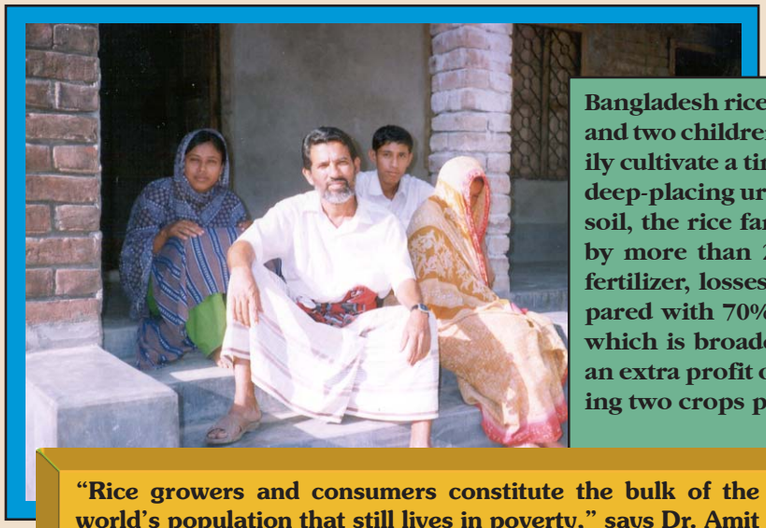
An IFDC Innovation

More Rice With Improved Nitrogen Efficiency

Deep Placement of Urea Supergranules



Bangladesh rice farmer—Abdul Jalil—lives with his wife and two children near Shiorda (Jessore). He and his family cultivate a tiny farm of less than one-half hectare. By deep-placing urea supergranule (USG) fertilizer into the soil, the rice farmer was able to increase his rice yield by more than 25%. With this environmentally sound fertilizer, losses of nitrogen amount to only 30%, compared with 70% for the traditionally used prilled urea, which is broadcast over the fields. This translates into an extra profit of more than $200 per hectare, considering two crops per year. The USG fertilizer has benefited Jalil's family in three ways. Because of increased yields and profits, he was able to repair his house, purchase clothing for his family, and pay for school costs. Jalil's life has improved in other ways since using USG; he was able to buy a cow and an irrigation pump with his profits from farming.

"Rice growers and consumers constitute the bulk of the world's population that still lives in poverty," says Dr. Amit H. Roy, IFDC President and Chief Executive Officer. "More than 90% of the world's rice is grown in Asia where one-half of the world's population and 80% of the world's poor are concentrated."

Rice—Essential Food for the Poor

Rice is a staple food crop for more than 2 billion people, including the Jalil family of Bangladesh. Rice, directly or indirectly, provides employment for about 1 billion people in southern and southeastern Asia. The crop is cultivated in about 110 countries on 5 continents.

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For Bangladesh farmers like Abdul Jalil, rice is the most important commodity in their daily lives. The average citizen in Bangladesh consumes 150-200 kilograms of rice annually, which accounts for two-thirds or more of caloric intake and approximately 60% of daily protein consumption.

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Even in Sub-Saharan Africa, rice is the second most important cereal food crop. Demand for rice driven by population growth is such that about 80-100 million new consumers of rice are added to the world population annually.

To satisfy the increasing demand for rice, production must increase by 70% to 907 million tons by the year 2027. Only 4% of the world's rice production of about 585 million tons is marketed internationally, and 96% or about 562 million tons is consumed in the countries where it is harvested. The importance of small-scale farmers in producing rice is evident in that about one-half of the rice grown in Asia is consumed by producers. Rice is more than a food crop—it is a way of life in many developing countries.

Nitrogen—The Essential Nutrient for Rice

Fertilizer, particularly nitrogen fertilizer, is the main driving force to produce large rice yields under irrigated and favorable rain-fed conditions. The cost of nitrogen fertilizer, for example, represents 15%-30% of the total production costs. The cost increases as more countries remove fertilizer and other input subsidies.

