/ha produced the highest number of panicles/m^2 (234.6) which was on par with USG, UIU and RCU at this level (112.5 kg N/ha).

2) Number of spikelets/panicle (Table 7)

It can be observed from the table that the levels of nitrogen, types of urea and their interactions had significant effect on number of spikelets per panicle. Number of spikelets per panicle showed an increasing trend with increase in the levels of N. The highest number of spikelets per panicle (118.47) was noticed with RCU and its effect was on par with SCU. UIU ranked next, and its effect was on par with all other types of urea. In the case of interaction, PU at 150 kg N/ha produced the highest number of spikelets per panicle.

Table 7. Effect of levels of N and types of urea on yield components of rice

Levels of N kg/ha \ Types of urea	Number of panicles / m^2							Number of spikelets/panicle						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	155.67	156.00	156.33	149.33	147.33	155.67	153.02	93.00	88.00	90.67	91.00	87.33	89.33	89.89
37.5	171.00	178.67	179.00	170.00	182.67	174.33	176.94	105.33	105.00	101.33	99.67	105.00	102.67	103.17
75.0	192.67	198.33	200.33	194.00	207.67	201.33	199.06	106.00	106.67	106.00	113.00	122.33	122.00	112.67
112.5	202.00	227.00	221.67	202.33	234.67	221.67	218.22	117.00	126.00	136.00	127.33	135.67	136.00	129.67
150.0	193.33	181.00	191.32	190.00	174.33	184.33	186.72	142.33	132.67	139.33	140.33	141.33	142.33	139.72
Mean	182.93	188.20	189.73	181.13	189.33	187.07	-	112.73	111.67	144.67	114.27	118.33	118.47	-

For comparing	CD	SEM±	CD at 5%	SEM ±
1. Levels of nitrogen	11.07	3.39	5.39	1.65
2. Types of urea	NS	-	3.93	1.38
3. Types of urea at a fixed level of nitrogen	16.30	5.73	8.80	3.09
4. Levels of N at a fixed type or different type of urea	18.51	6.10	9.65	3.27

3) Number of filled grains/panicle (Table 8)

Number of filled grains/panicle was influenced by N levels. There was an increase in the number of filled grains per panicle upto a level of 112.5 kg N/ha and after that it decreased considerably. Neither the types of urea nor their interaction with N levels affected this character.

4) Percentage of filled grains (Table 9)

The percentage of filled grains was highest with the plants received N at 75 kg N/ha. The types of urea did not bring about any appreciable change in the percentage of filled grains. The effect of interaction was found to be significant, and UIU at 75 kg N/ha produced the highest filled grain percentage, and this effect was on par with PU at the same level(75 kg N/ha).

5) Thousand grain weight (Table 8)

The thousand grain weight was increasing upto 112.5 kg N/ha and decreased thereafter. Types of urea influenced the test weight, and the highest values were noted with USG (25.36g) which was on par with SCU (25.17) and RCU (24.97 g). The lowest test weight (24.09 g) was noticed with NCU treatments.

Table 8. Effect of levels of N and types of urea on yield components of rice

Levels of N kg/ha. \ Types of urea	Number of filled grains/panicle							1000 grain weight (g)						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	72.00	67.67	68.00	71.00	69.00	67.00	69.11	23.48	23.13	22.47	23.63	22.93	23.30	23.16
37.5	70.67	73.67	75.00	70.33	78.00	80.33	74.67	23.14	24.23	24.42	22.71	24.62	23.32	23.75
75.0	92.00	91.67	93.67	89.00	91.33	92.67	91.72	24.75	24.79	24.07	23.87	24.88	25.43	24.63
112.5	92.00	95.33	97.33	96.33	99.33	95.33	95.94	26.16	27.30	26.33	25.90	28.70	27.17	26.93
150.0	89.00	91.67	90.00	89.00	86.00	82.33	88.00	25.32	27.35	25.43	24.35	24.72	25.62	25.47
Mean	83.13	84.00	84.00	83.13	84.73	83.63	-	24.58	25.36	24.54	24.09	25.17	24.97	-

For comparing	CD	SEM±	CD at 5%	SEM ±
1. Levels of nitrogen	3.75	1.15	0.75	0.23
2. Types of urea	NS	-	0.62	0.21
3. Types of urea at a fixed level of nitrogen	NS	-	1.39	0.48
4. Levels of N at a fixed type or different types of urea	NS	-	1.47	0.50

Table 9. Filled grain percentage and Harvest index as influenced by levels of N and types of urea

Levels of N kg/ha \ Types of urea	Filled grain percentage							Harvest index						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	61.93	61.52	60.10	60.44	62.78	60.26	61.16	0.36	0.31	0.36	0.36	0.40	0.29	0.34
37.5	54.97	56.90	59.38	57.12	59.44	62.31	58.35	0.36	0.37	0.38	0.40	0.38	0.39	0.37
75.0	68.82	62.73	70.21	62.80	59.78	60.62	64.15	0.35	0.31	0.34	0.34	0.31	0.36	0.33
112.5	62.45	60.46	57.88	60.41	58.71	56.99	59.49	0.34	0.36	0.38	0.44	0.43	0.43	0.39
150.0	53.47	56.32	54.26	52.92	51.27	49.59	52.96	0.35	0.38	0.34	0.38	0.32	0.32	0.34
Mean	60.72	59.58	66.40	58.73	58.40	57.95	-	0.35	0.35	0.36	0.38	0.37	0.36	-

For Comparing	CD at 5%	SEM ±	CD at 5%	SEM ±
1. Levels of nitrogen	4.12	1.26	NS	-
2. Types of urea	NS	-	NS	-
3. Types of urea at a fixed level of nitrogen	5.66	1.99	0.05	0.01
4. Levels of N at a fixed type or different types of urea	6.58	2.21	0.07	0.02

The interaction effect was marked, and SCU at 112.5 kg N/ha produced the highest test weight (28.7g), and its effect was on par with USG at 150 kg N/ha and USG at 112.5 kg N/ha.

6) Grain yield (Table 10 and Fig. 7 and 8)

Grain yield showed an increasing trend with increase in the levels of nitrogen upto 112.5 kg N/ha. At this level the grain yield was highest (3567 kg/ha), and its effect was on par with 150 kg/N/ha.

Types of urea also influenced the grain yield, and the highest yield (3132 kg/ha) was obtained for SCU which was on par with the effects of UIU and USG. The effects of UIU, USG as well as NCU were more or less the same. Similarly the grain yield obtained with RCU and prilled urea were also comparable. It was also noted that the lowest grain yield (2619 kg/ha) was noticed with PU.

The interaction between levels of N and types of urea was not significant on grain yield. However, the highest grain yield was obtained by the application of SCU at 112.5 kg/ha.

7. Nitrogen use efficiency (Table 11)

a) Nitrogen response

Nitrogen response was influenced by the levels of

Table 10. Influence of levels of N and types of urea on grain and straw yield (kg/ha.)

