Response of rice to different forms of nitrogen fertilizer

D. M. Rodrigo, B. M. Nizar

AND

P. S. G. Perera

Division of Agricultural Chemistry, Central Agricultural Research Institute, Peradeniya,

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INTRODUCTION

The anaerobic environment of flooded rice soils has important consequences on the nutrition of the rice plant. The absence of oxygen in water-logged soils prevents nitrogen mineralization from proceeding beyond the ammonium stage (Ponnamperuma, 1955 ; Rodrigo, 1961, 1962, 1967 ; Thenabadu, 1966 ; International Rice Commission, 1966). The production of ammonium in water-logged soils, in contrast to nitrate in uupland soils, is favourable for rice since the plant readily utilises ammonium nitrogen.

Surface applied nitrogen fertilizers are easily converted to nitrate in the superficial oxidizing layer of the soil and subsequently denitrified on reaching the reduced zone (Rodrigo, 1961, 1962, 1967 ; Matsuo, 1966 ; Thenabadu, 1966 ; Kalpage, 1967 ; Panabokke, 1967 ; Simsiman *et al.*, 1967). Denitrification appears to be universal in flooded rice soils and losses of nitrogen ranging from 20 percent to 50 percent have been recorded (Parsall, 1950 ; Abichandani and Patnaik, 1955 ; Mitsui, 1956 ; Patnalk, 1965). In order to reduce the loss of nitrogen by leaching and to prolong the period of availability of nitrogen for the purpose of ensuring its steady supply according to the needs of the plant, a new type of nitrogen fertilizer, Guanylurea, developed in Japan, with the property of slow and controlled release, appears to be promising (International Rice Commission, 1966).

There are reports that ammonium forms of nitrogen are superior in the early stages of growth of the rice plant but during the later stages nitrate forms appear equally effective (International Rice Commission, 1966). This could be explained by the fact that it is only during the late stages of the vegetative period that horizontal superficial roots or the mat of surface roots are developed. These roots which are functioning in the oxidizing surface layer of the soil

and even protruding to the layer of water above the soil should be able to absorb oxidised radicals, one of which is nitrate. From the above it is apparent the form of nitrogen fertilizer applied to rice is important.

In the United States urea forms of nitrogen are most commonly used for rice while anhydrous ammonia, ammonium sulphate and other forms are used in lesser amounts (International Rice Commission, 1966). In the Philippines ammonium sulphate and ammonium chloride at 40 kg/ha. were equally good for rice in Barrio Lamao, Limay and Bataan, while the plots which received urea did not produce yields higher than the control (International Rice Commission, 1964). In the U. A. R. yields obtained in greenhouse and field experiments using equivalent amounts of different forms of nitrogen fertilizer showed considerable differences in their effectiveness. Ammonium sulphate, aqua ammonia, calcium ammonium nitrate and urea, were about equal in value as sources of nitrogen, while calcium nitrate and calcium cyanamide were less effctive (International Rice Commission, 1964). In the degraded rice soils of Japan which are low in active iron where hydrogen sulphide toxicity is known to occur, ammonium chloride is used instead of ammonium sulphate. In Ceylon, urea performed better than ammonium sulphate in the sandy acid soils low in iron (Jayasekera and Ariyanayagam, 1962).

MATERIALS AND METHODS

Fertilizer trials were conducted in a number of Rice Experiment Stations, Government Farms, and in Cultivators' fields in Polonnaruwa Administrative District, for a number of seasons to test the relative efficiency of six forms of nitrogen, namely, urea, ammonium sulphate, ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate, and ammonium nitrate. The design of the experiment in the Rice Experiment Station and in Government Farms was a randomised block containing seven plots in a block and replicated four times. In Cultivators' Fields too the design was a randomised block with seven plots in a block and each location was considered a replicate. In the Yala (dry) season of 1967 there were six locations and in the Maha (wet) season of 1967/68 there were eight locations.

