Improved Nitrogen Use Efficiency in Lowland Rice Fields for Food Security

Fertilizer FOCUS

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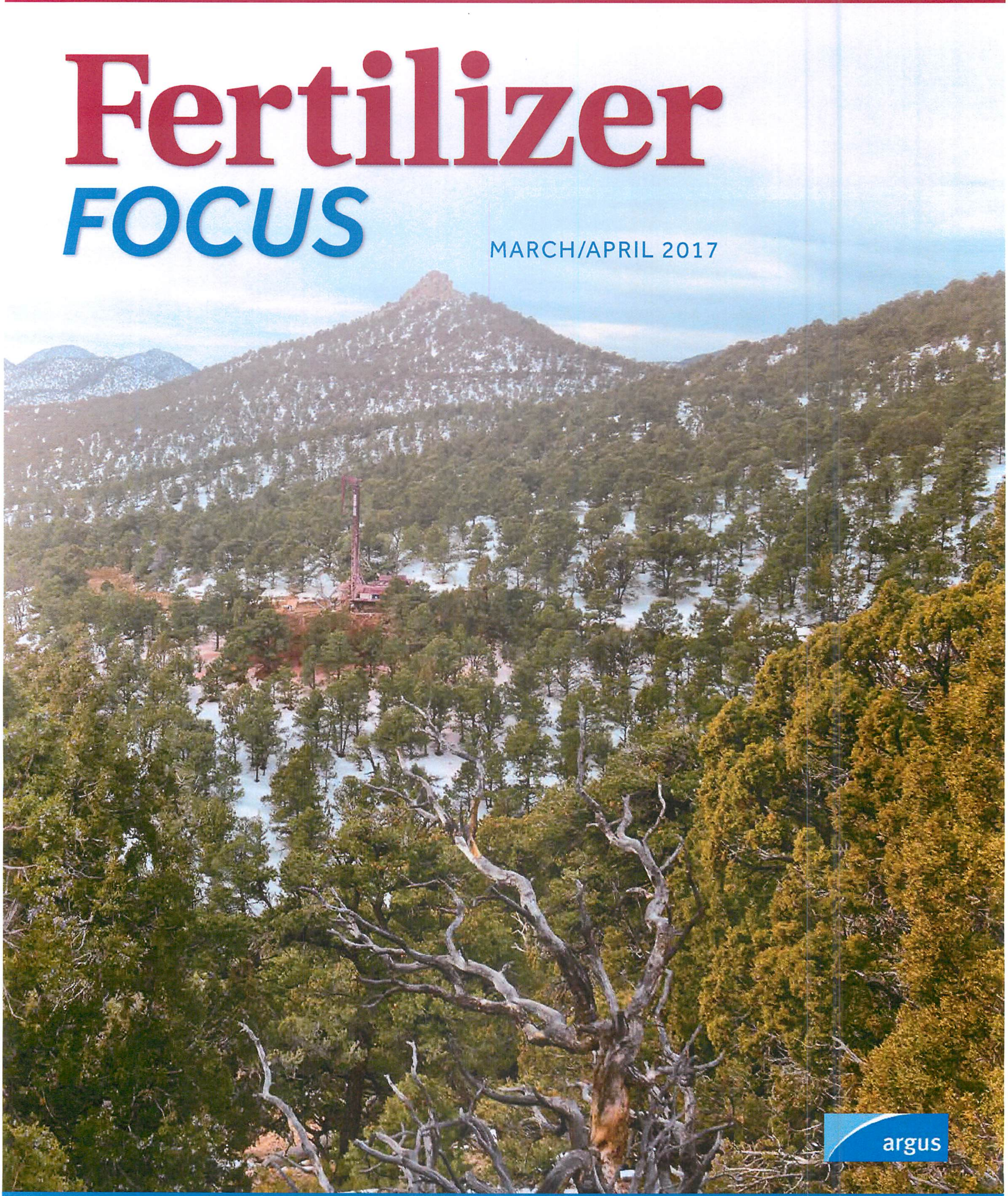

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Improved nitrogen use efficiency

in lowland rice fields for food security

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The productivity of agricultural systems must improve substantially to support increasing populations without further conversion of wilderness into farmland. By 2050, it is estimated that 70pc more food must be produced to feed an estimated global population of over 9 bn with changing food consumption patterns and preferences.