Levels of N kg/ha. \ Types of urea	Grain yield							Straw yield						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	1862	1930	2050	2012	2065	1701	1937	3239	4146	3530	3440	3077	4032	3577
37.5	2514	2969	3013	2753	2916	1554	2887	4398	5047	4691	4168	4742	4005	4509
75.0	2842	3035	3288	2768	3126	2987	3008	5202	6513	6158	5208	6931	5266	5880
112.5	3001	3693	3712	3399	4226	3373	3567	5653	6278	6045	4155	5609	4527	5378
150.0	3238	3572	3163	3371	3329	2862	3256	5850	5952	5861	5498	6908	6134	6034
Mean	2691	3040	3046	2861	3132	2695	-	4869	5587	5287	4494	5454	4793	-

For comparing	CD at 5%	SEM ±	CD at 5%	SEM ±
1. Levels of nitrogen	547.71	167.94	817.50	250.67
2. Types of urea	199.03	70.91	465.30	163.69
3. Types of urea at a fixed level of nitrogen	NS	-	1040.45	366.02
4. Levels of N at a fixed type or different types of urea	NS	-	1250.35	343.40

nitrogen. Nitrogen response decreased with the increasing levels of Nitrogen. The highest response (22.67 kg grain/kg of N applied) was noticed with the lowest level of applied Nitrogen.

Among the types of urea, the effect of USG, SCU, UIU, NCU and PU remained the same, SCU recording the highest N (Fig. 10) response. The effect of interaction between levels of nitrogen and types of urea was not pronounced.

b) Productive efficiency

The mean value of productive efficiency are presented in Table 11. Different urea modified materials had considerable effect on the productive efficiency, whereas the levels of nitrogen and its interaction with types of urea had very little influence on productive efficiency. Highest productive efficiency (37.62 kg grain/kg of N applied) was noticed with USG, and (Fig. 11) its effect was on par with UIU and SCU. The effect of PU, NCU and RCU on productive efficiency appeared to be the same.

8. Straw yield (Table 10)

Straw yield was influenced by the levels of nitrogen, types of urea and their interactions. There was a progressive improvement in the straw yield upto the highest level of

Table 11. N response and productive efficiency of rice as influenced by levels of N and types of urea

Levels of N kg/ha. \ Types of urea	N response							Productive efficiency						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37.5	15.41	27.53	28.69	21.77	26.12	16.46	22.67	30.96	60.07	51.82	30.10	35.96	26.54	39.24
75.0	12.07	14.64	18.02	11.09	15.85	14.00	14.28	30.02	35.01	36.08	19.53	24.86	22.65	28.03
112.5	9.46	15.61	15.78	12.99	20.35	12.76	14.49	23.05	23.35	26.84	24.02	32.07	22.46	25.47
150.0	8.67	10.90	8.19	9.56	9.27	6.16	8.79	23.50	32.06	25.36	38.78	39.44	28.50	31.27
Mean	11.40	17.17	17.67	13.85	17.90	12.35	-	26.88	37.62	35.17	28.11	33.08	25.05	-

For comparing	CD at 5%	SEM ±	CD at 5%	SEM ±
1. Levels of nitrogen	5.10	2.08	NS	-
2. Types of urea	3.19	1.41	9.15	4.19
3. Types of urea at a fixed level of nitrogen	NS	-	NS	-
4. Levels of N at a fixed type or different types of urea	NS	-	NS	-

nitrogen. The highest straw yield (6033 kg) was noticed with the application of 150 kg N/ha. The effect of nitrogen at 75 kg and 112.5 kg were on par with respect to straw yield.

Among the types of urea, the effects of USG, SCU and UIU remained the same, and USG applied plots produced the highest amount of straw (5587 kg/ha) (Fig. 9). The effects of PU, RCU and NCU were more or less similar with respect to straw yield.

Among interactions, the straw yield was highest (6931 kg/ha) from the plots which received SCU at the rate of 75 kg N/ha. This was on par with USG at the rate of 75 kg N/ha and SCU at 150 kg N/ha.

9) Harvest index (Table 9)

The main effects of levels of nitrogen and types of urea did not influence the harvest index, but their interaction effect was pronounced with respect to this parameter. The harvest index was highest when NCU was applied at the rate of 112.5 kg N/ha.

10) Correlation studies (Table 12)

There was significant positive correlation between grain yield and the following plant characters.

Table 12. Simple correlation coefficients between grain yield and plant characters

Sl. No.	Plant character	correlation coefficient
1.	Plant height	0.520 *
2.	Number of tillers	0.527 *
3.	Dry matter production at 20 DAT	0.609 *
4.	" " 40 DAT	0.683 *
5.	" " 70 DAT	0.705 *
6.	" " Harvest	0.805 *
7.	Nitrogen uptake at 20 DAT	0.322 *
8.	" 40 DAT	0.688 *
9.	" 70 DAT	0.753 *
10.	" Harvest	0.823 *
11.	Productive tillers /m^2	0.717 *
12.	Spikelets/panicle	0.703 *
13.	Number of filled grains/panicle	0.737 *
14.	Filled grain percentage	0.737 *
15.	Thousand grain weight	0.668 *

* Significant at 0.05 level.

1. Plant height
2. Number of tillers
3. Dry matter production at different stages
4. Uptake of N at different stages
5. Productive tillers
6. Number of filled grain per panicle
7. Spikelets per panicle
8. Thousand grain weight

The correlation between grain yield and filled grain percentage was not considerable.

D. Total nitrogen content in the soil after the experiment (Table 13)

The total N content of soil after the experiment was influenced by the levels of N and the plots applied with nitrogen analysed for higher amount of total nitrogen compared to control.

Types of urea also influenced the post harvest N content of the soil, and the plots applied with PU, USG, UIU, SCU and RCU contained more or less similar amounts of nitrogen. The lowest amount (383.8 kg N/ha) was noticed in the plots applied with NCU.

The interaction effect between types of urea and

Table 13. Total nitrogen content of the soil after the experiment (kg/ha.)

Levels of N (kg/ha.)	Types of urea						
	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	432.3	443.0	376.3	320.6	347.3	356.3	379.3
37.5	496.3	413.67	439.67	446.67	405.33	448.6	441.7
75.0	387.6	363.3	457.6	363.0	373.3	382.0	387.6
112.5	435.6	499.6	471.6	384.6	476.0	382.0	441.6
150.0	440.3	374.3	441.0	404.0	465.0	488.0	435.4
Mean	438.4	418.8	437.27	383.8	413.4	411.2	-

For comparing	CD at 5%	SEM ±
1. Levels of nitrogen	47.4	14.5
2. Types of urea	30.0	10.5
3. Types of urea at a fixed level of nitrogen	67.2	23.6
4. Levels of N at a fixed type or different ypes of urea	77.4	26.0

Table 14. Grain yield and straw yield (kg./ha.) of subsequent rice crop as influenced by levels of N and types of urea.