Total nitrogen, ammonium nitrogen and nitrate nitrogen contents of the six forms of fertilizer tested are given below.

	Total N%	*NH_4-N%*	*No_3-N%*
Urea	46	—	—
Ammonium sulphate	20·6	20·6	—
Ammonium chloride	25	25	—
Ammonium sulphate nitrate	26	19·5	6·5
Calcium ammonium nitrate	20·5	10·25	10·25
Ammonium nitrate	34	17	17

At different sites different quantities of nitrogen applied at different times were tested. However, at each site the response to equal quantities of nitrogen of the six different sources applied at identical times was evaluated.

The treatments at each site indicating the time of application and levels of nitrogen in kg/ha. are shown below.

Rice Experiment Station, Bombuwela

	At planting	*At 3 weeks from planting*	*At 3 weeks before heading*	*At heading*
T1 Control (C)	0	0	0	0
T2 Urea (U)	17	17	34	17
T3 Ammonium sulphate (AS) ..	17	17	34	17
T4 Ammonium chloride (AC) ..	17	17	34	17
T5 Ammonium sulphate nitrate (ASN)	17	17	34	17
T6 Calcium ammonium nitrate (CAN)	17	17	34	17
T7 Ammonium nitrate (AN) ..	17	17	34	17

1 kg/ha = 0.892 lb/acre.

Dressings of phosphorous and potassium were given to all plots including the control.

Phosphorous—At the rate of 189 kg/ha. of saphosphosphate applied at planting.

Potassium—At the rate of 126 kg/ha. of muriate of potash. Half this quantity was applied as a basal dressing ; quarter of it at three weeks from planting and the other quarter at three weeks before heading.

The variety of rice used was H-4.

Government Farms at Karapincha and Wagolla

	At 2 weeks from planting	*At one month before heading*	*At heading*
T1 Control	0	0	0
T2 Urea	17	34	17
T3 Ammonium sulphate	17	34	17
T4 Ammonium chloride	17	34	17
T5 Ammonium sulphate nitrate	17	34	17
T6 Calcium ammonium nitrate	17	34	17
T7 Ammonium nitrate	17	34	17

1 kg/ha. = 0.892 lb/acre

Dressings phosphorous and potassium were given to all plots including the control.

Phosphorous—At the rate of 189 kg/ha. of saphosphosphate applied at planting.

Potassium—At the rate of 95 kg/ha. of muriate of potash. 63 kg/ha. were applied as a basal dressing, and the remaining 32 kg/ha. were applied one month before heading.

At Karapincha the variety used was H-4 in all seasons. At Wagolla the variety H-4 was used in the Yala (dry) season of 1966, Podiwi a-8 in the Maha (wet) season of 1966/67, and H-7 in the Yala (dry) season of 1967.

Seed Paddy Stations at Hingurakgoda and Polonnaruwa, Government Farm at Paranthan, and Cultivators Fields in Polonnaruwa Administrative, District

	At 2 weeks from planting	*At 2 weeks before heading*
T1 Control	0	0
T2 Urea	25	50
T3 Ammonium sulphate	25	50
T4 Ammonium chloride	25	50
T5 Ammonium sulphate nitrate	25	50
T6 Calcium ammonium nitrate	25	50
T7 Ammonium nitrate	25	50

Dressings of phosphorous and potassium were given to all plots including the control.

Phosphorous—At the rate 126 kg/ha. of concentrated superphosphate applied at planting.

Potassium—At the rate of 95 kg/ha. of muriate of potash. 63 kg/ha. were applied as a basal dressing, and the remaining 32 kg/ha. were applied two weeks before heading.

At Hingurakgoda and Polonnaruwa Paddy Stations the variety used was H-4. At Paranthan the variety Pachchaiperumal was used in the Yala (dry) season of 1967 and H-4 was used in the Maha (wet) season of 1967/68. In cultivators' fields in Polonnaruwa, Pachchaiperumal was planted in the Yala (dry) season of 1967 and H-4 was planted in the Maha (wet) season of 1967/68.

