# UREA DEEP PLACEMENT FOR IMPROVING NITROGEN USE EFFICIENCY IN RICE-BASED SYSTEMS

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## INTRODUCTION

Rice-based production systems are among the most important farming systems in the world. Nearly 2.5 billion people depend on rice as their main source of food and obtain most of their income from cultivating rice. As the world population continues to grow, the demand for rice is expected to increase, placing an ever greater burden on limited soil and water resources. Since most land suitable for rice production is already under cultivation, the increasing demand for rice will also drive a demand for more nutrient inputs to increase and sustain productivity.

Of concern from both an economic and environmental perspective is the inefficient use of urea fertilizer, the primary source of nitrogen (N) for rice production. Broadcast applications of urea have been shown to be highly inefficient with N losses approaching 60%-70% of the N applied (De Datta and Buresh, 1989). Such large inefficiencies are attributed to high concentrations of N in the floodwater that result in the loss of N compounds mainly by ammonia volatilization, denitrification, and runoff. Many of the N compounds that are released by these processes disrupt natural ecosystems, impair water quality, and contribute to global warming. Therefore, broadcast applications of urea followed by large losses of N represent not only an economic drain for farmers, but also harm the environment.

An innovative yet simple technology that increases N use efficiency, and which is being widely disseminated for managing urea in flooded rice systems in Bangladesh, involves the deep placement of urea supergranules or briquettes into puddled soil shortly after transplanting rice. The briquettes are made by compressing prilled or granular urea in small machines with indented pocket rollers that, depending on the size of the pocket, produce individual briquettes varying in weight from 0.9 to 2.7 g. Within a week after transplanting rice, the briquettes are inserted into the puddled soil by hand, being placed to a depth of 7-10 cm in the middle of alternating squares of four hills of rice. Often referred to as urea deep placement (UDP), this technology improves N use efficiency by keeping most of the urea N in the soil close to plant roots and out of the floodwater where it is more susceptible to loss as gaseous compounds or runoff (Mohanty et al., 1999; Savant and Stangel, 1990).

As applied to flooded rice in Bangladesh, the UDP technology offers a compelling example of an effective approach to managing urea fertilizer that provides improved efficiency and results in greater yield with less urea fertilizer. Farmer awareness of the technology has been increased through training and promotional activities, including on-farm comparisons of UDP and broadcast urea in trials managed by farmers. This paper provides a summary analysis of data from on-farm trials in Bangladesh showing changes in grain yield, urea fertilizer use, and N use efficiency attributed to the use of UDP technology.

## METHODS

Rice is grown throughout the year in Bangladesh, with two principal cropping seasons: Boro (irrigated dry season) and Aman (wet season). The Boro crop is transplanted January-February and harvested May-June, while the Aman crop is transplanted July-August and harvested November-December. Yields are usually greater during the Boro season because of more favorable temperatures and solar radiation for crop growth.

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*On-farm trials*. During the 2000-2004 Boro and Aman seasons, farmers in seven districts (Bogra, Chandpur, Jessore, Kishoreganj, Mymensingh, Pabna, and Tangail) conducted 531 on-farm trials to measure rice yields obtained in side-by-side comparisons of UDP versus the current farmers' practice (FP) of applying split-applications of broadcast urea. Both treatments (UDP and FP) were managed equally except for urea, and all farmers used semi-dwarf, high-yielding varieties. At harvest, grain weights and moisture content were determined by taking yield cuts from two subplots of 11.2 $m^2$ in each of the UDP and FP main plots. Grain yields are reported as paddy (unmilled rice) at a standard moisture content of 14 percent.

Fertilizer inputs were recorded in 304 of the comparison trials (222 during the Boro and 82 during the Aman). The amount of N applied in the FP treatment was chosen by each farmer according to their own usual practice or local recommendations. For the FP Boro, the average was 149 kg N $ha^{-1}$ (range from 71 to 239 kg N $ha^{-1}$), and for the FP Aman it was 95 kg N $ha^{-1}$ (range from 35 to 253 kg N $ha^{-1}$). The amount of N applied by deep-point placement of urea briquettes (UDP treatment) was substantially less; the UDP Boro received an average of 79 kg N $ha^{-1}$ (range from 69 to 91 kg N $ha^{-1}$) while the UDP Aman received an average of 59 kg N $ha^{-1}$ (range from 53 to 64 kg N $ha^{-1}$). Phosphorus and K were applied according to local recommendations, with an average application of 21 kg P $ha^{-1}$ and 47 kg K $ha^{-1}$.