Levels of N kg/ha. \ Types of urea	Grain yield							Straw yield						
	PU	USG	UIU	NCU	SCU	RCU	Mean	PU	USG	UIU	NCU	SCU	RCU	Mean
0.0	2641	2821	2532	2892	2493	2582	2660	4667	4759	4964	4627	4506	5169	4782
37.5	2105	2406	1922	2264	2074	2016	2131	4376	4223	3768	4514	4435	4373	4281
75.0	2132	1959	1742	1958	2342	2336	2078	4299	4204	4090	4313	4549	3791	4208
112.5	2514	2825	2572	2681	2777	2336	2617	5914	5830	5167	6117	5547	5829	5734
150.0	2705	2577	2638	2492	2681	2471	2595	4655	4932	4781	4195	4853	4308	4621
Mean	2419	2518	2281	2457	2473	2350	-	4782	4790	4554	4753	4778	4394	-

For comparing	CD at 5%	SEM ±	CD at 5%	SEM ±
1. Levels of nitrogen	NS	-	NS	-
2. Types of urea	NS	-	NS	-
3. Types of urea at a fixed level of nitrogen	NS	-	NS	-
4. Levels of N at a fixed type or different types of urea	NS	-	NS	-

levels of N was also considerable, and the plots applied with USG at 112.5 kg N/ha contained the highest amount of total nitrogen (499.67 kg N/ha).

E. Residual study

The data on mean grain and straw yield obtained with the crop raised for the residual study are presented in Table 14. The data clearly reveal that the effect of N levels, types of urea or their interactions did not influence the grain yield or straw yield of the crop raised during the subsequent season.

DISCUSSION

D I S C U S S I O N

A field experiment was conducted at CSRC, Karamana to study the efficiency of urea modified materials at different levels of nitrogen on growth, yield, quality and nitrogen uptake of rice. The results of the experiment ~~are~~ are discussed in this chapter.

A. Growth characters

1) Plant height

The results presented in Table 2 revealed that the plant height was increased by increasing the levels of nitrogen upto 112.5 kg/ha. Different types of urea and their interaction with levels of nitrogen did not exert any marked influence on this character. The lowest height was noted with the plants which are not supplied with N, while the tallest ones were observed in the plots applied with nitrogen at the rate of 112.5 kg N/ha. Plant height is a growth character which is generally influenced by

management factors. The above results are in conformity with the findings of Sadayappan and Kolandaiswamy (1974), Sushamakumari (1981) and Anon. (1984 a).

2) Number of tillers/m^2

Tiller production was increased with increase in the levels of nitrogen upto 75 kg N/ha. Beneficial effect of N to enhance tiller production has been reported by many workers (Gunasena et al., 1979; De-Datta and Surjit 1981; Anon., 1985 C; and Ajithkumar 1984). Tillering is closely associated with the nutritional condition of the mother plant which supplies carbohydrates and nutrients to the tillers upto 3 leaf stage. A high concentration of external nitrogen favours vigorous tillering (Ponnamperuma, 1965 and Yoshida, 1981).

The highest tiller count (288.8/m^2)was obtained with the plants supplied with USG and its effect was on par with that of SCU. The superiority of USG and SCU on tiller production has been reported earlier by Rajagopalan and Palaniswamy (1985), Anon. (1984 a) and Anon. (1985 b).

3. Dry matter production

Dry matter production increased with increase in the levels of nitrogen, and the highest values were

observed with the plants supplied with 112.5 kg N/ha. This is in agreement with the findings of many workers (Nagre and Mahajan, 1981; Anon., 1985; and Anon., 1986 b). The increased tiller production and enhanced plant height observed due to the application of higher doses of N might have led to the enhanced biomass production.

Urea super granules and SCU applied at higher doses of N (112.5 kg/ha) had a favourable effect on dry matter production. It may be noted from Table 2 that application of SCU had a pronounced effect on tiller production, especially at higher levels of nitrogen, and hence the dry matter production. Similar results have been reported earlier (Anon., 1984a).

B. Chemical Analysis

1) Nitrogen content of plant parts

The results of N concentration presented in Table 4 and 4b revealed that the effect of N on the N concentration of plant parts was marked at all stages of growth. It showed an increasing trend with increase in N levels upto 112.5 kg N/ha. The N concentration of the plants decreased with the age of the crop, and this may be due to the dilution effect. Sadanandan et al. (1969) and Mani (1979) also observed similar results.

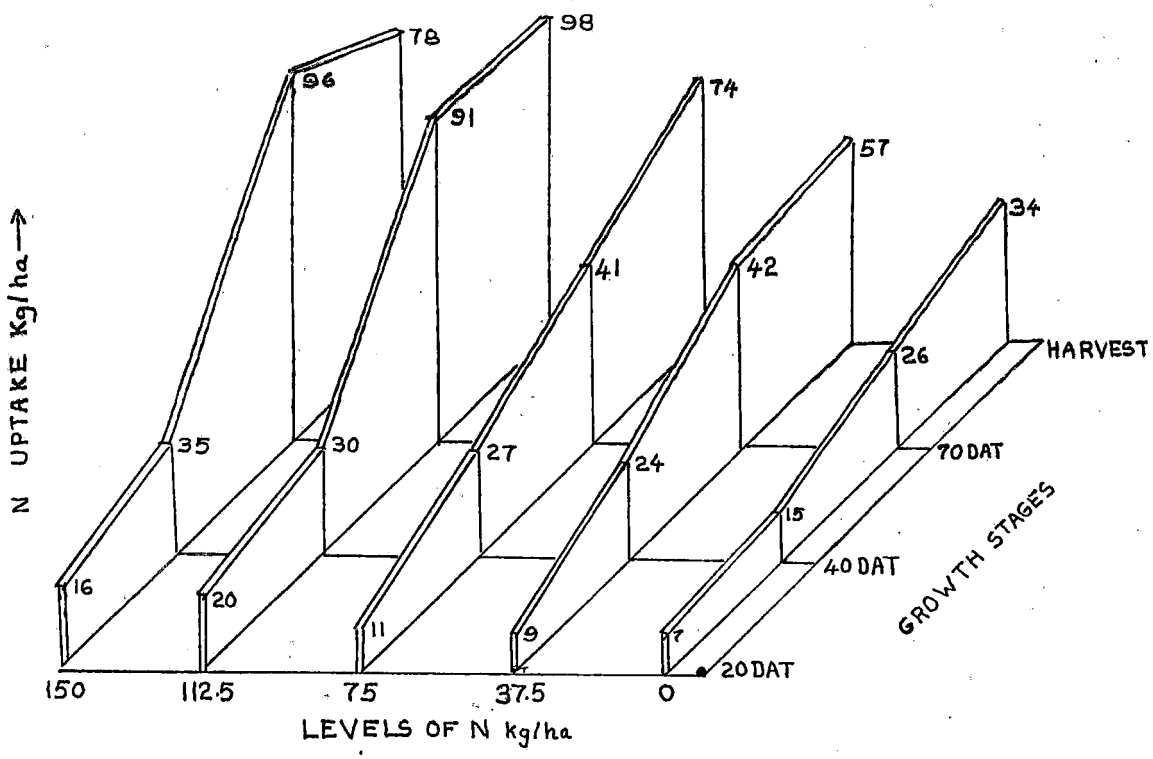
The influence of types of urea on N content was considerable during the early stages of plant growth and application of SCU and NCU resulted in a higher N concentration in plant parts. Perhaps, the loss of N from these materials might have been considerably less resulting in the maintenance of high amounts of available N in the soil. This might have favoured higher N concentration in plants. At 70 DAT, USG, SCU and RCU applied plants s owed high concentration of nitrogen. The deep placement of USG at the reduced zone decreases the loss of N from flooded paddies (Savant and De Datta, 1980; Chen and Zhu, 1982). As mentioned earlier, this might have resulted in the maintenance of higher amount of available N in the soil for a longer period of time and hence a higher N concentration in plants.