RESULTS AND DISCUSSION

Grain yields of paddy (rough rice) in kg/ha. obtained by using the different forms of nitrogen at the respective locations, coefficients of variation and the significant differences at 5 per cent level of significance are given in tables 1 to 7.

Table 1.—Yields of Paddy (Rough Rice) in Kilograms per hectare. At Rice Experiment Station, Bombuwela

Season	*T1 C*	*T2 U*	*T3 AS*	*T4 AC*	*T5 ASN*	*T6 CAN*	*T7 AN*	*Cof. V*	*L.S.D.*
Yala 1966	2406	3072	3859	4318	4000	3945	3027	9.1	474
Maha 1966/67	1584	2442	3062	3380	3087	2790	2603	9.0	363
Yala 1967	1539	2093	2507	2850	2805	2638	2285	9.8	348
Maha 1967/68	964	1599	1801	2391	1680	1902	1564	15.0	378
Mean	1623	2302	2807	3235	2893	2819	2370		

1 kg/ha = 0.0198 Bu/acre or 50 kg/ha approx : equal to 1 Bu/acre.

The above table clearly indicates the necessity for the application of fertilizer nitrogen as all nitrogen treatments were significantly better than the control treament in all seasons. Ammonium chloride performed best in all seasons. In the Yala (dry) season of 1966 there were no significant differences between ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate and ammonium sulphate. Further these four forms of nitrogen were significantly better than urea and ammonium nitrate. There was no significant difference between urea and ammonium nitrate. In the Maha (wet) season of 1966/67 there were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride, ammonium sulphate nitrate and ammonium sulphate, (*b*) ammonium sulphate nitrate, ammonium sulphate and calcium ammonium nitrate, (*c*) calcium ammonium nitrate, ammonium nitrate and urea. In the Yala (dry) season of 1967 there were no significant differences within the following groups, (*a*) ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate and ammonium sulphate, (*b*) ammonium sulphate and ammonium nitrate, (c) ammonium nitrate and urea. In the Maha (wet) season of 1967/68 ammonium chloride was significantly better than all other forms of nitrogen fertilizers. There were no significant differences between the other forms of nitrogen. However the order of merit is as follows :—calcium ammonium nitrate, ammonium sulphate, ammonium sulphate nitrate, urea and ammonium nitrate.

Table 2.—Yields of Paddy (Rough Rice) in Kilograms per hectare At Government Farm Karapincha

Season	*T1 C*	*T2 U*	*T3 AS*	*T7 AC*	*T5 ASN*	*T6 CAN*	*T7 AN*	*Cof. V*	*L.S.D.*
Yala 1966	2860	3360	3415	3617	3455	3597	3294	4·9	247
Maha 1966/97	2880	3496	3587	3849	3577	3652	3425	4·4	227
Yala 1967	3400	3703	3758	3915	3814	3909	3602	3·7	207
Maha 1967/68	2608	3012	3012	3425	3097	3138	2931	5·5	247
Mean	2937	3393	3443	3702	3486	3574	3313		

1 kg/ha = 0·0198 Bu/acre or 50kg/ha approx : equal to 1 Bu/acre.

The need for nitrogen is clearly seen from the above table as all nitrogen treatments are significantly better than the control treatment in all seasons. Ammonium chloride performed best in all seasons. In the Yala (dry) season of 1966 there were no significant differences among the different forms of nitrogen fertilizer as the F value for within nitrogen treatments was not significant. In the Maha (wet) season of 1966/67 there were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride and calcium ammonium nitrate, (*b*) calcium ammonium nitrate, ammonium sulphate, and ammonium sulphate nitrate, (c) ammonium sulphate, ammonium sulphate nitrate, urea and ammonium nitrate. In the Yala (dry) seson of 1967 there were no significant differences within the following groups, (*a*) ammonium chloride, calcium ammonium nitrate, ammonium sulphate nitrate, and ammonium sulphate, (*b*) calcium ammonium nitrate, ammonium sulphate nitrate, ammonium sulphate and urea, (*c*) ammonium sulphate, urea and ammonium nitrate. In the Maha (wet) season of 1967/68 ammonium chloride was significantly better than all other forms of nitrogen fertilizer. There were no significant differences between the other forms of nitrogen fertilizer. However, the order of merit is as follows :— calcium ammonium nitrate, ammonium sulphate nitrate, urea, ammonium sulphate and ammonium nitrate.