Rice is the staple food of more than half of the world's population. More than 90pc of the world's rice is grown in Asia where one-half of the world's population and 80pc of the world's poor are concentrated. In Bangladesh, one of the most climate-vulnerable nations, farmers intensively cultivate rice on 80pc of the agricultural lands. With the increasing population growth rate, it is estimated that the demand for rice will be 56pc higher by 2050 than in 2001. Therefore, rice productivity should be increased to meet the food demand of a growing population, taking into account the dwindling amount of land area available for farming. This requires judicious use of agricultural inputs, including quality seeds and fertilizers and water management, among other good agricultural practices.

Rice field trials with different fertilizer treatments in Bangladesh

Nitrogen retention

Fertilizer use has played a crucial role in meeting the food demand of a growing world population. Among the fertilizers, nitrogen (N) fertilizer is the main driving force to produce large rice yields under irrigated and favorable rain-fed conditions. Farmers usually apply urea as a broadcast

Figure 1. Fertilizer briquetting machine producing urea briquettes

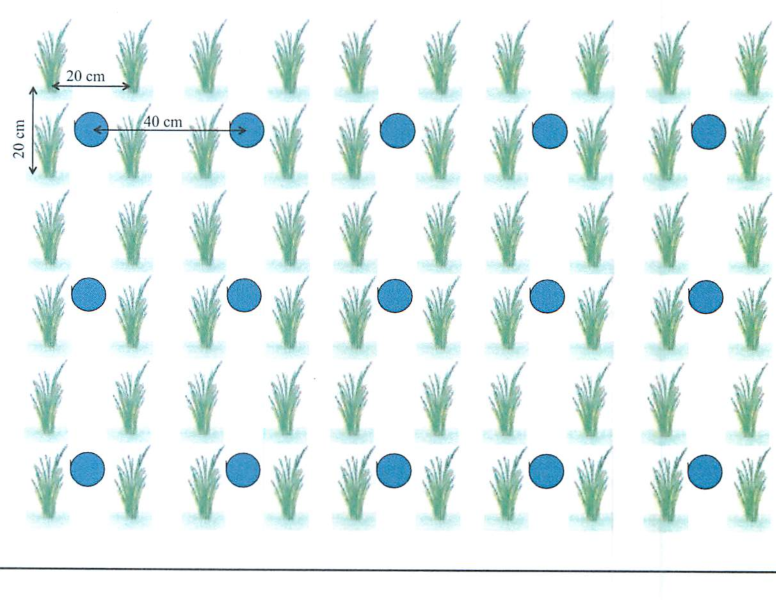
method. Much research conducted across countries reported that more than 50pc of applied nitrogen is not utilized by crops and lost to the environment as reactive forms (ammonia, nitrate, nitrogen oxides) through volatilization or surface water runoff, contributing to greenhouse gas emissions and other environmental problems such as eutrophication and groundwater pollution. This also results in higher costs for farmers given that N fertilizers generally represent over 10-15pc of crop production costs. Therefore, fertilizer management should consider the 4R concept - right methods, right time, right rates and right sources to increase use efficiency, crop yield, soil health and farm profits and to reduce negative environmental effects.

Selecting a right placement method – urea deep placement

Over the past years, many research and development groups, including the International Fertilizer Development Center (IFDC), have worked on improving N use efficiency (NUE) through urea deep placement (UDP), urease inhibitors and slow and controlled N fertilizers such as polymer- and sulphur-coated fertilizers. Research conducted across different countries showed that UDP could be one the best management techniques to achieve the multiple benefits of increasing grain yields, farm profits and NUE while reducing negative environmental effects; in short, more yield with less fertilizer. In the UDP technique, urea is made into 'briquettes' (see Figure 1) of one to three grams based on required N rate and placed at a depth of 7-10 cm at a spacing of 40 cm or at the centre of four rice plants (see Figure 2) within seven days after transplanting.