*Parameters evaluated*. The effectiveness of UDP technology was assessed through the following parameters: changes in grain yield (ΔGrain yield; kg $ha^{-1}$), changes in fertilizer N applied (ΔN applied; kg N $ha^{-1}$), and changes in the efficiency of fertilizer N use as measured by the partial factor productivity of N (ΔPFP-N; kg grain yield per kg N applied). These parameters were calculated for each individual on-farm comparison of UDP and FP as follows:

ΔGrain yield = UDP grain yield – FP grain yield
ΔApplied N = UDP applied N – FP applied N
ΔPFP-N = PFP-N for UDP – PFP-N for FP

**RESULTS**

The relationship between UDP and FP grain yields is shown in Figure 1. The 1:1 line in the figure provides a reference by which the performance of UDP can be compared directly to that of the current practice of broadcast urea (FP); hence, points to the left of the line indicate UDP dominance while points to the right indicate FP dominance. Clearly, in side-by-side comparisons of UDP versus FP, grain yields were consistently greater with deep-point placement of urea briquettes.

Two aspects of the comparison shown in Figure 1 are revealing. First, the yield increase with UDP was achieved using much less urea fertilizer than FP. On average, the amount of N applied to the UDP Boro crop was only 53% of that applied to FP Boro. Likewise, the UDP Aman crop received only 62% of the N applied to FP Aman. The second aspect of interest is the consistency of the UDP yield benefit across a wide range of yield environments. The regression of UDP yields on FP yields provided a highly significant linear relationship defined by the following equation: UDP = 1.02 + 1.00 FP (r = 0.92, SE of regression coefficient = 0.019). The slope equal to one indicates that the average yield benefit of 1.02 t ha (SE = 0.08) was the same for all farmers regardless of whether they were at the low end or at the high end of the yield gradient.

The comparative distributions for changes in grain yield (ΔGrain yield), N fertilizer use (ΔApplied N), and the partial factor productivity of applied N (ΔPFP-N) for Boro and Aman crops are shown in Figure 2. Invariably, UDP was superior to FP for all parameters, providing greater yield with less applied N, which meant the PFP of applied N increased as well. For the Boro season, the UDP yield benefit was greater than 700 kg grain ha-1 in 75% of the on-farm comparisons, increasing to more than 1400 kg grain ha-1 in as many as 25% of the comparisons. At the same time, 75% of the farmers realized a reduction in applied N of more than 45 kg N ha-1, while as many as 25% of the farmers achieved a savings that exceeded 90 kg N ha-1. Furthermore, in 75% of the comparisons, the increased yield and savings in applied N translated into increases in the PFP-N of more than 30 kg of grain per kg of applied N. Similar distributions but with somewhat smaller values were obtained for all three parameters during the Aman season. Except for a few cases where the use of applied N was greater for UDP Aman than FP Aman (i.e., ΔApplied N was positive), all distributions showed UDP provided greater benefits in both seasons, and there was essentially no risk of obtaining a less favorable outcome using UDP versus FP.

The average UDP yield benefit over current practice was 1120 kg grain ha-1 (SE = 32.4) during the Boro season and 890 kg grain ha-1 (SE = 32.5) during the Aman. Importantly, the saving in applied N amounted to 70 kg N ha-1 (SE = 2.4) during the Boro season and 35 kg N ha-1 (SE = 9.1) during the Aman. As impressive as these numbers appear, they are certainly realistic and within the range of values cited by others for both on-farm and on-station experiments (Daftardar et al., 1997; Mohanty et al., 1999; Pasandaran et al., 1999; Savant and Stangel, 1990).

**DISCUSSION AND CONCLUSIONS**

The current practice of broadcasting urea represents a tremendous waste because much of the applied N is lost before it can be effectively used by the plant. Greater adoption of UDP by rice farmers could improve the use efficiency of applied N and successfully reduce losses to the environment. If the numbers obtained from the on-farm studies are taken to be representative for all of Bangladesh, then the 7 million hectares of rice (4 million Boro, 3 million Aman) grown annually in the country could potentially produce about 7 million tonnes more rice, and do so with about 0.4 million tonnes less applied N using UDP technology.

The efforts to improve N use efficiency using UDP technology in Bangladesh and other Asian countries have also helped to identify situations where the effectiveness of UDP may be less than expected and where adoption may also be limited (Mohanty et al 1999). For example, UDP would not be as effective on soils with high internal drainage. Additionally, it is important to recognize that UDP will be most effective when using high-yielding varieties and good management practices.

For flooded rice systems, there are few practical improvements in fertilizer management or products that prove to be as cost-effective as UDP in increasing fertilizer use efficiency and addressing food production and environmental concerns. As UDP technology continues to be improved and adopted in Bangladesh, it promises to significantly reduce N losses to the environment while also increasing grain yield and improving farmer incomes.

