Enhanced efficiency fertilizers

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Abstract
World food security is challenged by many issues, including weather and climate variability, degraded soils and persistent poverty. To address these problems, we must look for solutions to reduce the delivered cost of agricultural inputs-especially fertilizer-that improve stakeholder returns and promote agricultural intensification. Improving fertilizer use efficiency by reducing nutrient losses is a critical step towards increasing soil fertility and agricultural productivity for poor farmers. This paper presents results from both field and greenhouse studies that illustrate the use of improved management practices, such as fertigation and deep placement of nitrogen (N) and phosphorus (P), and use of innovative new modified fertilizers that increase nutrient use efficiency (NUE). The results show how the controlled delivery of nutrients, where nutrient delivery is synchronized to crop demand, creates opportunities to increase yields and improve NUE.

Key Words
Enhanced efficiency fertilizers, nutrient use efficiency, deep placement, controlled-release.

Introduction

World population growth, increasing demand for food, water shortages, soil losses, environmental issues and weather uncertainty are among the many challenges that threaten food security in many regions of the world. An estimated 1.5 billion people, or a quarter of the global population, depend directly on land that is being degraded (FAO 2009). Twice as many people around the world are subsisting on less than US $2 a day amidst strained natural resources. Almost 33% of people in Sub-Saharan Africa (SSA) and 17% in Asia are undernourished. In Asia, the main challenge remains how to maintain steady growth in crop yields in the face of diminishing marginal returns to agricultural inputs. In SSA, the main challenge is how to reduce the delivered cost of inputs so that farm intensification becomes economically preferable to opening new land. The high cost of agricultural inputs, especially fertilizer, adds to the growing concern about having enough food for people around the world. The farm-gate cost of fertilizer is higher for farmers in SSA than in Asia partly due to higher transportation costs (Chemonics 2007). Farmers can improve their net returns from agriculture with lower cost inputs and/or enhanced efficiency of input use. Reducing nutrient losses is a critical step towards improving soil fertility and agricultural productivity for poor farmers. It makes sense from every perspective-agronomic, economic and environmental. The low nutrient absorption rate of 30%-40% by crops for applied N, P and potassium (K) fertilizers is inefficient and must be improved. For example, by improving N use efficiency 15%-20%, the projected food production increase for 2030 can be obtained with 20 million tons less fertilizer than based on the current average fertilizer N recovery of 35% (Daberkow *et al.* 2000). Improved management practices, products and crop attributes all lead to increased nutrient use efficiency. The integrated use of mineral fertilizers and recycled waste products not only reduces the amount of fertilizer applied but further improves nutrient and water use efficiency. The key to both improving efficiency of applied nutrients and reducing losses is the synchronization of the nutrient delivery from soils, biological nitrogen fixation, organic materials and mineral fertilizers with the crop requirements (Singh 2005). The paper will present results from field and greenhouse studies illustrating the use of improved management practices, such as fertigation and deep placement of N and P, and use of new and innovative products that increase nutrient use efficiency.

Methodology

Improved management practices

Deep placement of fertilizers, particularly urea, has resulted in improved yields and lower N and P losses from flooded rice fields (Kapoor *et al.* 2008; Bowen *et al.* 2005). Fertilizer deep placement (FDP) involves placing 1- to 3-gram briquettes of urea, urea + diammonium phosphate (DAP), or urea + DAP + potassium chloride at 7-10 cm soil depth shortly after transplanting rice. The technology addresses the challenges of low productivity in rice ecologies by increasing nitrogen use efficiency and reducing P runoff losses. Deep placement of urea eliminates nitrogen losses due to volatilization, denitrification and floodwater run-off,

allowing farmers to realize a 30% increase in yields over the same nitrogen when conventionally applied (Bowen *et al.* 2005). Deep placement also ensures N availability beyond the flowering stage due to reduced early tillering and more available N, encourages algal biological nitrogen fixation because of low floodwater N concentration and reduces weed competition (Singh 2005).