Nitrogen fertilizer is usually broadcast as prills on a rice paddy prior to transplanting. This application is followed by one or more topdressings in the floodwater within the period from transplanting to flowering.

Numerous research reports, however, have shown that such practices are inefficient because generally only about one-third of the fertilizer nitrogen is used by plants. The remainder is lost through gaseous losses, runoff, and leaching or is immobilized in the soil. One means to reduce nitrogen losses and improve fertilizer efficiency is to deep place fertilizer nitrogen as USG of compacted prilled urea. USG can be produced by a village-level briquetting machine.

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ment , IFDC has developed a urea deep placement (UDP) technology package to increase rice yield with reduced nitrogen-fertilizer application and reduced nitrogen loss," says Dr. Lawrence L. Hammond, Director of IFDC's Resource Development Division. "This technology has been successfully adopted in Bangladesh and introduced in Nepal and Vietnam."

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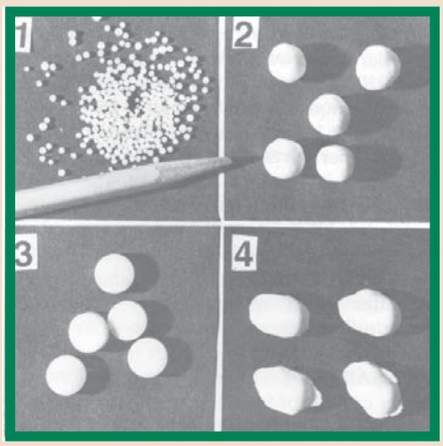
Basically, UDP technology involves the deep placement of USG or USG combined either with phosphorus or phosphorus and potassium. USG is hand placed in the puddled soil between each set of four hills of rice at a depth of 7-10 cm about 1-7 days after transplanting rice. Although this method of nitrogen application increases labor time compared with broadcasting urea, UDP can ensure yield increases of 0.5-1.0 tons more per hectare than traditional methods that use 40-60 kilograms more nitrogen per hectare.

The potential yield increases through the use of USG have prompted the interest of national and international organizations to demonstrate this technology on the fields of farmers in developing countries. The agricultural technology of USG and the nitrogen management practice of deep placement hold promise for those developing-country farmers who cultivate rice on small plots where increased yields with improved input use efficiency are of critical importance. Increased labor cost for UDP is less than greater cost for urea for split broadcast application.

Production of Urea Supergranules



Granulation and compaction processes can be used to produce urea supergranules that are larger than common fertilizer-grade prilled urea (1-2 mm in diameter). There are four main processes for production of granular urea products—namely, pan granulation, falling curtain, fluid bed, and briquetting.

Because of the simplicity of the process and cost effectiveness, briquetting appears to be the most viable method to produce USG and related products in the introductory phase of this technology.

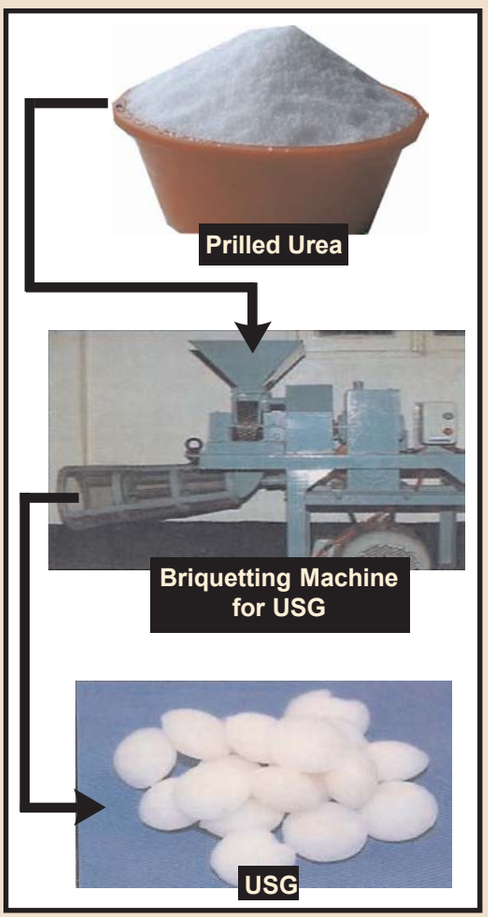
USG fertilizer is a simple physical modification of ordinary urea fertilizer. It consists of large discrete particles of urea containing 46% nitrogen. Weight may vary considerably, but the general range that has been evaluated is 1-3 grams per particle.

