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Band placement of urea solution : a new technique to increase urea-N efficiency in transplanted rice (*Oryza sativa*)

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ABSTRACT

Alternative strategies studied for N fertiliser management to increase the N-use efficiency in lowland rice (*Oryza sativa* L.) were studied in 1993-94. The field experiment was conducted to evaluate the band placement of urea solution in comparison with the application of prilled urea (PU) and neem-coated urea (NCU) and the point placement of urea supergranules (USG). Grain yield and N-use efficiency were higher for band placement of urea solution at both 50 and 100 kg N/ha levels compared with the conventional split application of PU at 100 kg N/ha. A total ^{15}N recovery of 58.66% and 51.65% was recorded for the treatment with band placement of urea solution at 50 and 100 kg N/ha level respectively compared with 47.78% for NCU and 28.53% for conventional split application as PU.

Key words : Band placement, ^{15}N recovery, N-use efficiency, Neem-coated urea, Urea supergranules

Urea is the dominant nitrogen fertiliser for rice in Asia, where more than 90% of the world's rice cultivation (De Datta, 1981) is concentrated. High losses of N occur when urea (or other N fertilisers) is applied to flooded soils. Research on deep placement (DP) of fertilisers has demonstrated that fertiliser-use efficiency in lowland rice production could be significantly increased by placing fertiliser in the reduced soil layer at depths ranging from 5 to 15 cm (Obcemea *et al.*, 1984). In spite of more than 40 years of research in deep placement of fertilisers, it has not been possible to transfer these research findings to the farm level, since fertiliser materials like urea briquettes or urea supergranules (USG) are not easily available and are perhaps more expensive to purshase. Schnier *et al.*, (1988) developed a band placement concept in which liquid urea solution (prilled urea dissolved in water) is band placed 5-6 cm deep in the soil. Their results showed that band placement significantly increased the nitrogen-use-efficiency (NUE) and rice

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yield and was comparable with the USG point placement.

The present study was carried out using the newly developed urea-solution applicator to compare and evaluate the different methods of application of fertiliser N in rice, to investigate the N uptake over time, work out the NUE of the applied fertiliser, estimate the recovery and retention of fertiliser N and to study the effect of fertiliser application on grain yield.

MATERIALS AND METHODS

During 1993–94, field experiments were conducted at Agricultural Research Station, Aliyarnagar in Tamil Nadu. The station is geographically located at 10°39'N latitude and 77°0'5'E longitude at an altitude of 260 m above mean sea-level. The experimental soil had pH 7.4, 25 g organic C/kg, 2.3 g total N/kg, CEC 10.15 cmol/kg and 17 g clay/kg. The experimental design was randomised complete block with 11 treatments and three replications for experiment I (in June-September with 'IR 50' and October to January with 'ADT 36' as test varieties), and with five treatments and four replications (as confirmatory experiment with 'IR 50' as test variety using radioisotope ^{15}N) for experiment II. Land preparation and other cultural operations excluding treatments were done as per the standard recommendations. The urea solution was applied through the IRRI model urea solution applicator, which is a push-type simple machine with a peristaltic pump assembly for uniform discharge of the solution in the soil. The operator mounts the urea solution (PU dissolved in water) and operates the machine. The implement covers 4 plant rows in a single pass and delivers the urea solution in the form of band at about 7.5 cm depth in the soil.

For experiment II, to meet the required precision for the use of ^{15}N in band placement, the solution was injected as band with the help of specially made syringe (a plastic syringe with a hard mouth tube injects solution 7.5 cm deep as band when dragged continuously) in the microplots and the unlabelled urea solution was applied with the help of the mechanical applicator in the main plots. Flood-water depth was maintained near 5 cm and irrigation was withdrawn 20 days prior to harvest.

The total N in plant samples at different growth stages was analysed by Kjeldhal's method (Bremner, 1995). The content was multiplied by the respective dry-matter yield to arrive at the N uptake. The ^{15}N Nanalysis was taken up as per the pocedures suggested by Buresh *et al.* (1982). At harvest the grain and straw were weighed, dried and the grain weight was expressed at 14% moisture.

RESULTS AND DISCUSSION

Experiment I

Nitrogen-use efficiency

The NUE as estimated by Agronomic efficiency (AE) and Apparent recovery (AR) was favourably influenced by band placement of urea solution. Agronomic efficiency indicates the quantity of rice grain produced per unit quantity of N applied and is the product of efficiency of absorption and utilization. Band placement

of urea solution at 50 kg N/ha resulted in higher AE of 30 and 59 kg grain/kg N in 'IR 50' and 'ADT 36' respectively (Table 1). Band placement of N in the reduced zone of the soil decreased the losses of N, leading to efficient uptake and utilization of applied N. The rate of N release in these treatments also probably matched well with the N requirement of rice, enabling the realisation of higher grain yield as a result of greater efficiency (Schnier *et al.*, 1990).

