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Journal of Bangladesh Academy of Sciences, Vol. 11, No. 2, 215-226, 1987

A STUDY OF SLOW-RELEASE N-CARRIERS ON RICE

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(Received September 28, 1986)

ABSTRACT

A field experiment was carried out to monitor the relative efficiency of urea, urea formaldehyde (UF), sulphur coated urea (SCU) and isobutylidene diurea (IBDU) each at the rate of 40, 80 and 120 kg N/ha on growth, yield and chemical composition of rice grown during aman season. Application of nitrogen caused a significant increase in number of tillers, height and yields of straw and grain irrespective of the sources. Among the chemical composition (N, P, K, Ca and Mg) of straw and grain only N content was significantly improved. All these components increased with nitrogen rate. The effectiveness of the N-carriers in increasing the parameters followed the order: SCU> Urea> IBDU> UF. Percent recovery of added nitrogen generally decreased with increasing amount of nitrogen. SCU was found to be superior to conventional urea whereas IBDU and UF were inferior due to slow release of nitrogen.

Anaerobic incubation of urea, UF, SCU and IBDU for 4 weeks caused a significant release of NH_4-N from 59.9 to 78.2%. An initial rapid production of NH_4-N was followed by a gradual release with time. More than 75% urea and SCU decomposed to NH_4-N within 2 and 4 weeks respectively. UF was more resistant to decomposition as compared to SCU and IBDU. However, the trend of degradation was similar for all the compounds. Accumulation of a small quantity of NO_3-N disappeared rapidly within 2 weeks time.

INTRODUCTION

Because of the critical position of the nitrogen supply in crop production and soil fertility, a deficiency markedly reduces yield as well as quality of crops. This is true for very different crops growing under the most widely varying conditions throughout the world. There is general agreement, that of all the plant nutrient amendments made to soils, N-fertilizer has had by far the most important effects in terms of increasing crop production(1). The nature of N-fertilizer is one of the significant determining factor of its efficiency to crop production. Of the various types, urea occupied the top most position. However, the application of huge tons of urea and its output made a gape between cost and production, and it is probably due to insufficient use of fertilizer-N.

The chemical nature of urea and its susceptibility to rapid transformation, made it inprofitable particularly for rice production. Moreover, the same climate and soil condition which favours rice production are responsible for a rapid turnover and loss of nitrogen from the soil. Losses of urea-N through leaching, denitrification and volatilization resulting low recoveries by rice plant(3,4) have led to the development of a number of slow-release N-fertilizers with the objective of making the amount of nitrogen released coincide with that required by growing plants, thereby reducing nitrogen losses. Any saving in the consumption of nitrogen fertilizer without affecting the productivity will, therefore, be not only an economic advantage but also a strategic necessity for a developing country like Bangladesh(5).

Thus a field experiment was conducted to study the relative efficiency of some slow-release N-fertilizers as compared to conventional urea with rice. Moreover, an incubation experiment was also performed to assess their extent of hydrolysis and decomposition in soil.

EXPERIMENTAL

(*A*) *Field trial*

A field experiment with rice (*Oryza sative* L. var BR-4) was carried out in the Central Experimental Farm of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during aman season. The soil belongs to Kalma series. The physical and chemical characteristics of soil were determined by standard analytical techniques. The soil was clay loam with a pH 6.2, organic carbon 1.22%, total nitrogen 0.11%, and available N, P and K were 68, 14 and 69 μg/g soil respectively.

Urea (42.2% N), urea formaldehyde (UF, 37.4% N), sulphur coated urea (SCU, 32.0% N) and isobutylidene diurea (IBDU, 31.3% N) each at the rate of 40, 80 and 120 kg N/ha together with a control were used in the experiment. To equalize the additional effect of S coming from SCU, elemental S was added with other sources of N. A basal dose of phosphorus (60 kg P/ha) and potassium (40 kg K/ha) was applied as triple superphosphate and muriate of potash respectively. The whole amount of all the fertilizers except urea was applied one day before transplantation. Split application of urea was done in three equal instalments namely before transplantation, at maximum tiltering stage and before panicle initiation. The unit plot size was 5m × 4m.

