Published November, 1968

# Influence of Placement on Uptake of Tagged Nitrogen by Rice[1]

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### ABSTRACT

**The placement of two N-15 tagged fertilizer sources applied to lowland rice was studied to determine the effects on yield components, fertilizer N uptake and the residual N present after cropping. Tiller number and bearing tillers were increased by fertilization, but the source and placement had no effect. Grain yield was increased by N fertilization with ammonium sulfate and urea but was not affected by source. Broadcast applications gave lower yields than other treatments while the highest yields were obtained with half the N placed in the soil and the balance top-dressed. Fertilizer N in the Y-leaf and total plant uptake showed the superiority of banding with variations in total N uptake varying from 26 to 47%. Ammonium sulfate provided a larger increment of N to grain production than urea and also showed a lower magnitude of N loss from the soil-plant system.**


***Additional index words:*** **banded, broadcast, ammonium sulfate, urea.**

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THE nitrogen fertilization of flooded rice requires different management than upland crops because of the unique physio-chemical and biological properties of submerged soils. Flooded soils are known to develop two distinct layers after submergence, a surface oxidizing layer only a few millimeters thick and a deep subsurface layer which is in a chemically reduced state (11, 13). These layers with different oxidation-reduction potentials exert a great influence on the processes of N transformation and plant availability. Ammonium-form N fertilizers applied to the surface-oxidized layers will undergo nitrification and become partially subject to losses as leaching occurs and denitrification products develop in the underlying reduced substratum. Ammonium-form N fertilizer properly placed in the reduced layer, however, is not subject to nitrification and remains chemically unaltered as an effective source of N for flooded rice.

Source of N, time and method of application are important factors affecting the efficiency of fertilizer utilization by flooded rice. The superiority of the ammoniacal N sources over other N forms for flooded rice is widely recognized (3). The most effective time and method of N application, however, are not generally agreed upon. Since rice is grown by several methods, N fertilizer management must bring into consideration differences in varietal behavior, climatic conditions, soil characteristics and management practices. Surface application of N to flooded rice is associated with high denitrification losses. Mitsui (9) reports losses from surface applied ammonium N in Japan ranging from 30 to 50% as compared with deep placement, and in India Abichandani and Patnaik (2) observed losses from 20 to 40% for the same treatment comparisons. Losses due to leaching of nitrate and ammonium N occur on sandy loam soils planted to rice, but this type of loss seldom occurs since rice is most often grown on impervious clay soils. Under highly alkaline soils some volatilization losses have been measured. Gupta (5) showed a loss of nearly 22% of the N applied in 5cm (2 inches) of water on certain alkaline soils of West Bengal.

Losses of N from flooded rice soils can be minimized by deep placement of ammonium-form N either before planting or by incorporation into the soil after planting. In Asia, placement 5 to 10 cm deep between the rows of transplanted rice has proven about 2.5 times more effective than surface applications (1, 2, 12). Incorporation of broadcast ammoniacal fertilizers in Japan has increased availability of N by 30 to 50% over unincorporated broadcast applications (9, 13). Mikkelsen and Finfrock (8) reported that N incorporated 5 to 10 cm (2 to 4 inches) deep in dry soil prior to flooding increased plant recovery of N about 20% and increased yields over broadcast treatment by 25 to 35%. Miears and Patrick (7) have also shown that the most efficient uptake of N and optimum rice yields were obtained when N was placed 12 cm (6 inches deep. Split application of fertilizer N, with part applied as a basal sub-surface application and the balance as surface top-dressed N, is often used in rice culture. Difficulties in determining the seasonal N needs of the rice crop and the desire of some growers to regulate plant growth through manipulation of N fertility makes top-dressing a common practice. However, many experimental data show that top dressings are often uneconomical, should be used only as remedial treatment, and should not replace an adequate amount of N placed in the soil as a basal application.