Apparent recovery, which indicates the absorption efficiency of applied N, was higher with the band placement of urea solution treatment. As in AE, AR also was higher with lower levels of N. Better availability of N and reduced N losses increased the AR. The conventional method of fertiliser application would increase the losses and reduce the recovery of N, because of higher rates of ammonia volatilization and denitrification (Schner *et al.*, 1988). The curvilinear response of deep-placed N compared with split applied PU, especially at lower rates, was reported by Savant and Stangel (1990) for USG application. This resulted in considerable saving of fertiliser urea compared with PU broadcast method.

Grain yield

Perusal of grain-yield data (Table 1) suggested that band placement of urea solution and application of USG and NCU increased the grain yield compared with PU broadcast. Production of more number of panicles/m^2 contributed to the increase in grain yield. Schnier *et al.* (1988) reported reduced N losses with the band placement of urea solution, which also led to development of a thick root mat. This probably improved the nutrient uptake, resulting in increased yield-contributing factors and grain yield. Production of more number of panicles/m^2 together with the significant reduction in number of immature grains/panicle contributed to the increased yield. A comparison of yield data of 'IR 50' and 'ADT 36' showed that the latter yielded higher than the former variety and the yield increase could be attributed to favourable weather factors for 'ADT 36', particularly the optimum temperature (around 35°C) that prevailed during the ripening period. The grain-yield increase with band placement of urea solution in 2 splits at 50 kg N/ha, which was on a par with 100 kg N/ha, was 10.26 and 25.45% more than that obtained with conventional 3 split applications of PU in 'IR 50' and 'ADT 36' experiments respectively.

Experiment II

^{15}N recovery

The ^{15}N study clearly brought out that broadcast PU was subjected to various losses and only 5% of ^{15}N was recovered from plant 20 DAT (Fig. 1). Band placement of 1/3 fertiliser N 15 DAT registered higher ^{15}N recovery and the efficiency was higher at 50 kg N/ha than at 100 kg N/ha. Though there was higher level of available N at this stage in 100 kg N/ha band placement, all this N may not be fully utilised by the crop, as it would not have developed an adequate root system in the soil to utilise fully the available soil N. Also, when $NH4^+$-N is available in high

Table 1. Effect of treatments on number of panicles/m², yield and NUE in rice

Treatment (N, kg/ha)	No. of panicles/m²		Yield (t/ha)				NUE			
			Grain		Straw		AE		AR	
	'IR 50'	'Adt 36'	'IR 50'	'ADT 36'	'IR 50'	'ADT 36'	'IR 50'	'ADT 36'	'IR 50'	'ADT 36'
No N	460	420	3.55	3.83	3.75	4.66	-	-	-	-
BC 100 (RS)	510	435	4.58	5.41	4.58	5.61	10.25	15.78	18.25	22.80
BC 100 (LS)	555	490	4.70	5.53	4.77	6.80	11.50	16.95	21.83	26.34
BP 50 (4)	540	515	4.67	5.59	4.81	6.68	22.32	35.12	40.28	49.80
BP 100 (4)	560	555	4.70	5.66	5.07	6.91	11.50	18.23	22.95	29.35
BP 50 (3)	590	580	5.00	5.95	5.21	7.24	29.00	42.30	54.10	66.82
BP 100 (3)	600	575	5.15	6.11	5.27	7.88	16.00	22.73	30.09	36.37
BP 50 (2)	600	603	5.05	6.79	6.08	8.30	30.00	59.10	62.08	95.20
BP 100 (2)	615	625	5.18	7.07	6.22	8.42	16.25	32.40	35.30	55.85
USG (100)	565	550	4.90	6.58	5.18	7.50	13.50	27.45	25.75	42.87
BC 100 (NCU)	555	495	4.78	6.57	4.96	7.98	12.25	27.30	22.47	40.94
CD (P = 0.05)	12	29	0.33	0.73	0.29	0.86				

BC=Broadcast; BP=band placement; RS=Researcher's split (50% N basal +25% at active tillering + 25% at panicle-initiation stages)
LS=Late split (25% N each at basal, active tillering, panicle initiation and leading stages); NCU=neem-coated urea
Numbers in parentheses indicate the number of band applications of urea solution