Thirteen treatments in triplicate were arranged in a randomized complete block design. Three healthy rice seedlings (four weeks' old) of uniform size were transplanted with the spacing 20 cm from hill to hill and 25 cm from row to row. The plots were irrigated regularly throughout the experimental period to keep them submerged. Weeds were removed as they appeared. Number of tillers, height of plant, yield of straw and grain were recorded. Plant and grain samples were chemically analyzed for N, P, K, Ca and Mg contents.

(*B*) *Incubation test*

Sample of surface soil (0-15 cm) was collected from the same field, air-dried, ground and passed through 2 mm sieve. A set of 10 glass bottles (150 ml) was taken. 10g of soil was weighed in each bottle. Nitrogen at the rate of 200 μg/g soil from each source of urea, UF, SCU and IBDU was separately added in duplicate bottles as solid. A control treatement was also included in the test. 50 ml of distilled water was added in each bottle, mixed thoroughly and covered with parafilm. Five treatments in duplicate were incubated anaerobically for 0, 1, 3, 7, 14 and 28, days at 30°C (±0.5°C) in a randomized complete block design. Similarly five more sets of experiment were arranged.

After specified time interval, one set of experiment was analyzed for NH_4-N and NO_3-N. 14.92g KCl (AR) and 50 ml distilled water were added in each bottle so that the concentration of KCl in the extract was 2M and the soil and solution ratio 1 : 10. The suspension was shaken for 1 hour in a receprocating shaker and filtered. The filtrate was used for determinations.

(*C*) *Analytical methods*

Extraction was done for avalable nitrogen by 2M KCl([6]), phosphorus by 0.002N H_2SO_4([7]) and potassium by N NH_4OAc. The straw and grain samples were digested with HNO_3-$HClO_4$ mixture for P, K, Ca and Mg while with H_2SO_4-$HClO_4$ mixture for N determinations([8]).

Determinations were made of particle-size distribution by hydrometer method, pH with a glass/calomel electrode using a cornning pH meter, organic carbon by wet oxidation method([9]) and nitrogen by Kjeldahl distilation procedure. Available and plant phosphorus was determined colorimetrically as sulphomolybdate blue and venadomolybdate yellow complexes respectively using Coleman Junior 11 spectrophotometer. Potassium was estimated flamephotometrically by Galenkamp Flame Analyzer. Calcium and magnesium were determined by EDTA complexometric titration method([10]).

RESULTS AUD DISCUSSION

(A) Field information

(a) *Growth of rice plant.*

The rice plant started tillering within two weeks after transplantation (Table I). The treatments produced significant increase in tiller numbers. Number of tillers increased with increased supply of nitrogen irrespective of its source. Height of the plant was also significantly increased due to treatments effect (Table I).

TABLE I NUMBER OF TILLER AND HEIGHT OF PLANT AT DIFFERENT TIME INTERVALS (DAYS) AS INFLUENCED BY N-SOURCES.