The interaction effect between levels of N and types of urea on N concentration of plants was noticed upto 40 DAT, and application of NCU, SCU or USG resulted in high N concentration in plants. But this effect disappeared at the harvest stage.

2) Nitrogen uptake

The data presented in table 5a and 5 b and Fig.(4) clearly reveal that nitrogen application increases N uptake

FIG . 4 . UPTAKE OF NITROGEN AS INFLUENCED BY LEVELS OF NITROGEN STAGE WISE



at all stages of growth. In general N uptake increased with N application upto 112.5 kg N/ha. Similar results were reported by many workers (Gopalaswamy and Raj, 1977), Agarwal, 1978).

The N uptake was different due to the difference in the types of urea applied. The highest N uptake was observed due to the application of SCU (Fig. 5). The data presented in table 3a, 3b, 4a and 4b) reveal that the dry matter production as well as N concentration in plants were highest with the plants applied with SCU. The above results are in agreement with the findings of many workers (Mellu and Rekhi, 1983; Anon., 1985 c).

Apparant N recovery

The recovery percentage of applied N was high at a level 37.5 kg N/ha, and it decreased with increase in the levels of applied nitrogen. This means that at high doses of N application, the rate of loss was more than the rate of absorption compared to lower rates of N application.

Recovery of applied N from different types of urea was also different. Nitrogen use efficiency in terms of its recovery percentage was highest with SCU (56.91%) (Fig.6). Application of NCU also resulted in similar efficiency (54.5%). Among the types of urea tried, PU

FIG . 5 . UPTAKE OF NITROGEN AS INFLUENCED BY TYPES OF UREA

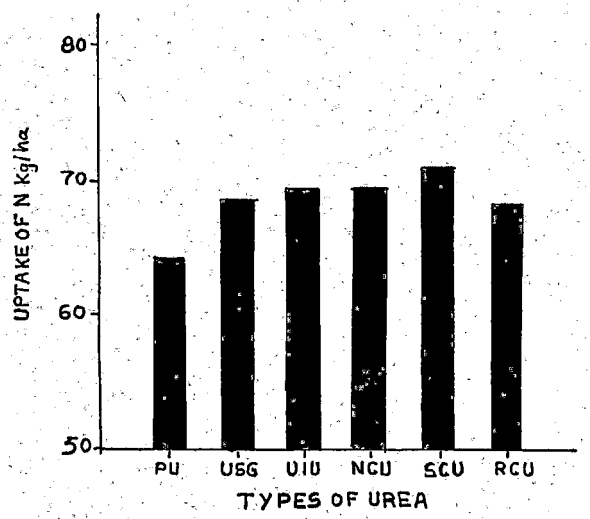
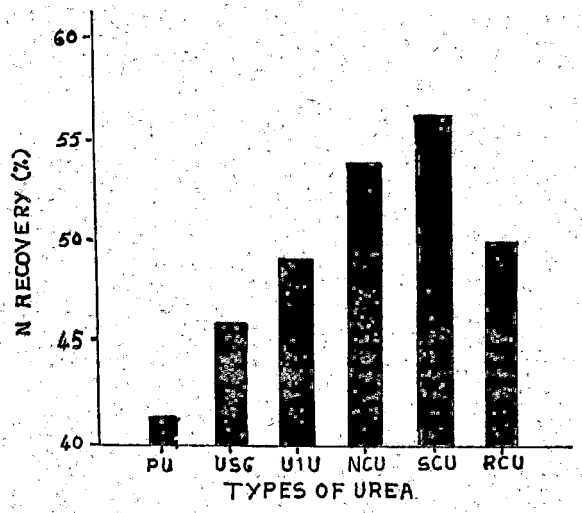


FIG . 6 . APPARENT RECOVERY OF NITROGEN AS INFLUENCED BY TYPES OF UREA



proved to be less efficient to enhance N recovery.

Protein content

Protein percentage of grain was enhanced by the application of higher doses of N. The highest protein percentage was noticed when N was applied at 112.5 kg/ha. Higher rates of N absorption consequent to higher rates of N application resulted in the production of quality grains. Abraham et al., 1974, Ajithkumar, 1984, and Surendran, 1985 have reported similar results. The interaction between levels of N and types of urea was also considerable. Application of USG at 112.5 kg/ha resulted in the production of quality grains. As explained earlier, deep placement of USG in the reduced zone might have decreased the loss of N maintaining a higher rate of N availability for a longer period. It can be seen from table 5a that there was gradual increase in the N uptake with increase in the levels of applied N. The enhanced uptake of this nutrient might have contributed to the production of quality grains.

C. Yield components and yield

1) Number of panicles/m^2

Number of panicles/m^2 increased with increase in

the rate of nitrogen upto 112.5 kg/ha and thereafter it declined. Availability of N to the plants might have been optimum at this particular level of N application. At higher doses of applied N there was luxuriant vegetative growth as well as incidence of more number of pests and diseases. Further there was competition between plants for space leading to tiller mortality. All these factors together contributed to the decreased number of panicles/m^2 at higher rates of N application. Similar effects of N on panicle production per unit area were reported by many workers (Koyama and Niamsrichand 1973; Balasubramanian, 1984; Anon., 1984 b). Panicle production per unit area remained more or less the same in the plots supplied with different typew of urea. But the interaction effect between levels of N and types of urea was marked, and application of SCU at 112.5 kg N/ha produced the highest number of panicles/m^2 (234.6), and this effect was on par with that of USG, UIU and RCU at this N level.

2) Number of spikelets/panicle.

The number of spikelets per panicle increased with N application upto the highest level tried (150 kg N/ha). This result is in agreement with the findings of Sushama-kumari 1981; Anon., 1984a; Alexander et al., 1974.