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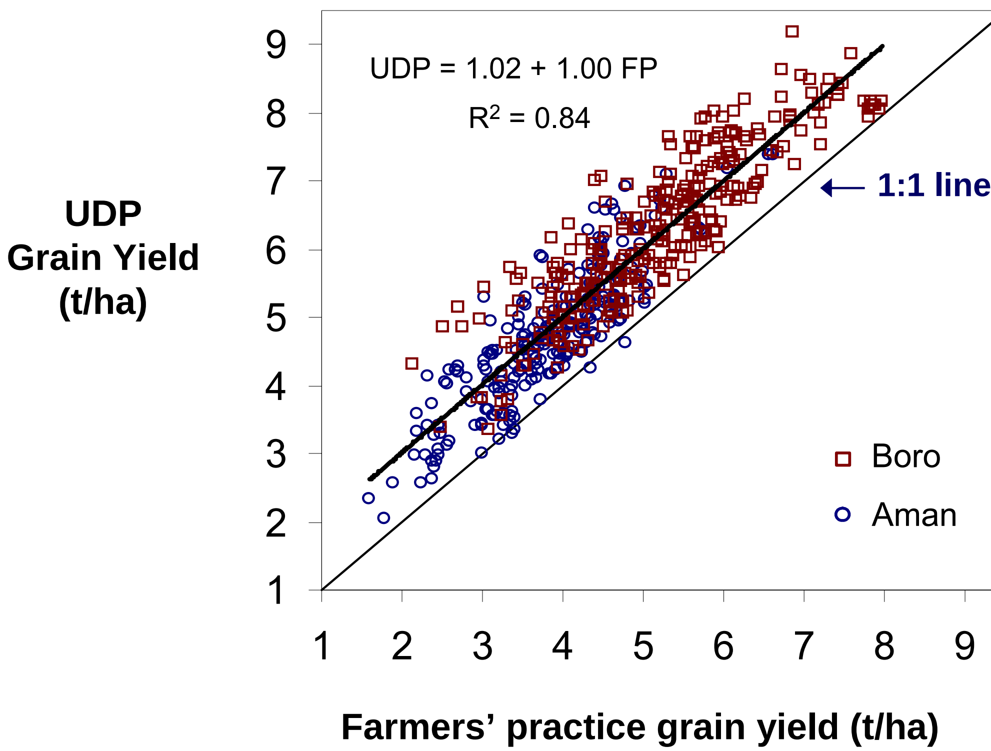


**Figure 1**. Rice yields (paddy) obtained in Bangladesh using deep-point placement of urea briquettes (UDP) plotted against yields obtained using broadcast urea (farmers' practice) in side-by-side comparisons on farmers' fields during 2000-2004.

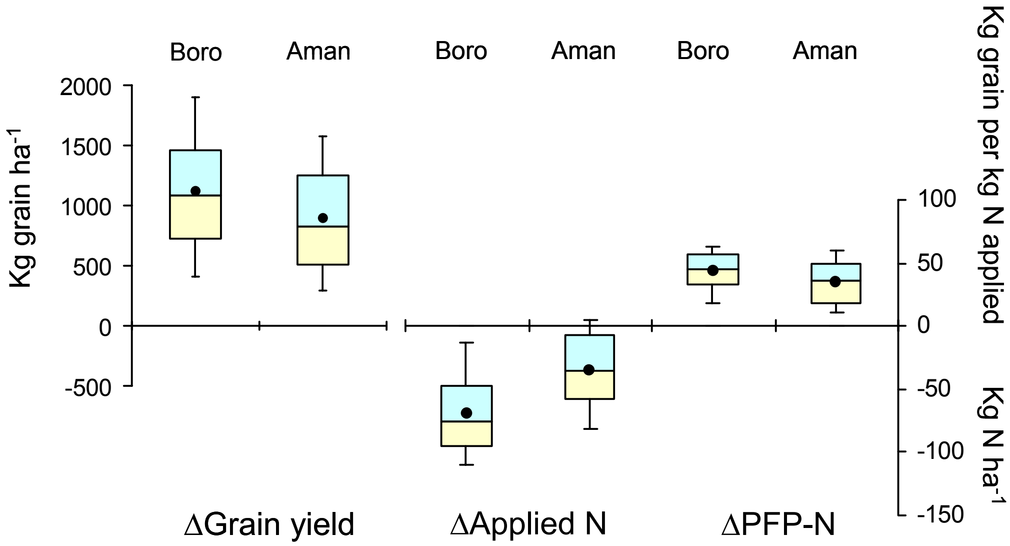


**Figure 2**. Comparative distributions showing the changes in grain yield (ΔGrain yield), N fertilizer use (ΔApplied N), and partial factor productivity of applied N (ΔPFP-N) attributed to UDP technology versus farmers' practice (FP) for the Boro and Aman rice crops. The box plots display the 10th, 25th, 50th, 75th, and 90th percentile observations along with the mean (solid marker).