N-source	*N-rate (kg / ha)*	*Tiller number/plant*					*Height (cm /plant)*				
		15	30	45	60	75	15	30	45	60	75
Control	0	5.8	14.6	12.4	11.7	9.3	33.4	48.5	68.7	77.6	96.4
Urea	40	5.9	15.1	13.6	13.5	10.1	34.5	54.5	76.4	89.3	106.8
	80	8.4	17.0	15.6	14.8	12.3	35.7	58.0	81.2	94.6	108·2
	120	8.9	17.0	15.8	15.3	11.5	35.6	55.9	79.5	92.3	107.8
UF	40	6.8	14.8	13.1	11.9	10.3	33,9	52.3	70.7	80.1	98.7
	80	7.1	15.0	13.3	12.1	10.4	34.8	52.9	71.0	81.5	98.9
	120	7.4	15.1	13.8	11.7	10.6	34.9	53.7	72.7	81.6	99.8
SCU	40	6.8	16.3	14.0	12.9	11.0	34.2	54.7	73.2	84.3	102.1
	80	8.3	19.9	16.3	14.9	13.1	36.5	59.3	78.4	90,7	105.5
	120	8.5	20.1	16.5	15.5	13.4	36.5	59.1	80.4	91.0	109.0
1BDU	40	6.1	14.6	14.2	12.4	10.6	33.7	54.3	72.2	84.3	101.6
	80	6.8	16.8	14.6	13.8	10.8	35.3	37.1	76.1	87.7	103.2
	120	7.0	16.9	14.7	14.1	11.2	36.5	37.6	77.9	82.2	104.1
LSD at 0.1% level		1.82	4.65	2.56	3.10	2.58	NS	5.92	6.79	6.94	7.04

Height usually increased with time and amount of fertilizer. N-forms did not show much variation among themselves to change height and number of tillers.

(b) *Yield of dry matter and grain.*

Evaluation of results showed that nitrogen application significantly increased the yields of straw and grain over control (Table II). The highest yields of both the components were obtained with the application of SCU at the rate 120 kgN/ha. Increase in nitrogen supply generally increased the production of dry matter and grain. The relative efficiency of the N-fertilizers may be arranged as - SCU > Urea > IBDU > UF. The best performance and superiority of SCU might be associated with its slow-release characteristics.

The results demonostrate that SCU was superior to urea while IBDU and UF were inferior to conventional urea. These findings corroborated well with the observations of other investigators[11-14]. Better efficiency of SCU over single or split application of urea in rice production was observed by Sharma[15]. In Peru, Sanchez *et al.*[16] found that under intermittent flooding yield response of rice to SCU was significantly higher than uncoated urea and ammonium sulphate applied at various growth intervals. Under flooding and intermittent flooding conditions SCU resulted about 20%[16] and 15-30%[17] more yield of rice. From USA Wells and Shockley[18] also reported higher yield of rice with slow-release fertilizers (SCU and IBDU) than uncoated urea.

The relative effectiveness of IBDU and UF in straw and grain production was inferior to conventional urea. Hamamoto[19] from Japan, and Gopalswamy *et ai.*[20] and Gaikwad *et al.*[21] from India similarly reported the lower efficiency of UF as compared to urea particularly in rice production.

(c) *Nutrient content.*

N content of both straw and grain was significantly increased by N-fertilization irrespective of the suorces (Table II). N content generally increased with increased supply of nitrogen. The highest contents of N in straw (at harvest) and grain were 0.63 and 1.30% respectively recorded from plots treated with 120 kgN/ha as SCU. Hamissa[22] also reported that rice plant could absorb more nitrogen from SCU and thus considered it as a superior N-carrier than urea and IBDU. In India, Nair and Tomy[13] with transplanted aman rice found that SCU improved the N-use efficiency whereas split application of urea failed to do so.

Content of P in grain was significantly increased by nitrogen application over untreated grain (Table III). Grain nitrogen showed positive relation with quantity of nitrogen supply. P content in straw was only significantly increased upto 30 days of transplantation thereafter no such effect was observed. Contents

TABLE II. INFLUENCE OF N-SOURCES ON DRY MATTER AND GRAIN YIELD OF RICE.