Types of urea also had influence on spikelet number/panicle, and the highest value (118.4) was noticed with the application of RCU, and its effect was on par with that of SCU. It may be noted from table 5a that the N uptake was higher with the plots applied with RCU and SCU, and perhaps this may be the reason for the beneficial effect of these types of urea on spikelet number/panicle. Saravana (1979) and Meelu and Rekhi (1983) observed similar results. Application of PU resulted in the production of minimum number of spikelets/panicle. Though PU was applied in best splits, its loss from soil might be more, and consequently the amount of N available at the time of spikelet formation and development might be less compared to SCU and RCU. The data presented in table 5a indicate that the N uptake by the plants was low from the plots applied with PU (Anon., 1972).

3. Number of filled grains/panicle

There was considerable increase in the number of filled grains per panicle by the application of nitrogen upto 112.5 kg N/ha, and thereafter it declined. The filled grain number indicates the actual capacity of sink to receive and store synthates from the carbon assimilating area of the plant. The decline in the number of filled

grain after a particular level may be due to the production of more number of tillers at higher levels of N application. Consequently there might have been mutual shading between plants. The net photosynthate production might also have decreased due to improper distribution of light in the canopy. De Datta and Surjith (1981) and Sobhana (1983) reported similar results.

4) Percentage of filled grain

Filled grain percentage was more with the plants applied with N at 75 kg N/ha, and it declined thereafter. The reasons attributed for the decreased number of filled grains per panicle at higher doses of nitrogen hold good for the decrease in the percentage of filled grain at higher dose of nitrogen. Ramanujan and Rao (1971) and Matushima (1980) reported that at higher dose of applied N, the total number of spikelets as well as the number of unfilled spikelets per panicle increased.

Though the types of urea did not bring about any appreciable change in the percentage of filled grains, the effect of its interaction with levels of nitrogen was pronounced. The superiority of UIU and PU at 75 kg N/ha was noticed in this respect. Similar results were reported by Singh et al. (1985).

5. Thousand grain weight

The results of the data presented in table 8 clearly reveal that thousand grain weight increased with levels of nitrogen upto 112.5 kg/ha. A further increase in N level decreased the test weight. Application of higher doses of N might have stimulated excessive vegetative growth leading to mutual standing. Consequently the net photosynthate production might have reduced. As a result the source activity might have been insufficient to meet the demand of the sink resulting in a decreased test weight at higher levels of N. Similar results were reported by Kalyanikutty and Morachan (1974) and Nair (1976).

The application of USG resulted in the highest test weight of grains and its effect was on per with that of SCU. These types of urea might have provided N slowly according to the demand of the crop even at the later stages. Perhaps, this effect of USG and SCU might have reflected on the test weight as well. Similar results were reported by Bains et al. (1971) and Arunachalam et al. (1974).

The interaction effect was marked and application of SCU at 112.5 kg/ha resulted in higher test weight of grains, and this effect was on par with that of USG at higher levels.

6. Grain yield

The data presented in table 10 indicate that the grain yield increased progressively with successive addition of nitrogen upto 112.5 kg N/ha, and thereafter the response of the crop to applied nitrogen flattened. The highest grain yield (3567 kg/ha) was obtained by the application of 112.5 kg N/ha and this was on par with the yield obtained at 150 kg N/ha. The yield contributing characters like number of panicles/m^2, filled grains/ panicle and thousand grain weight were highest at a level of 112.5 kg N/ha. The plant growth (tables 2, 3a and 3b) as well as the nutrient uptake (table 5a and 5b) were higher at this level of nitrogen application. The cummulative effect of N on the growth characters, yield components and N uptake might have resulted in a higher grain yield at this level of N (112.5 kg N/ha). It may be noted from table 13 that the experimental soil was low with reference to available nitrogen. Consequently there was response to added nitrogen, and for the variety of rice tested (Jaya) the optimum appears to be around 112.5 kg N/ha. Singh et al. (1979) opined that the most profitable nitrogen rate for the rice var Jaya is 100 kg N/ha. Similar results are reported by Rethinam et al., 1975; Sharma and De 1976 and Anon., 1985 b.

The response of Jaya to N was following a quadratic response function (Fig. 7). The response equation fitted for this purpose was $Y = 1943.72 + 908.64\ x - 141.67\ x^2$, When $X = \frac{N}{37.5}$. From this equation the physical optimum dose was estimated as 120 kg N/ha. Considering the cost of 1 kg N as Rs.5 and price of 1 kg paddy as Rs.2.5 the economic optimum dose was estimated as 119 kg/ha. Hence it can be suggested that for the variety under test a nitrogen dose of 119 kg/ha can be safely recommended for obtaining optimum grain yield.

Among the types of urea, the highest grain yield (3132 kg/ha) was obtained by the application of SCU (Fig. 8) and its effect was on par with that of UIU and USG. The grain yield obtained by the application of SCU, UIU and USG are respectively 16.4 per cent, 13.2 per cent and 13 per cent more than that obtained by the application of PU. Field experiments conducted at different centres to compare the efficiency of slow release N fertilizers over prilled urea conclusively proved the superiority of slow release nitrogen sources to reduce nitrogen losses and to increase the grain yield in rice (Rajendra Prasad et al., 1970).

It may be noted from table 7 and 8 that the plants applied with SCU produced more number of spikelets per