Fertilizer deep placement trials were conducted in Nangarhar, Afghanistan, with conventional and conservation tillage practices in 2008. The impact of improved versus local rice variety was also evaluated. A survey study that included 3,230 rice-growing households, distributed through 80 upazilas and 14 districts in Bangladesh, was conducted during the 2008 Boro season. Paddy yields, labor requirements and production costs were compared for deep placement versus conventional urea application (Thompson and Sanabria, 2009). Greenhouse and field trials were conducted to expand deep placement to upland vegetable crops. The greenhouse study was conducted in Muscle Shoals, Alabama, U.S.A., and the field trials were in collaboration with the Bangladesh Agricultural Research Institute in Jodhpur, Bangladesh.

Innovative N products

The innovative N products evaluated under laboratory, greenhouse and field conditions were designed to control or modify the delivery of N to synchronize with plant N demand. The improvement in efficiency of these products was achieved through the following mechanisms:

(1) Urease inhibition,
(2) Nitrification inhibition,
(3) Modifying soil rhizosphere, and
(4) Controlled- or slow- release of nutrients due to solubility of product, type of coating or mineralization of product.

Field trials with controlled-release fertilizers under rainfed and irrigated conditions using the simple Chapin bucket drip kit system were conducted at Bujumbura in Burundi, Ashaiman in Ghana and Kigali in Rwanda during 2008. Additional tests with modified products, including fertilizers made using municipal wastewater residuals (Reimers and Weber 2008), were conducted at IFDC's laboratories and greenhouse in Muscle Shoals, Alabama.

Results

Improved management practices

The rice grain yields from the Afghanistan study were significantly higher with FDP than with broadcast application of urea using the leaf color chart (LCC) for side-dressing of N with conventional tillage (Figure 1). Under zero-tillage, rice grain yield was significantly higher for the Kunduz rice variety. The on-farm survey in Bangladesh showed that the average yield on farms using FDP was significantly higher than the yields with broadcast application of urea in all 14 districts. Yield increases due to FDP between 100-3,000 kg/ha occurred in all upazilas and in 62 of 80 upazillas, yield increases were 1,000-1,700 kg/ha. The expansion of FDP to upland crops was evaluated in the greenhouse (Figure 2) and under field conditions. In Bangladesh, upland crops including tomatoes, cabbages and eggplants gave very favorable returns to farmers with FDP (Table 1).

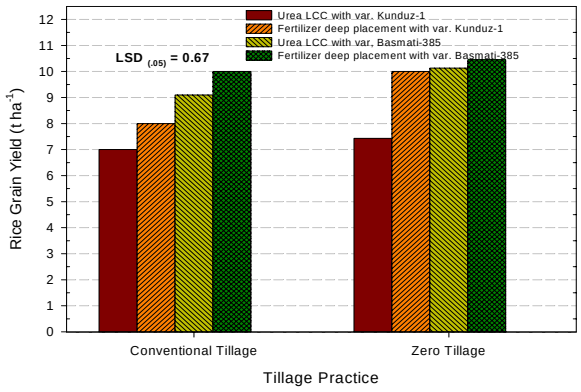

Figure 1. Effect of fertilizer deep placement on grain yield of lowland rice.

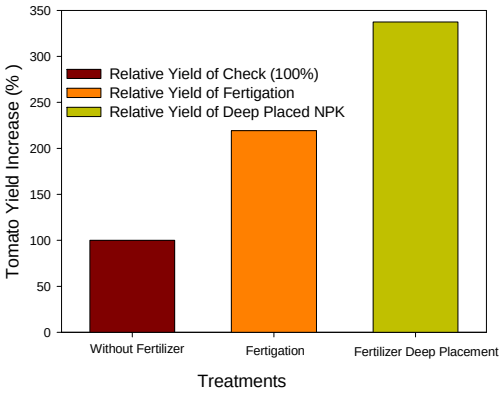

Figure 2. Comparison of tomato yields with fertigation and fertilizer deep placement.