The efficiency of recovery of applied N is most accurately determined with labelled N sources, but only a few experiments of this type have been conducted with flooded rice. Results of the N placement and time of application studies at 16 locations coordinated by the FAO/International Atomic Energy Division (4) using N-15 labelled fertilizer show that placement at 5 cm gave a marked increase in fertilizer recovery over surface-applied N. Losses of 10 to 60% of applied surface N have been observed depending upon soil type, pH, and the oxidation-reduction potentials of the soils. At 13 of 16 locations where top-dressed N was applied, N recovery was most effective during a period up to 2 weeks before primordial initiation. Average recovery of N was 35.1% when applications were made 2 weeks before primodial initiation and only 19.6% when broadcast on the soil surface at the time of transplanting rice. Patnaik and Broadbent (10) top-dressed labelled ammonium sulfate at different stages of rice plant development and determined that highest N recovery and grain yield were obtained when the application was delayed until the boot stage of rice. Recovery of fertilizer N was 51% at the boot stage as compared with 37% recovery when all the N was placed in the soil at the time of transplanting. Results obtained at the International Rice Research Institute (6) show that the efficiency of N utilization from complete N incorporation, 10-cm-deep ball placement, and half-incorporated and half-top-dressed at panicle initiation gave 29, 20, and 16% N recovery in the grain respectively and 23, 16, and 14% recovery in the harvested straw. The two labelled N sources used showed no differences in their effects on yield, but the percentage of plant utilization of ammonium sulfate was higher than that of urea.

## EXPERIMENTAL PROCEDURE

Sacramento clay soil, pH 6.8 (1:1 ratio) was collected from the surface 15-20 cm of a field which had previously been under rice cultivation. This was dried, screened, and 4-kg lots were weighed into glazed greenhouse pots. Solutions of $N^{15}$ tagged ammonium sulfate and urea containing the requisite quantity of N were prepared and samples for addition to each individual pot were obtained by pipetting an aliquot of the fertilizer solution onto a 20-g sample of quartz sand which was wetted uniformly and then dried in an oven. The dry sand with adhering solid fertilizer was then used for the following placements:

1. Broadcast on the surface. Some fertilizer passed between the dry soil particles to a depth of about 2 cm.
2. Banded by placing the entire 20-g sample in a small circle of 8 cm diameter at a depth of 10 cm.
3. Top dressed by distributing uniformly over the surface of the soil and then incorporating by mixing to a depth of 2 or 3 cm. Subsequent top-dressings were made into the water covering the soil to a depth of 4-6 cm.
4. A split application involving half the total quantity banded at the time of planting and the other half top-dressed 47 days after planting.

Fertilizer was added at two levels, nominally 120 and 240 mg N/pot.

Immediately after application of the fertilizer, the pots were flooded with water to a depth of about 8 cm. Rice seedlings (*Oryza sativa*, var. 'Calrose') selected for uniformity were planted and subsequently these were thinned to 10 rice plants per pot.

At 47 days after planting the most recently matured apical leaves (Y-leaf with auricles and ligules visible) were sampled from plants in each pot. The leaves from all plants in a given pot were composited, dried, ground, and analyzed for total N. Fertilizer N in the plants was determined by mass spectrometer analysis of the N in the leaves.

Harvest was made when the grain was fully mature and the average seed moisture percentage 18 to 20%. Plants were fully matured as evidenced by senescence and general yellowing. The number of tillers and panicles were counted in each pot, the grain harvested separately, and the plants cut off as near the soil surface as possible. The vegetative material was dried, ground, and analyzed as before. The grain was weighed and analyzed separately. $N^{15}$ was determined in grain and vegetative material.

Soil in the pots was allowed to dry out following harvest of the rice. It was removed from the pots, mixed thoroughly, and a 50 g sample taken for total N analysis. The soil was then replaced in the pots and a crop of sudan grass (*Sorghum vulgare*, var. 'Piper') planted to measure the value of residual fertilizer N. The sudan grass was cut just prior to heading, dried, weighed, and analyzed for total N and $N^{15}$.

## RESULTS AND DISCUSSION

### Yield and Yield Components

Table 1 gives rice yield and yield components as affected by kind, amount, and placement of fertilizer N. The number of tillers per pot was significantly increased by the addition of fertilizer and was also influenced by the quantity of fertilizer, but the kind of fertilizer applied had no effect. The differences among the various placements were not significant. The number of bearing panicles was significantly affected by both kind and amount of fertilizer, but again, placement had no significant influence. The number of producing panicles is roughly correlated with number of tillers. The yield of grain was significantly affected by the amount of fertilizer and ammonium sulfate produced more grain than urea. With respect to placement, the broadcast application gave significantly lower grain yields than the other types of placement, which did not differ from each other except for the split application where ammonium sulfate was banded followed by top dressing. This treatment was superior to the other methods of placement in terms of grain yield. The effect of fertilizer on grain yield was through the interaction of panicle number and panicle weight. Total dry matter production was substantially increased by all treatments. Ammonium sulfate at both levels produced more dry matter than the correspoding levels of urea. The influence of placement on dry matter production was barely significant.