Table 3.—Yields of Paddy (Rough Rice) in Kilograms per hectare At Government Farm, Wagolla

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T4* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*Cof. V*	*L.S.D.*
Yala 1966	2820	4121	4308	4434	4247	4212	4278	6·1	368
Maha 1966/67	3334	3799	3698	4046	3894	3889	3622	3·6	197
Yala 1967	3682	4182	4152	4363	4303	4268	4212	3·0	227
Mean	3279	4034	4053	4281	4148	4123	4037		

It is seen from the above table that nitrogen is necessary as all nitrogen treatments were significantly better than the control treatment in all seasons. Ammonium chloride performed best in all seasons. In the Yala (dry) season of 1966 there were no significant differences between the different forms of nitrogen fertilizer. In the Maha (wet) season of 1966/67 there were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride, ammonium sulphate nitrate, and calcium ammonium nitrate (*b*) ammonium sulphate nitrate, calcium ammonium nitrate, urea, and ammonium sulphate, (*c*) urea, ammonium sulphate, and ammonium nitrate. In the Yala (dry) season of 1967 there were no significant differences between the different forms of nitrogen fertilizer.

Table 4.—Yields of Paddy (Rough Rice) in Kilograms per hectare. At Seed Paddy Station, Hingurakgoda.

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T4* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*Cof. V*	*L.S.D.*
Yala 1967	4308	5519	4873	5317	4934	5236	5135	9·7	726

The table indicates the necessity for fertilizer nitrogen as the F value for the control treatment versus the nitrogen treatments was significant. Further there were no significant differences between the different forms of nitrogen fertilizer.

Table 5.—Yields of Paddy (Rough Rice) in Kilograms per hectare At Seed Paddy Station, Polonnaruwa

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T7* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*Cof. V*	*L.S.D.*
Yala 1967	3360	3940	4348	3879	4076	3768	3859	10.2	590
Maha 1967/68	4222	5342	5221	5761	5145	5019	5085	6.2	469
Mean	3791	4641	4785	4820	4611	4394	4472		

The above table reveals the need for nitrogen as the F value for the control treatment versus the nitrogen fertilizer treatments was significant in both seasons. In the Yala (dry) season of 1967 there were no significant differences between the different forms of nitrogen fertilizer. During this season the trial was affected by a severe drought. In the Maha (wet) season of 1967/68 ammonium chloride performed best and the others performed in the following order of merit ; urea, ammonium sulphate, ammonium sulphate nitrate, ammonium nitrate, and calcium ammonium nitrate. There were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride and urea, (*b*) urea, ammonium sulphate, ammonium sulphate nitrate, ammonium nitrate, and calcium ammonium nitrate.

Table 6.—YieldsofPaddy (Rough Rice) in Kilograms per hectare At Government Farm, Paranthan

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T7* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*Cof. V*	*L.S.D.*
Yala 1967	1624	2875	2658	2966	2679	2457	2522	6.8	257
Maha 1967/68	1448	2653	2517	2830	2714	2391	2164	5.3	192
Mean	1536	2764	2588	2898	2697	2424	2343		