Table 1. Economic benefits of fertilizer deep placement due to yield increase and N saving on eggplants in Bangladesh.

Urea quantity (kg/ha)	Yield (t/ha)	Money (Taka/ha)			Increase over recommended dose	
		Gross income	Cost of cultivation	Net profit	Yield (%)	Taka/ha
320-broadcast urea	26.97	228,420	61,163	167,257	-	-
320-FDP	35.16	300,930	62,897	238,033	31	70,776
288-10% less FDP	32.39	279,210	62,175	217,035	20	49,778
256-20% less FDP	28.56	249,330	61,525	187,805	6	20,548

Innovative N products

The inhibition of urease and nitrification activity, and thus lower N losses due to volatilization and leaching, were dependent on soil properties and the efficacy of the modified fertilizers. In general, the urease inhibitor, NBPTP, significantly reduced volatilization losses on a wide range of soils (Figure 3). Application of a nitrification inhibitor (dicyandiamide [DCD]) and use of DCD containing fertilizers such as AgrotainPlus delayed nitrate formation and hence could improve NUE by reducing nitrate leaching and denitrification losses (Figure 4).

Combined biosolids-inorganic fertilizer showed significant reduction in volatilization loss-2% and 21% of applied fertilizer N compared with 33% and 57% with urea under upland and flooded conditions, respectively. Leaching losses were also significantly lower for biosolid-inorganic fertilizer, 4%-13% compared with 41%-86% of applied fertilizer N with urea. These results also translated into higher grain yields for rice, wheat and vegetables. Up to 30% higher yields were obtained with controlled-release fertilizers with okra, cabbage and sweet pepper in Ghana, Burundi and Rwanda.

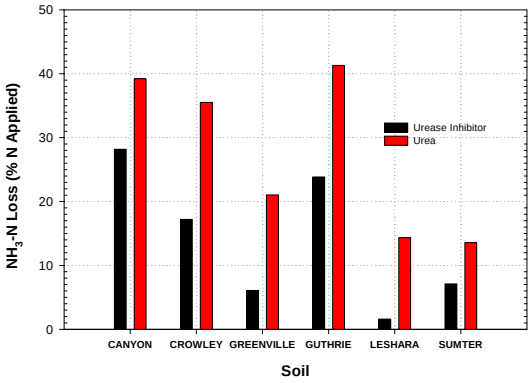

Figure 3. Cumulative ammonia volatilization loss after 17 days under flooded condition.

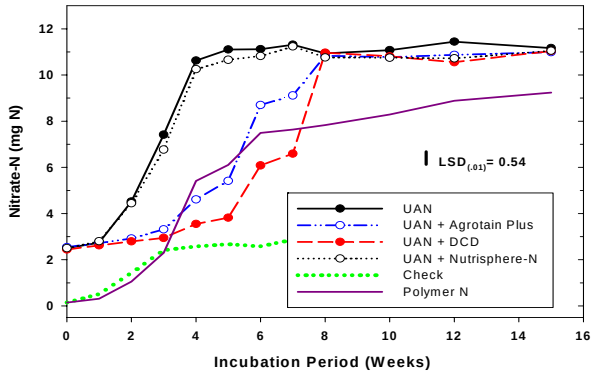

Figure 4. Nitrate formation after adding nitrification inhibitor (DCD) to urea ammonium nitrate (UAN) compared to nitrate release from polymer N fertilizer.

Conclusions

There are opportunities to increase yields and improve NUE by using enhanced efficiency fertilizer products and improved management practices. Innovative technologies enable farmers to minimize risks by controlled delivery of nutrients, deep "point placement" of nutrients and by the use of decision support tools for improved crop recovery of nutrients. Fertilizer research to develop enhanced efficiency fertilizers at lower costs for smallholder farmers in the developing world is an ongoing activity of IFDC and collaborating partners.

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