**Table 1. Rice yield components as affected by kind, amount, and placement of fertilizer N.**

| Fertilizer | Mg N applied | Placement | No. tillers | No. panicles | Grain wt, g | Total dry matter, g |
|---|---|---|---|---|---|---|
| None | 0 | | 19 | 10 | 15.9 | 32.9 |
| $(NH_4)_2SO_4$ | 124 | Broadcast | 24 | 14 | 19.8 | 44.1 |
| | 124 | Banded | 27 | 13 | 21.6 | 44.4 |
| | 124 | Top-dressed | 25 | 12 | 20.2 | 44.1 |
| | 125 | Banded + T-D* | 27 | 16 | 25.0 | 44.8 |
| | 125 | T-D + T-D | 23 | 14 | 22.7 | 47.8 |
| $(NH_4)_2SO_4$ | 247 | Broadcast | 34 | 16 | 25.8 | 56.9 |
| | 247 | Banded | 32 | 16 | 28.0 | 60.6 |
| | 247 | Top-dressed | 34 | 16 | 24.8 | 54.1 |
| | 248 | Banded + T-D | 34 | 18 | 30.3 | 63.6 |
| | 250 | T-D + T-D | 30 | 17 | 27.2 | 57.8 |
| Urea | 105 | Broadcast | 25 | 11 | 17.8 | 37.8 |
| | 105 | Banded | 28 | 13 | 20.9 | 44.3 |
| | 105 | Top-dressed | 25 | 14 | 20.7 | 43.5 |
| | 124 | Banded + T-D | 23 | 12 | 20.8 | 43.3 |
| | 124 | T-D + T-D | 25 | 13 | 20.6 | 42.1 |
| Urea | 269 | Broadcast | 29 | 14 | 22.1 | 49.9 |
| | 269 | Banded | 33 | 16 | 25.8 | 55.2 |
| | 269 | Top-dressed | 33 | 15 | 25.0 | 54.5 |
| | 239 | Banded + T-D | 28 | 16 | 24.6 | 51.1 |
| | 243 | T-D + T-D | 30 | 18 | 27.7 | 57.4 |
| Fertilizer variable | | | | F value | | |
| | | Kind | 1.21 | 5.79* | 9.03 | 17.0** |
| | | Amount | 55.9** | 47.4** | 199.2** | 174.0** |
| | | Placement | 1.28 | 2.20 | 9.94** | 2.73* |

*T-D = Top-dressed.

## Nitrogen Uptake

In Table 2 are shown data indicating uptake of soil and fertilizer N by the rice plants. The N content of the y-leaf (most recently matured leaf on the rice culm) during the active period of tiller formation gives an excellent representation of the N status of the rice plant and is positively correlated with yield.[3]

Analysis of the leaves at 47 days showed a striking advantage of the banded application over the other placements in terms of the percentage N in the leaves derived from fertilizer. It may be noted that data for the two split applications are not comparable with the other three methods of placement because at the time of leaf sampling the second half of the split application had not been made. However, in the split application where the first half was banded, N uptake from the fertilizer was almost as good as in the broadcast and top-dressed treatments where the N level was twice as high.

Total N uptake was significantly increased by the application of fertilizer at all levels, as expected, but placement differences were not significant. Gross recoveries of fertilizer N, when calculated in the conventional way,

$$\%\ \text{uptake} = \frac{(\text{N in treated pots} - \text{N in control pots})}{\text{fertilizer N applied}} \times 100$$

ranged from 46 to 70%. While these data were obtained in a pot experiment, they are quite comparable to the field data of Fried (4).

Total plant uptake of fertilizer N based on tracer N in the plant showed that somewhat more N was

[3] Thenabadu, M. W. 1966. The nitrogen nutrition of *Oryza sativa* and its status as evaluated by plant analysis. Ph.D. Thesis, University of California, Davis.