FIG. 7. RESPONSE OF RICE TO NITROGEN

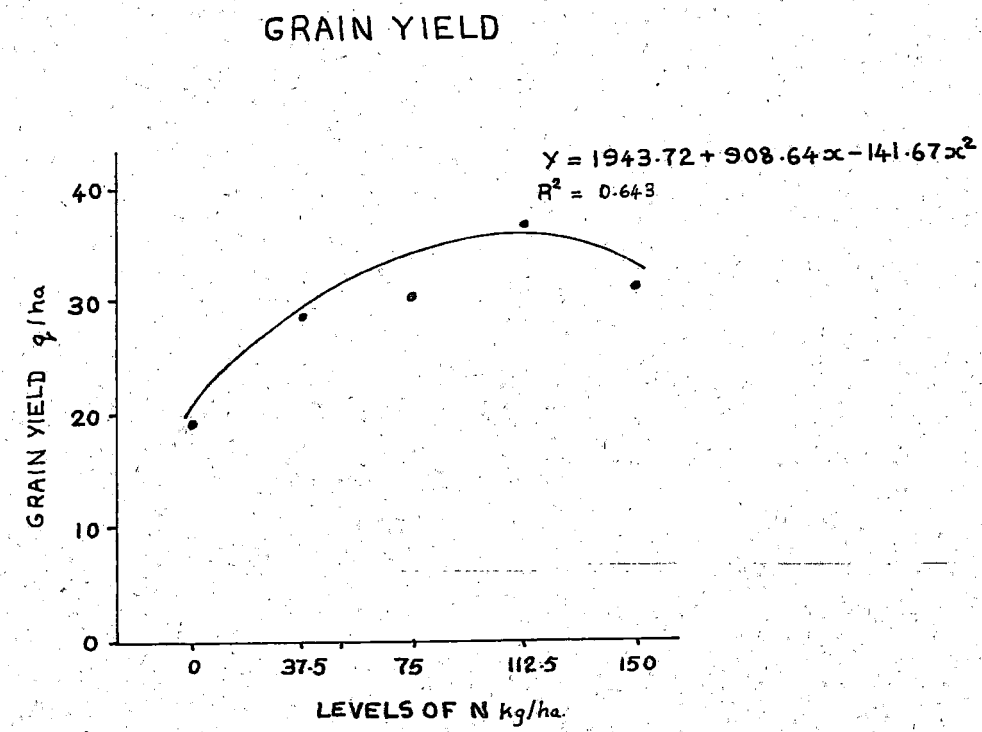


FIG. 8. GRAIN YIELD OF RICE AS INFLUENCED BY TYPES OF UREA

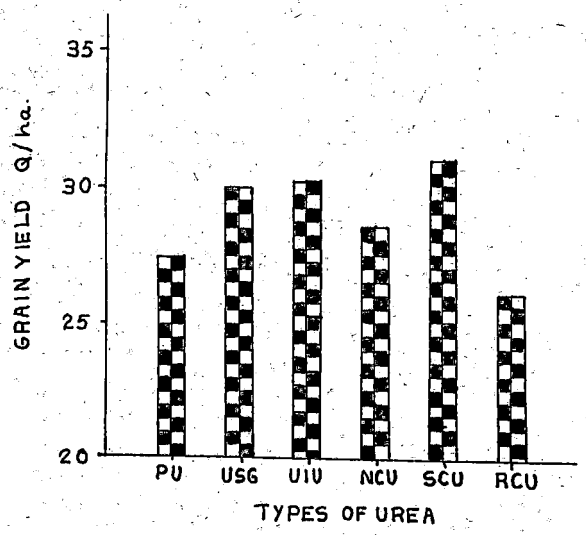
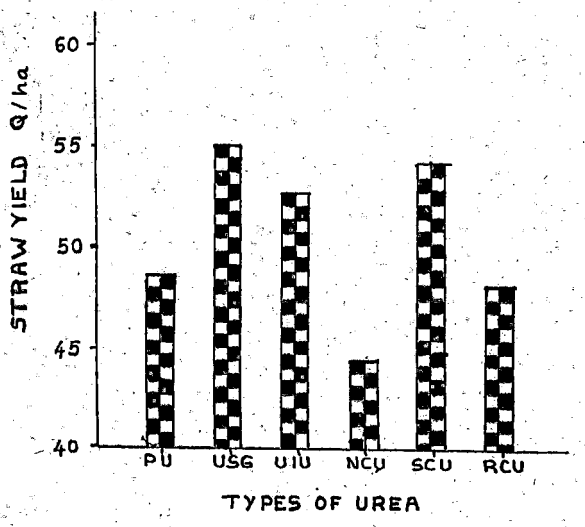


FIG. 9. STRAW YIELD OF RICE AS INFLUENCED BY TYPES OF UREA



panicle and grains with higher test weight. The uptake of N was also higher with the plants supplied with SCU, and there was a significant positive correlation between N uptake and grain yield in rice (Table 12). These beneficial effects of SCU might have enabled the plants to express its production potential to a greater extent. Trials conducted by the AICRIP during 1972 proved that SCU is a better source of nitrogen for basal dressings. It gave an increased yield of 25 per cent over prilled urea (Anon., 1972).

The superiority of SCU compared to PU to increase the grain yield has been reported by many workers (Bandyopadhyay and Biswas, 1982; Mellu and Rekhi, 1983; Rana et al., 1984; Anon., 1985b; Anon., 1985 c). The increased grain yield by the placement of USG was also reported by many workers (Anon., 1984 a; Rambabu et al., 1983; Cao and De Datta, 1983).

The PU appeared to be inferior to other urea modified materials. Horn (1979) reported that PU exposes 237 cm^2 surface area/g of material. Further, PU dissolves in water at a very faster rate and as a result there will be tremendous loss of N by leaching. This might have led to the production of lesser number of panicls/m^2, filled grains/ panicle and ultimately lesser 1000 grain weight in PU treated

plots compared to the ones applied with the other types of urea. Hence the relatively less favourable effect of PU on yield contributing factors might have resulted in lesser yields.

The interaction effect between the types of urea and levels of nitrogen was found to be nonsignificant on grain yield.

7. Nitrogen Use efficiency

(a) N response

The data on N response presented in table 11 reveal that the N response decreased with increase in the levels of nitrogen. Highest response was obtained with the application of 37.5 kg N/ha. Further increase in N resulted in a decrease in grain production per kg of applied nitrogen.

It was interesting to note that the N response was more or less the same due to the application of different types of urea (Fig. 10) like USG, SCU, UIU, NCU and PU. This means that the production of grain /kg of applied N cannot be changed by changing the type of urea.

(b) Productive efficiency

While the productive efficiency remained unaffected by levels of nitrogen, it was influenced by the types of

FIG. 10. NITROGEN RESPONSE AS INFLUENCED BY TYPES OF UREA

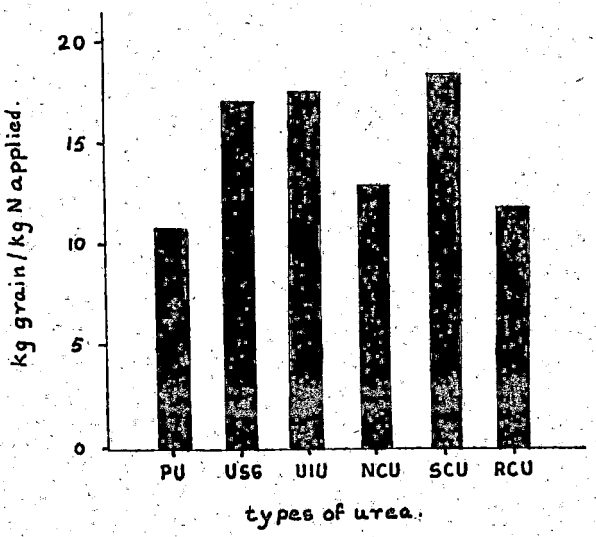
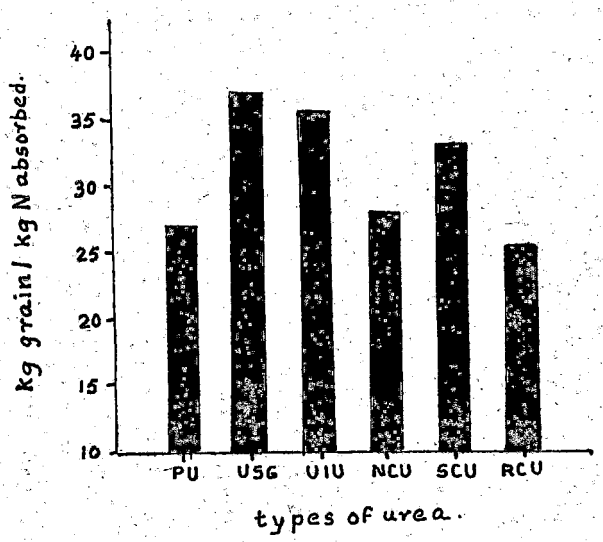