Since IFDC introduced UDP to smallholder Bangladeshi rice farmers since 2008, more than 2 mn now apply the technology on 1 mn hectares of rice. The technology reduces urea use by more than 30pc while increasing yields by an average of 15-20pc. Farmers experience 24pc higher incomes, while the government of Bangladesh saves USD30 mn per year on fertilizer subsidies. If the technology is scaled up to 11 mn hectares of rice, the government's subsidy saving will be huge. There is large potential of UDP in the Asian rice growing countries where N fertilizer subsidies exist.

Figure 2. Geometry of urea deep placement



Limiting losses

In lowland rice fields, placement of N in the root zone reduces its losses and increases use efficiency and crop productivity. However, in broadcast urea, most of the N is lost within a week of application either as ammonia volatilization or surface runoff. Studies conducted by Bangladesh Rice Research Institute and Bangladesh Agricultural University show the negligible amount of N losses as ammonia volatilization, surface runoff and emissions of greenhouse gas nitrous oxide when urea was deep-placed in continuously flooded rice soils. Seasonal total nitrous oxide emissions in the dry (boro) season were 60-80pc lower in UDP compared to broadcast urea (see Figure 4).

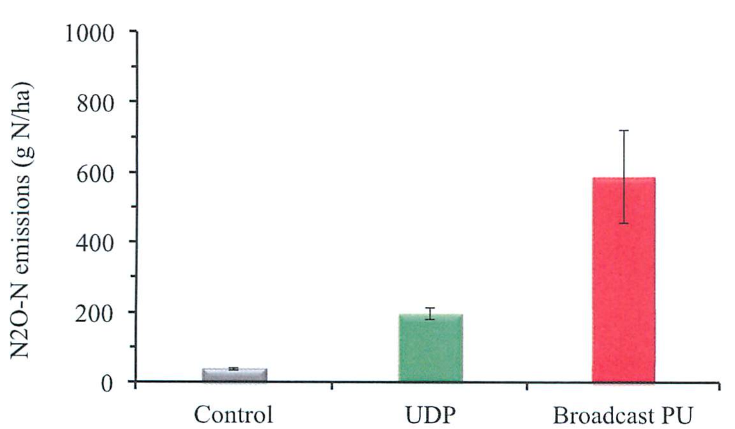
In deep placed urea, the majority of N remains in the form of ammonium, which is much less mobile than nitrates. As a consequence, more N is available to the crop throughout rice growth stages. Therefore, losses to the atmosphere, groundwater and waterways are drastically reduced. With the reduction of these losses and increased plant uptake, UDP increases N use efficiency up to 80pc compared to 30-45pc of broadcast application.

Figure 3. Farmers applying urea briquette in rice field

In addition to favourable irrigated and rain-fed environment, UDP is a potential technology for stress-prone environments such as drought, submergence and salinity. Farmers in those areas have poor control over water and in turn for fertilizer application. For conventional split application of nitrogen, farmers in drought-prone areas are unable to catch optimum timing due to an extended drought. UDP is a better alternative because it reduces the dependence of fertilizer application on weather compared with broadcast fertilization.

> *Most farmers in developing countries are not familiar with balanced fertilization*

Figure 4. Nitrous oxide (N2O) emissions from UDP, broadcast urea and control (without N) in dry season rice 2014 in Bangladesh



Balanced use of fertilizers

Fertilizers, particularly nitrogen, phosphorus and potassium – with balanced use of other secondary and micronutrients – is a major input required to produce high crop yields and improve soil fertility. However, most farmers in developing countries, such as Bangladesh, are not familiar with balanced fertilization practices. They often use excessive N and insufficient phosphorus and potassium fertilizers, with little or no secondary and micronutrient fertilizers. To address these issues, use of compound fertilizer (NPK) briquettes was recently introduced in Bangladesh, supplying all three major nutrients in a compound briquette.

The compound briquette is deep placed as with UDP. Since many farmers do not practice balanced fertilization, deep placement of compound fertilizer briquettes offers the potential for higher yields, improves fertilizer use efficiency and soil fertility because of balanced use of nutrients and reduced nutrient losses. It also saves labor with a one-time application of NPK briquette. Field trials conducted across different districts in Bangladesh showed that deep placement of NPK briquettes used approximately 30pc less fertilizer compared to broadcast prilled urea with conventional P and K application and produced grain yields and N use efficiency similar or higher than UDP.