**Table 2. Uptake of N by rice plants as influenced by kind, amount, and placement of fertilizer N.**

| Fertilizer | Mg N applied | Placement | % N in leaves from fert. at 47 days | Total N uptake, mg/pot | Gross fert. recovery, % | Fert. N uptake, mg/pot | Recovery of applied N, % | % applied fert. in grain | Soil N uptake, mg/pot |
|---|---|---|---|---|---|---|---|---|---|
| None | 0 | | - | 208 | - | - | - | - | 208 |
| $(NH_4)_2SO_4$ | 124 | Broadcast | 24.8 | 275 | 54 | 35.7 | 29 | 14.5 | 239 |
| | 124 | Banded | 41.6 | 276 | 57 | 49.6 | 40 | 20.6 | 229 |
| | 124 | Top-dressed | 23.1 | 278 | 56 | 36.0 | 29 | 14.9 | 241 |
| | 125 | Banded + T-D* | 20.2 | 294 | 68 | 48.7 | 39 | 21.8 | 244 |
| | 125 | T-D + T-D | 12.4 | 289 | 65 | 45.7 | 36 | 21.6 | 243 |
| $(NH_4)_2SO_4$ | 247 | Broadcast | 42.8 | 394 | 57 | 85.0 | 34 | 17.8 | 263 |
| | 247 | Banded | 56.5 | 378 | 68 | 110 | 44 | 22.8 | 267 |
| | 247 | Top-dressed | 39.9 | 333 | 51 | 80.8 | 33 | 17.2 | 252 |
| | 248 | Banded + T-D | 35.9 | 388 | 72 | 117 | 47 | 28.5 | 271 |
| | 250 | T-D + T-D | 21.7 | 348 | 56 | 100 | 40 | 25.3 | 248 |
| Urea | 105 | Broadcast | 21.8 | 262 | 51 | 28.3 | 26 | 13.3 | 234 |
| | 105 | Banded | 28.6 | 283 | 70 | 38.8 | 37 | 18.4 | 243 |
| | 105 | Top-dressed | 19.9 | 278 | 66 | 32.5 | 28 | 15.9 | 247 |
| | 124 | Banded + T-D | 20.0 | 265 | 47 | 41.0 | 33 | 22.5 | 225 |
| | 124 | T-D + T-D | 18.4 | 264 | 46 | 39.2 | 32 | 18.4 | 226 |
| Urea | 269 | Broadcast | 41.8 | 315 | 40 | 74.2 | 27 | 14.1 | 241 |
| | 269 | Banded | 49.0 | 339 | 49 | 98.9 | 37 | 19.6 | 241 |
| | 269 | Top-dressed | 37.4 | 349 | 53 | 76.5 | 28 | 15.2 | 273 |
| | 239 | Banded + T-D | 27.4 | 355 | 55 | 97.9 | 38 | 24.8 | 249 |
| | 243 | T-D + T-D | 15.8 | 357 | 61 | 80.0 | 33 | 21.0 | 277 |
| | | Fertilizer variable | | | F value | | | | |
| | | Kind | 29.0** | 4.31* | | 58.6** | 30.9** | | |
| | | Amount | 344.3** | 231.3** | | 1,578. ** | 37.8** | | |
| | | Placement | 139. ** | 2.13 | | 42.0** | 81.1** | | |

* T-D = Top-dressed.

utilized from the ammonium sulfate treatments than from the corresponding levels of urea. Moreover, placement differences were highly significant. In general, it can be said that the broadcast and top-dressed treatments were somewhat poorer than the other forms of placement. The split application involving two top-dressings was not as good as the two placements in which banding was utilized. There was a significant interaction between fertilizer, both kind and amount, and placement.

Actual uptake of fertilizer N, based on the isotope data, ranged from 26 to 47%. These data confirm the value of the banded and split applications. Top-dressed N applied 47 days after planting was effectively utilized since the plants had developed an extensive root system. At about the time of maximum tillering there occurs extensive development of superficial "water roots" which permeate the surface 10 cm of soil and readily intercept available N applied as a top-dressing into the flood water.

An important practical consideration is the proportion of a fertilizer application which is actually used for the production of grain. These data (Table 2) indicate that ammonium sulfate was superior to urea in this regard at the higher level of application and that the most effective placement from the standpoint of N in the grain was the split application of banding followed by top-dressing. The broadcast application and the top-dressing alone were quite inferior in this respect.