FIG. 11. PRODUCTIVE EFFICIENCY AS INFLUENCED BY TYPES OF UREA



urea (table 11). Data on productive efficiency reveal that the grain production/kg of absorbed nitrogen was highest with the application of USG (Fig. 11), and its effect was on par with that of UIU and SCU. Data presented in table 5a and 10 reveal that nitrogen uptake and grain yield were comparable between USG, UIU and SCU. From the above results it appears that the urea modified materials, USG, UIU and SCU behave more or less similarly in the soil. The productive efficiency of PU, NCU and RCU was low compared to USG, UIU and SCU.

8. Straw yield

There was progressive improvement in straw yield upto 75 kg N/ha, and the effects of 75, 112.5 and 150 kg N/ha were comparable. The favourable influence of N on straw yield is very well documented (Rao and Ramanujam, 1971; Raj et al., 1974; Venkateswarlu, 1978).

Among the types of urea, application of USG (Fig.9) resulted in the production of highest amount of straw (5587 kg/ha). The effects of USG, SCU and UIU on straw production were more or less the same. The straw production was more or less the same. The straw production was less when N was supplied through PU, NCU and RCU. Data presented in tables 2 and 3a reveal that the vegetative growth was

greater when N was supplied through USG, SCU and UIU compared to other types of urea. Consequently straw yield was more with these treatments. Increased straw yield with the application of USG has been reported by Anon.(1984 a) and Rajagopalan and Palaniswamy (1985).

Interaction effect between levels of N and types of urea was considerable on straw production. Application of SCU, USG or UIU at 75 kg N/ha could produce more amount of straw. It can be seen that the main effect of N on straw production was restricted upto a level of 75 kg N/ha and among the types of urea, application of USG, SCU and UIU resulted in higher straw production.

9. Harvest index

The levels of nitrogen and types of urea did not influence the harvest index. But, their interaction effect was significant, and the harvest index was highest when NCU was applied at 112.5 kg N/ha.

10. Correlation studies

There was significant positive correlation between grain yield and growth characters such as plant height, number of tillers and dry matter production. The correlation between grain yield and dry matter production was the highest.

It may be noted that application of N could improve the plant growth characters and enhance the grain yield.

The yield attributing factors such as productive tillers/m^2, number of spikelets per panicle and thousand grain weight were positively correlated with grain yield.

The N uptake of rice at different growth stages is well correlated with grain yield. The correlation between N uptake at 70 DAT (flowering) and grain yield was the highest. This indicates the importance of N nutrition of rice at flowering.

D. Total nitrogen content in the soil after the experiment

The total N content of soil after the experiment was different due to difference in the rates of N application. Plots applied with fertilizer N analysed for higher amounts of post harvest total nitrogen content of the soil, than the control plots. This means that there remains residue of applied N after the experiment.

The total N content in the soil after the experiment was more or less the same in the plots applied with PU, USG, UIU, SCU and RCU. These results reveal that the residual effects of the above urea modified materials are similar. In other words PU, USG, UIU, SCU and RCU leave

more or less similar amounts of N in the soil under identical conditions.

The plots supplied with USG at 112.5 kg N/ha are analysed for higher amounts of N after the experiment. Placement of USG in the reduced zone (10 cm depth) results in a decreased loss of N from the soil (Chan and Zhu (1982), and hence the result.

E. Residual study

The data presented in table 14 clearly reveal that the levels of N types of urea or their interactions did not change the grain or straw yields of the crop raised during the subsequent seasons. These results point to the fact that though there was change in post harvest N content of the soil due to the treatments, it was insufficient to influence subsequent crop in terms of grain and straw yield. It may be noted that to the crop raised for the residual study, 50 per cent of the recommended dose of N was also applied. Perhaps, application of this dose of N might have nullified the residual effect.

SUMMARY

SUMMARY

An experiment was conducted at the cropping system Research Centre, Karamana, Trivandrum during 1985-86 to evaluate the comparative efficiency of different urea modified materials at different levels of N on the growth yield, quality and nitrogen uptake of rice, as well as to study their residual effects in the subsequent rice crop.

The experiment was laid out in split plot design with three replications. There were five levels of nitrogen (0, 37.5, 75, 112.5 and 150 kg/ha) in the main plots and six types of urea (Prilled urea, urea super granuls, Urease inhibited urea, Neem cake coated urea sulphur coated urea and Rock phosphate coated urea) in the sub plots. In total there were 30 treatment combinations. The rice variety used was 'Jaya'. The results of the experiments are summarised below.

1. Urea super granules and sulphur coated urea proved their superiority over other types of urea in increasing

tiller production in rice. The tiller production was highest when USG was applied @ 150 kg N/ha. The tallest plants were obtained with the application of N @ 112.5 Kg N/ha. Application of SCU @ 112.5 kg N/ha resulted in the production of highest amount of dry matter at harvest.

2. Nitrogen concentration increased with increase in the levels of N upto 112.5 kg/ha. Plants supplied with SCU contained more amounts of N. Application of SCU or USG @ 112.5 kg N/ha resulted in highest N uptake.

3. The recovery of applied nitrogen decreased with increased levels of N. The highest recovery of N was observed either with NCU or SCU when applied @ 37.5 kg N/ha.

4. Nitrogen application increased the productive tillers/m^2, spikelets/planicle, filled grains per panicle, percentage of filled grains and thousand grain weight. Application of SCU and USG resulted in the production of more number of spikelets/panicle as well as enhanced test weight.

5. Application of nitrogen @ 112.5 kg N/ha resulted in the highest grain yield. The plots applied with SCU produced highest grain yield, and its effect was on par with that of UIU and USG. The yield levels obtained by

the application of SCU, UIU and USG were respectively 16.4, 13.2 and 13 per cent more compared to that of PU.

6. Nitrogen response was highest when the plants were supplied with USG, and its effect was on par with that of SCU, NCU, UIU and PU. Nitrogen response was higher at lower levels of nitrogen application (37.5 kg N/ha).

7. A progressive increase in straw yield was noticed with increase in the levels of N upto 150 kg N/ha. Application of USG resulted in the production of highest amount of straw, and its effect was on par with that of SCU and UIU. Straw yield was highest from the plots which received SCU @ 75 kg N/ha.