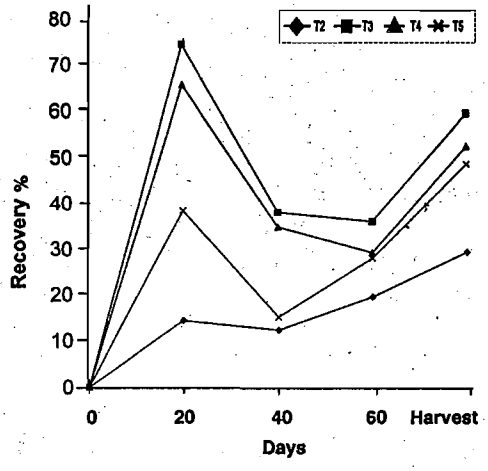

Fig. 1. Total ^{15}N recovery in rice 'IR 50'

quantities, the roots would tend to absorb less $NH4^+$-N, resulting in less absorption, as reported by Savant and De Datta (1982). This clearly indicates that N management should be designed at this stage to reduce the basal applied PU and to ensure steady availability of N through band placement of N.

The crop received the entire quantity of N by 35 DAT and the effect of the application was much reflected in the observation at 60 DAT, when higher plant recovery was obtained for band placement of urea solution. It indicated that 2/3 band placement of N 35 DAT was more effective, as it coincided with the peak requirement of N just before panicle initiation (PI) stage of the crop. This also indicated that fertilisation should be completed before PI for higher yield and recovery, as reported by Schnier *et al.*, (1988). Band placement of urea solution registered higher recovery of ^{15}N in grain and straw and also in total plant tissue, compared with the application of NCU or PU. Its band placement at 50 kg N/ha recorded low retention of ^{15}N compared with the same treatment with 100 kg N/ha and NCU. Higher uptake and less losses of N due to band placement of urea solution could be the reasons for higher recovery and low retention of ^{15}N.

The ^{15}N balance at harvest stage indicates that band placement of urea solution at 50 kg N/ha recorded a total ^{15}N recovery of 58.66% with a crop recovery of 53.18%. The same treatment at 100 kg N/ha recorded a total ^{15}N recovery of 51.65% and a crop recovery of 42.75%. The split application of PU is subjected to many

Table 2. Effect of treatments on number of panicles/m^2, yield and NUE in rice 'IR 50' (Experiment II)

Treatment (N, kg/ha)	No. of panicles/m^2	Yield (t/ha)		NUE	
		Grain	Straw	AE (kg/ka)	AR (%)
T_1 No N	400	3.86	5.18	-	-
T_2 BC 100 (RS)	500	5.92	6.27	20.64	28.74
T_3 BC 50 (3)	650	6.40	6.98	50.88	70.02
T_4 BP 100 (2)	600	6.88	7.51	30.24	44.42
T_5 BP 100 (NCU)	550	6.21	6.39	23.54	32.89
CD (P = 0.05)	131	0.37	0.47		

losses, as 71.47% was recorded for unaccounted quantity as losses of N in this treatment. Low ammonia volatilization, presence of higher quantity of ammonium in exchangeable form and reduced losses due to nitrification-denitrification all increased the uptake of N by the plant in band placement (Schnier *et al.*, 1988, 1990). The same trend was also reflected in NUE (Table 2).

Grain yield

Band placement of urea solution gave significantly higher grain yield than the researcher's split. Both the researcher's split and NCU gave 1.76 and 2.36 more t/ grain/ha over the (no N) control. The band-placement method increased the grain yield by 3.02 and 2.54 t/ha for 100 and 50 kg N/ ha respectively over the control. Higher availability and reduced losses of N under band placement of urea solution led to improved growth and yield components, ultimately resulting in higher yield.

The study evaluated alternative technology for improved practices in increasing the NUE in lowland rice. The band placement of urea solution at 7.5 cm depth with the newly designed urea-solution applicator was an effective management practice for minimising the N losses, thus increasing the fertiliser NUE. Grain yield, recovery of fertiliser N and agronomic efficiency were significantly higher for the band placement of urea solution than those for PU broadcast by researcher's split. Further, this technology at 50 kg N/ha offers reduction of the N dose needed for the crop compared with researcher's split and gave significantly higher yield than the grain yield obtained by researcher's split (50% N as basal +25% AT + 25% at PI stages).

It was concluded that band placement of urea solution is an alternative fertiliser-management practice, where the N losses are minimised and the environment is protected from pollution like ammonia volatilisation, nitrate leaching and denitrification..

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