The influence of fertilizer N on the release of soil N is clearly shown in the last column of Table 2. The average uptake of soil N in all placements of ammonium sulfate at the lower level was 239 mg N/pot, an increase of 31 mg over the control. At the higher level of ammonium sulfate the increase was 52 mg/pot. Corresponding values for the urea treatments were 27 mg N/pot increase at the lower level and 48 mg N/pot at the higher level. In other words, application of fertilizer N produced a dividend of soil N equivalent to 20-25% of the amount of fertilizer applied.

## Residual Value and Loss

Table 3 gives data on the residual fertilizer N in the soil after the rice harvest and the relative availability of this tagged N to sudan grass following rice. The two split applications showed smoewhat lower levels of residual N where ammonium sulfate was applied than did the other treatments. In the case of urea, the levels of addition were not strictly comparable. Of particular interest are the figures for fertilizer N losses expressed as percent of the quantity initially added. Here the advantage of the banded application is clearly evident. At the higher level of application, somewhat greater losses of urea were sustained than of ammonium sulfate. The reduced efficiency of urea on rice was also reported by Fried (4). Even though the pots were flooded immediately after application of the fertilizer and there was no opportunity for leaching to occur, fertilizer losses were of significant magnitude, particularly in the case of urea at the higher level. The data suggest that at least part of the losses may be attributed to volatilization of ammonia from the surface.

**Table 3. Residual fertilizer N in soil after rice harvest, fertilizer N losses during growth of rice, and uptake of residual N by sudan grass following rice.**

| Fertilizer | Mg N applied | Placement | Residual fert. N, mg | Fert. N lost, % | Total N in sudan-grass, mg | Residual fert. N in sudan-grass, mg |
|---|---|---|---|---|---|---|
| None | 0 | - | - | - | 30.0 | - |
| $(NH_4)_2SO_4$ | 124 | Broadcast | 71.6 | 13.5 | 27.7 | 1.0 |
| | 124 | Banded | 65.2 | 7.4 | 35.2 | 1.5 |
| | 124 | Top-dressed | 71.6 | 13.2 | 36.6 | 1.5 |
| | 125 | Banded + T-D* | 62.8 | 10.8 | 24.0 | 0.8 |
| | 125 | T-D + T-D | 61.2 | 14.5 | 30.0 | 1.1 |
| $(NH_4)_2SO_4$ | 247 | Broadcast | 117 | 18.2 | 27.8 | 1.9 |
| | 247 | Banded | 121 | 6.5 | 24.5 | 1.5 |
| | 247 | T-D | 137 | 11.7 | 27.6 | 2.0 |
| | 248 | Banded + T-D | 105 | 10.7 | 23.7 | 1.3 |
| | 250 | T-D + T-D | 119 | 11.7 | 25.0 | 1.5 |
| Urea | 105 | Broadcast | 58.4 | 17.8 | 44.4 | 1.7 |
| | 105 | Banded | 59.3 | 6.5 | 28.8 | 1.1 |
| | 105 | Top-dressed | 58.1 | 16.2 | 33.4 | 1.3 |
| | 124 | Banded + T-D | 65.2 | 12.5 | 24.6 | 1.0 |
| | 124 | T-D + T-D | 62.4 | 16.0 | 30.6 | 1.3 |
| Urea | 269 | Broadcast | 138 | 21.0 | 38.8 | 3.1 |
| | 269 | Banded | 124 | 17.2 | 40.0 | 3.2 |
| | 269 | Top-dressed | 126 | 24.5 | 36.8 | 2.7 |
| | 239 | Banded + T-D | 98.4 | 21.0 | 34.7 | 2.3 |
| | 243 | T-D + T-D | 88.1 | 30.8 | 33.8 | 1.7 |

* T-D = Top-dressed.

Although more than half the fertilizer N initially applied remained there after growth of the rice crop th residual availability of this N to sudan grass (Table 3) was uniformly low. Fertilizer N uptake by the sudan grass expressed as a percentage of that in the soil at the time of planting ranged from 1.3 to 2.9%. A second crop of sudan grass was grown which showed severe N deficiency. Because of the very small amoust of dry matter produced, it was not considered worth harvesting.

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