The need for nitrogen is clearly seen from the above table as all nitrogen treatments were significantly better than the control treatment during both seasons. In the Yala (dry) season of 1967 ammonium chloride performed best and then came the following in order of merit, urea, ammonium sulphate nitrate, ammonium sulphate, ammonium nitrate, and calcium ammonium nitrate. There were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride and urea, (*b*) urea, ammonium sulphate nitrate, and ammonium sulphate, (*c*) ammonium sulphate nitrate, ammonium sulphate, and ammonium nitrate (*d*) ammonium sulphate, ammonium nitrate, and calcium ammonium nitrate. In the Maha (wet) season of 1967/68 ammonium chloride performed best. The following is the order of merit of the other fertilizers, ammonium sulphate nitrate, urea.

ammonium sulphate, calcium ammonium nitrate, and ammonium nitrate. There were no significant differences within the following groups, (*a*) ammonium chloride, ammonium sulphate nitrate, and urea, (b) urea and ammonium sulphate, (*c*) ammonium sulphate and calcium ammonium nitrate.

Table 7.—Yields of Paddy (Rough Rice, in Kilograms per hectare In Cultivators Fields in Polonnaruwa Administrative District

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T4* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*Cof V*	*L.S.D.*
Yala 1967 Mean of 6 Locations	3723..	4626..	4812..	4868..	4767..	4712..	4273..	7·7..	409
Maha 1967/68 mean of 8 Locations	3698..	4333..	4394..	4611..	4298..	4348..	4142..	7·4..	318
Mean ..	3711..	4480..	4603..	4740..	4533..	4530..	4208		

The above table indicates the need for nitrogen as all nitrogen treatments were sngnificantly better than the control treatment in both seasons. There were no significant differences between the different forms of nitrogen fertilizer as the F value for within the different forms of nitrogen treatments was not significant in both seasons. However, during both seasons ammonium chloride performed best and ammonium nitrate was the worst.

From the above-mentioned data and inferences drawn from them two definite conclusions could be made. They are :—

1. The application of fertilizer nitrogen in whatever form gave significant and remunerative yield responses.
2. Ammonium chloride performed best in all locations in all seasons except at Hingurakgoda Farm. At Hingurakgoda Farm urea performed best and then came ammonium chloride. However, the trial was conducted only in one season at this farm and furthermore there were no statistical significant differences between the different forms of nitrogen fertilizer.

From these field trials no reasons could be adduced for the better performance of ammonium chloride. Nevertheless, its superiority over the other forms of nitrogen fertilizer has been attributed to the following characteristics.

1. Ammonium chloride inhibits the growth of nitrifying soil bacteria, nitrosomonas and nitrobacter. Nitrification is therefore retarded, consequent to which denitrification and loss of nitrogen is lessened (Okuda and Takahashi, 1966).

2. Cholorine is an effective trace element in strengthening the stems and roots of plants (Goto, 1968 ; Okuda, 1959, 1960).

3. Chlorine improves the ripening of rice (Honya, 1966 ; Okuda *et al.*, 1965).

4. Chlorine imparts extra resistance to disease (Honya, 1966).

5. Ammonium chloride shortens the internodal lengths at the lower parts of the plant (Omura, 1968 ; Kishida, 1968 ; Sato, 1968).

6. There is no danger of incipient hydrogen sulphide toxicity as ammonium chloride contains no sulphur (Mitsui *et al.*, 1951).

SUMMARY

Fertilizer trials were conducted in a number of Rice Experiment Stations, Government Farms and in Cultivators' Fields in one Administrative District for a number of seasons to test the relative efficiency of six forms of nitrogen fertilizer, namely, urea, ammonium sulphate, ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate, and ammonium nitrate. At each location the response to equal quantities of nitrogen of the six different forms of fertilizer applied at identical times was evaluated. Dressings of phospharus and potassium fertilizers were given to all plots including the control.

From these trials two definite conclusions could be inferred. They are :—

1. The application of fertilizer nitrogen in whatever form gave significant and remunerative yield responses.

2. Ammonium chloride performed best in all locations in all seasons except at Hingurakgoda Farm where the trial was conducted only one season when there were no significant differences between the different form of nitrogen fertilizer.

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