8. The post harvest N content of the soil was more in the plots applied with N. More or less similar amount of residual nitrogen was noticed in the plots applied with PU, USG, UIU, SCU and RCU.

9. The residual effect of levels of N, types of urea or their interactions were not pronounced on the grain and straw yield of the subsequent rice crop.

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* Original not consulted.

APPENDICES

APPENDIX I

Weather data during the cropping period

Month	Temperature (°C)		Monthly rain-fall	Relative Humidity (%)
	Max.	Min.		
June '85	28.7	22.8	424.3	93
July	29.8	22.9	82.5	88
August	30.1	23.3	61.8	86
September	30.9	23.6	96.8	84
October	30.4	23.6	162.7	87
November	30.1	22.7	170.4	83
December	31.7	22.9	39.5	76
January '86	32.5	22.8	2.2	73
February	32.2	22.6	28.8	76
March	33.3	24.2	2.1	76

APPENDIX II

Abstract of Analysis of variance table on Growth Characters

Source	d.f	M.S.S					
		Plant height	Number of tillers/m^2	Dry Matter Production stagewise			
				20DAT	40 DAT	70 DAT	Harvest
Replication	2	46.56	3283.25	921.00	91352.00	175488.00	59904.00
Levels of N	4	276.87**	37008.13**	134017.3**	1960068.00**	29541510**	51007300**
Error a	8	20.84	2095.31	2064.25	38260.00	118592	100032
Typesof urea	5	41.12	4180.9**	5741.2	57811.20	1072000**	684441.6**
Level of N x Types of urea	20	27.56	2174.82**	5902.65	37472.00	304947**	574976**
Error b	50	20.43	1184.1	4063.86	26610.24	74915.85	100925.40

* Significant at 5% level

** Significant at 1% level

APPENDIX III

Abstract of Analysis of variance table on N concentration of plant parts and protein condent of grain

Source	d.f	M.S.S				
		N concentration in plant stage-wise				Protein condent
		20 DAT	40 DAT	70 DAT	Straw at harvest	
Replication	2	0.0642	-0.000015	0.0587	0.01712	1.584
Levels of N	4	2.176**	0.3984**	1.789**	0.1139**	24.636**
Error a	8	0.0083	0.00918	0.0402	0.0043	0.2233
Types of urea	5	0.01577**	0.0176*	0.0787*	0.0128	0.9659
Levels of n x Types of urea	20	0.0125**	0.0226**	0.02855	0.0098	1.2671*
Error b	50	0.00437	0.00662	0.02570	0.00613	0.6295

* Significant at 5% level

** Significant at 1% level

APPENDIX IV

Abstract of Analysis of variance table on N uptake and recovery percentage of applied N

Source	d.f	M.S.S				
		Nitrogen uptake stage-wise				Apparent N recovery %
		20 DAT	40 DAT	70 DAT	Harvest	
Replication	2	59.93	28.06	125.35	76.67	123.49
Levels of N	4	476.61**	1032.35**	17351.77**	10345.96**	3349.16**
Error a	8	51.90	14.48	42.84	30.69	67.21
Types of urea	5	44.65	29.39*	740.41**	94.35**	380.39**
Levels of N x Types of urea	20	49.00	14.89	156.80**	127.10**	190.64**
Error b	50	54.34	10.90	30.97	27.07	44.67

* Significant at 5% level

** Significant at 1% level

APPENDIX V

Abstract of Analysis of variance table on yield components

Source	d.f	M.S.S				
		No.of panicles/m^2	No. of spikelet/panicle	Filled spikelet/panicle	1000 grain weight	Filled grain %
Replication	2	182.12	45.68	60.06	0.31	23.65
Levels of N	4	10775.00**	7210.53**	2371.64**	39.57**	306.42**
Error a	8	207.59	49.26	23.89	0.97	28.68
Types of urea	5	189.40	120.07**	8.46	3.27**	15.51
Levels of N x Types of urea	20	176.72**	77.50**	27.36	1.62*	23.12*
Error b	50	92.75	28.75	17.30	0.71	11.93

* Significant at 5% level

** Significant at 1% level

APPENDIX VI

Abstract of Analysis of variance table on Grain yield, Straw yield, Harvest index and Nitrogen use efficiency

Source	d.f	M.S.S				
		Grain yield	Straw yield	Harvest index	N-response	Productive efficiency
Replication	2	220224	4176640	0.0101	495.679	2399.853
Levels of N	4	6856880**	19002690**	0.0118	588.310*	644.609
Error a	8	507720	113104	0.0069	39.097	215.805
Types of urea	5	543193.6**	2696755**	0.0023	99.631*	305.236*
Levels of N x Types of urea	20	110995.2	718310.4*	0.00275**	21.825	186.632
Error b	50	73541.12	401920	0.00098	14.973	132.064

* Significant at 5% level

** Significant at 1% level

APPENDIX VII

Abstract of Analysis of variance table on Total N content of soil after the first agreement and grain and straw yields of the subsequent rice crop

Source	d.f	M.S.S		
		Total N content of the soil after the 1st experiment	Yield of subsequent rice crop	
			Grain yield	Straw yield
Replication	2	306.5	593040	1397568
Levels of N	4	17263.25*	1474768	6734880
Error a	8	3806.87	586136	4136064
Types of urea	5	6070.40**	113843.2	123494.4
Levels of N x Types of urea	20	5095.55**	87825.6	267814.4
Error b	50	1679.5	143265.9	336972.8

* Significant at 5% level

** Significant at 1% level

A B S T R A C T

With a view to evaluate the comparative efficacy of different urea modified materials at various doses of N, an experiment was conducted at the Cropping Systems Research Centre, Karamana during 1985-86. The experiment was laid out in a split plot design with three replications. There were five levels of nitrogen (0, 37.5, 75, 112.5 and 150 kg/ha) in the main plots and six types of urea (prilled urea, urea super granules, urease inhibited urea, Neem cake coated urea, sulphur coated urea and Rock phosphate coated urea) in the sub plots. The rice variety used was Jaya. The abstract of the results are given below.

The highest tiller production was observed when USG was applied @ 150 kg N/ha. Application of SCU @ 112.5 kg N/ha, resulted in the production of highest amount of dry matter at harvest.

Application of SCU or USG @ 112.5 kg/ha, resulted in the highest N uptake. Nitrogen recovery percentage was highest when NCU or SCU was applied @ 37.5 kg N/ha.

Plants supplied with SCU or USG resulted in the production of more number of spikelets/panicle and higher test weight.

The response of the rice variety Jaya to applied N followed a quadratic response function, and dose of 119 kg N/ha can be recommended for obtaining economic optimum grain yields. Among the types of urea, SCU, UIU and USG were superior compared to NCU, RCU and PU to increase the grain yield. Highest straw yield was observed when SCU was applied @ 75 kg N/ha.

The residual effects of levels of N, types of urea or their interactions were not pronounced on the grain and straw yields of the subsiquent rice crop.