It is a fundamental principle that crop productivity is often controlled by the most limiting nutrient. For example, if soil is deficient in any essential nutrients, addition of other nutrients will not have any yield benefits. Therefore, IFDC is currently focusing research on balanced fertilization, particularly inclusion of secondary and micronutrients. Our research being conducted in Myanmar shows that phosphorus, sulphur and potassium are as critical as N and the extent of the deficiency depends on soil type (see Figure 5). Soil analyses also show zinc as a limiting element in some soils. The availability of nutrients such as phosphorus, sulphur, iron and zinc are also influenced by changes in soil pH, as well as wetting and drying cycles, which may become more common as a management practice or due to climatic variability. IFDC is also conducting similar studies in African countries.

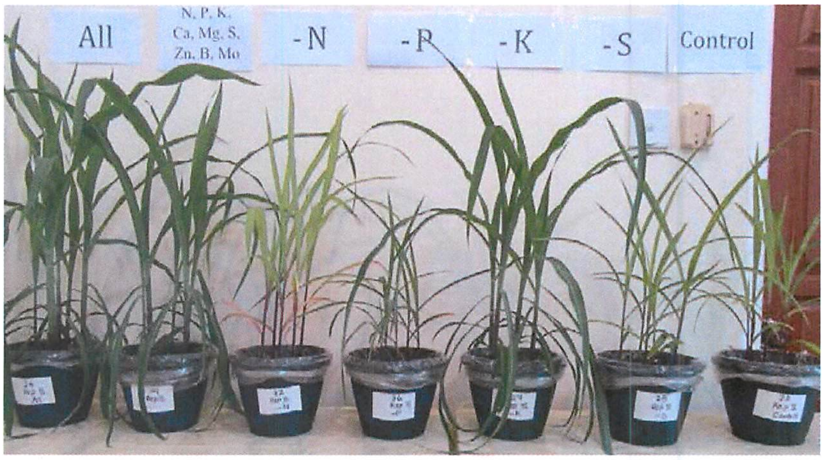


Figure 5. Maize plants grown in nutrient omission trial in Myanmar

Wider adoption of UDP requires government and private sector initiatives

Reducing barriers of wider adoption

The majority of the farmers in Bangladesh are small land holders (<2 ha). Fertilizer deep placement technology is being disseminated by the Government of Bangladesh in partnership with IFDC by developing micro-enterprise briquette producers. Each local entrepreneur who owns a briquetting machine – many of whom are fertilizer dealers – produces fertilizer briquettes amounting to approximately one tonne per day.

Farmers access fertilizer briquettes through retailers' networks. This approach is effective in small scale farming where household labour is sufficient for cultivation, but requires modifications to work in larger scale farming systems such as in Myanmar where labour availability is an issue. Due to the increasing trend of labour outmigration, availability of labour has become one of the major issues of UDP adoption.

Wider adoption of UDP requires government and private sector initiatives to make fertilizer briquettes more widely available through industrial-level briquette production while developing suitable tools for smallholder production systems to reduce the labor intensity of manually placing UDP briquettes. In Myanmar, IFDC is working with agri-machinery companies to design and develop a combine seeder and UDP applicator that can be driven using either a power tiller or four wheel tractor for rice and for maize. This will have immediate impacts, particularly for large producers and consumers of N fertilizer such as China and India. China alone consumes 29pc of the world's total fertilizer followed by South Asia (20pc). Given that China and India have recently committed to increasing fertilizer use efficiency – with China's laudable goal of zero growth in N fertilizer by 2020 being a prime example – UDP could be a key technology to contribute to these goals. ■

IFDC's current work in Asia addresses nutrient use efficiency, climate-smart agriculture, balanced soil fertility management, enhanced smallholder productivity and profitability and improved agricultural input and service markets. IFDC is promoting UDP as a climate smart agriculture because it has proven record of increasing productivity in a sustainable manner, improves adaptation of rice to stress environments by reducing risks associated with climatic variability and it reduces GHG emissions directly with lower nitrous oxide emission and indirectly with reduced ammonia volatilization and runoff losses.