N-source	*N-rate (kg/ha)*	*Dry matter yield (g/5 plant)* 30 days	60 days	at harvest	*Grain yield (t/ha)*	*Source mean (t/ha)*	*Straw yield (t/ha)*	*Source mean (t/ha))*
Control	0	1.9	9.9	14.2	3.88	3.88	4.04	4.04
	40	2.2	13.3	16.2	4.64		4.95	
Urea	80	2.5	14.5	16.4	5.02	4.77	5.48	5.31
	120	2.9	15.5	18.0	4.66		5.50	
	40	2.0	13.0	15.1	4.10		4.53	
UF	80	2.2	13.3	16.2	4.56	4.43	4.87	4.80
	120	2.4	14.7	16.8	4.62		5.01	
	40	2.2	13.3	16.7	4.75		5.02	
SCU	80	2.5	15.5	16.9	5.74	5.57	6.20	5.95
	120	2.8	16.4	18.0	5.92		6.62	
	40	2.1	13.1	15.6	4.24		4.81	
IBDU	80	2.4	14.0	16.2	4.59	4.53	4.97	4.98
	120	2.6	14.8	17.0	4.76		5.17	
LSD at 0.1% level		0.40	1.05	2.63	0.59		0.70	

TABLE III. NUTRIENT CONTENT OF STRAW AND GRAIN AS INFLUENCE BY N-SOURCES.

N-source	N-rate (kg/ha)	Straw						Grain				
		%N			%P			%N	%P	%K	%Ca	%Mg
		30 days	60 days	at harvest	30 days	60 days	at harvest					
Control	0	1.80	1.02	0.37	0.33	0.32	0.17	1.01	0.30	0.32	0.30	0.18
	40	2.26	1.24	0.52	0.35	0.34	0.18	1.12	0.33	0.33	0.30	0.18
Urea	80	2.27	1.25	0.57	0.37	0.35	0.20	1.19	0.35	0.33	0.30	0.18
	120	2.45	1.45	0.58	0.37	0.35	0.21	1.28	0.36	0.36	0.32	0.20
	40	2.16	1.09	0.45	0.34	0.33	0.18	1.10	0.32	0.33	0.30	1.18
UF	80	2.18	1.14	0.49	0.36	0.33	0.19	1.14	0.33	0.33	0.31	0.18
	120	2.26	2.26	0.52	0.36	0.35	0.20	1.28	0.34	0.34	0.30	0.19
	40	2.24	1.27	0.56	0.35	0.33	0.18	1.11	0.33	0.34	0.30	0.20
SCU	80	2.26	1.28	0.60	0.35	0.34	0.20	1.22	1.34	0.34	0.31	0.18
	120	2.36	1.56	0.63	0.38	0.35	0.20	1.30	0.35	0.35	0.32	0.19
	40	2.22	1.18	0.48	0.34	0.34	0.17	1.12	0.31	0.32	0.30	0.18
IBDU	80	2.24	1.27	0.51	0.36	0.34	0.18	1.16	0.33	0.34	0.31	0.19
	120	2.28	1.45	0.59	0.36	0:35	0.18	0.18	0.34	0.34	0.31	0.18
LSD'	at 0.1% level	0.47	0.43	0.10	0.02	NS	NS	0.15	0.06	NS	NS	NS

TAHLE III. CONTINUED

N-source	N-rate (kg/ha)	Straw %K 30 days	Straw %K 60 days	Straw %K at harvest	Straw %Ca 30 days	Straw %Ca 60 days	Straw %Ca at harvest	Straw %Mg 30 days	Straw %Mg 60 days	Straw %Mg at harvest	%N recovery
Control	0	2.65	2.73	1.57	0.56	0.40	0.40	0.24	0.20	0.20	—
	40	2.82	2.77	1.60	0.56	0.42	0.42	0.24	0.20	0.21	59.4
Urea	80	2.87	2.80	1.80	0.58	0.43	0.40	0.24	0.20	0.20	46.0
	120	2.97	2.97	1.87	0.58	0.43	0.42	0.25	0.21	0.21	31.3
	40	2.77	2.77	1.58	0.56	0.42	0.40	0.24	0.20	0.20	28.4
UF	80	2.82	2.80	1.70	0.57	0.43	0.40	0.24	0.21	0.21	27.1
	120	2.85	2.87	1.80	0.57	0.43	0.42	0.24	3.21	0.21	25.9
	40	2.80	2.75	1.70	0.56	0.42	0.40	0.24	0.20	0.20	66.3
SCU	80	2.82	2.87	1.77	0.57	0.44	0.40	0.25	0.22	0.21	66.6
	120	2.95	2.97	1.77	0.58	0.44	0.42	0.25	0.22	0.22	53.7
	40	2.77	2.73	1.62	0.56	0.40	0.40	0.24	0.20	0.20	40.9
IBDU	80	2.83	2.83	1.72	0.56	0.42	0.40	0.24	0.20	0.20	30.5
	120	2.88	2.87	1.75	0.57	0.42	0.41	0.24	0.21	0.20	27.2
LSD at 0.1% level		0.26	NS	NS	NS	NS	NS	NS	NS	NS	

of K, Ca and Mg either in straw or grain were not improved significantly (Table III).

(d) *Nitrogen recovery*

Recovery of applied nitrogen by rice generally decreased with increased rate of supply (Table III). The amount recovered was found to be dependent on source of nitrogen. The range of recovery varied between 25.9 and 66.6% from UF and SCU respectively. Generally highest percentage of nitrogen was removed by rice from SCU followed by urea. The decreasing order of N-recovery of the N-carriers could be arranged as follows on the basis of their mean data.

SCU (62.2%) > urea (45.6%)> IBDU (32.7%)> UF (27.1%) DeDatta *et al.*([23]) reported that with the best agronomic practices, the fertilizer-N recovered

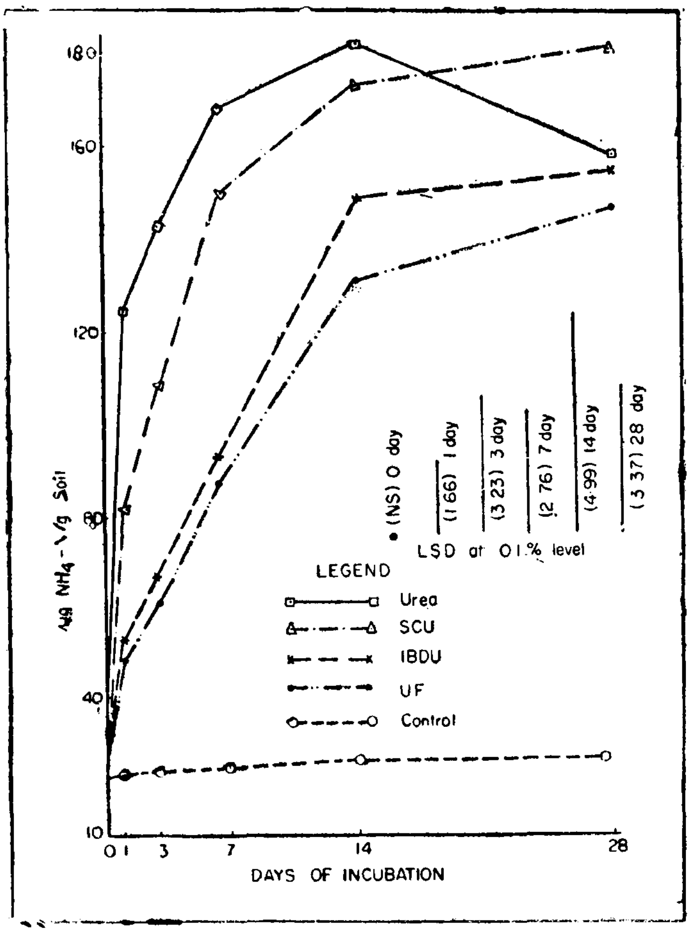

Fig. 1. Release of NH_4-N from different sources of N-carriers during anaerobic incubation of soil.

by the rice crop might be as high as 68%. Hong([24]) also observed that rice plant could recover upto 64% N from SCU with relasing rate of 20%/7 days.

(B) Decomposition of slow-release N-fertilizers

The nature and release of NH_4-N during anaerobic inculation of urea, UF, SCU and IBDU varied significantly (Fig.1) but the trend was more or less similar. Release of NH_4-N from all the compounds increased very rapidly upto 14 days of incubation followed by a gradual increase with time except urea which showed a dedcline. The percentage of HN_4-N released from SCU, IBDU and UF were 77.1, 63.6 and 59.9 after 28 days of incubation. Maximum release from urea was 78.2% observed at 14 days of incubation. Variation in production of NO_3-N from the N-carriers was significant and the values decrased with time. NO_3-N disappered after 14 days from all the compounds except urea which showed trace amount after 28 days of incubation (Fig.2). Accumulation of mineral-N (NH_4-N

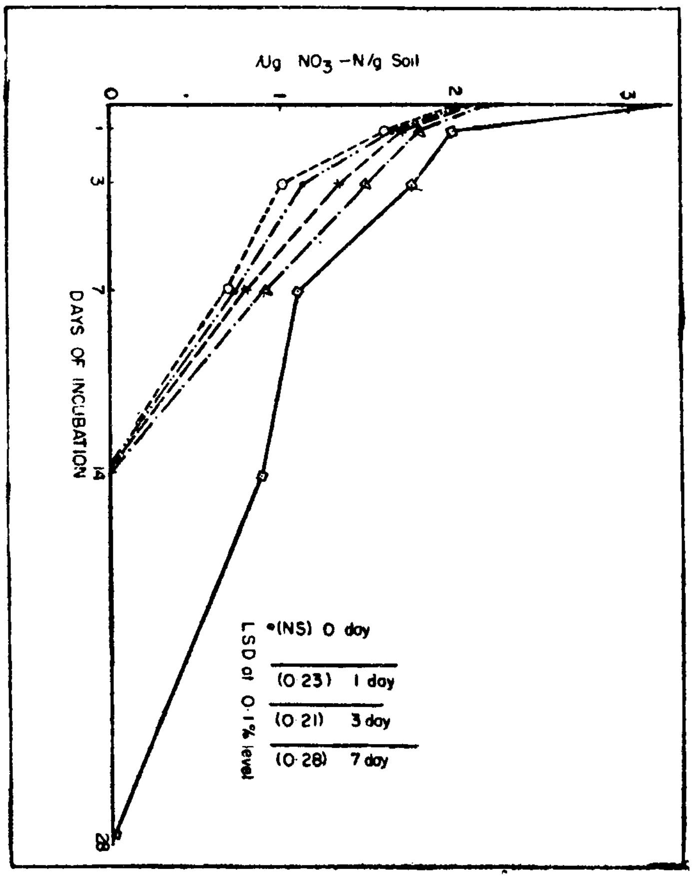

Fig. 2. Release of NO_3-N from different sources of N-carriers during anaerobic incubation of soil. For legend see Fig. 1.

+ NO_3-N) was 183.1 and 181.2 μg/g soil recorded from urea and SCU after 14 and 28 days of incubation respectively. This indicates that slow but continuous release of mineral nitrogen was favourable for crop requirement which was clearly supported by the crop yield data (Table II) of the previous section.

The relalive efficiency of the compounds to release mineral-N showed the following increasing order; UF $<$ IBDU $<$ SCU $<$ urea. Similar results were observed by Islam and Parsons[25]. They found least mineralization of UF as compared to urea, SCU and urea-phosphate under waterlogged condition. Furthermore, Reddy and Prasad[26] and Nair and Sharma[27] recorded that coated fertilizeres generally mineralized at a slower rate than uncoated urea and SCU could retain urea-N in soil even after 4 weeks of incubation.

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Journal of Bangladesh Academy of Sciences, 11(2), 215—226, 1987