The shape of the granules depends on the production process used. USG prepared by any one of the melt-type granulation processes (pan, falling curtain, and fluid bed) is nearly spherical and without edges, but they may vary in size and weight. Those prepared by briquetting are pillow shaped, oblong, or oblate, with broken edges due to webbing, and they are reasonably uniform in size and weight.

Briquetting is a special type of compaction process. The basic principle of production of 1- to 3-gram supergranules by briquetting is the application of pressure to the fertilizer material as it passes between two indented pocketed rollers rotating at the same speed but in opposite directions.

Institutions that have developed equipment to produce briquettes of urea fertilizer include IFDC; Fujian Academy of Agricultural Sciences, People's Republic of China; Metal Industries Development Center, Indonesia; and the Indian Farmers' Fertiliser Cooperative, India. The prototype IFDC machine has a capacity of 250 kilograms per hour of 1-gram USG.

Briquetters produce material of various briquette sizes at production rates of 250-1,000 kg per hour and of varying compositions of nitrogen, phosphorus, and/or potassium. This technology allows for site-specific fertilizer recommendation, balanced fertilization, reduced nitrogen loss, and a labor saving because one large granule can be used rather than two to three 1-gram size granules. Deep placement permits a single application of multiple nutrients. USG is being used by farmers for vegetable and fruit production and in fish ponds.



In the past, nutrient imbalance was uncommon because of recycling of residues, the production of a single crop per year, and high soil phosphorus and potassium status. However, because 2-3 crops are now produced per year on the same field and residues of phosphorus, potassium, and secondary and micronutrients are removed, deficiency is on the rise.

In addition to the above benefits associated with the USG products, the emphasis toward village-level briquetting also has a positive impact on (1) availability of the granules, (2) transportation and handling, and (3) economic development in the villages through increased labor requirement (producing briquettes and placement into paddy fields). Hence, because of the benefits and site-specific recommendations,

USG products and deep placement have much to offer to small-scale rice farmers.

Nitrogen Transformations in the Rice Field

To appreciate fully the role of deep placement of USG, it is necessary to understand the nitrogen dynamics that take place in a rice field. Almost all nitrogen taken up by plants is in two forms—nitrate or ammonium—regardless of whether the fertilizer source is organic or inorganic. Under submerged paddy almost all nitrogen remains in the ammonium form because of the oxygen-depleted environment.

Nitrogen can be lost from the system through a variety of ways. Proper deep placement of USG in the soil, however, reduces the presence of nitrogen in floodwater, thus reducing losses due to ammonia volatilization and runoff and increasing uptake efficiency of applied urea. Urea deep placement results in very highly localized concentration of urea near the placement site; therefore, deep placement is not recommended for sandy soils because of enhanced leaching potential.

Proper deep placement requires that soil covers the USG after placement. With machine deep placement of USG, failure to properly cover the USG has been the main problem and has resulted in high amounts of urea-nitrogen in floodwater and, hence, high potential for runoff and/or volatilization losses. Good water control and well-puddled soils improve the efficiency of deep placement. The keys to the success of deep placement include keeping all applied nutrients in the rooting zone, eliminating their presence in the floodwater, and selecting soils with a low percolation rate.

Agronomic Performance of Deep-Placed USG

USG can be placed efficiently by hand soon after transplanting of rice seedlings at the rate of one USG near the center of each four rice hills at a 7-10 cm soil depth. The rate of application depends on the weight of each granule; their nitrogen, phosphorus, and potassium composition; and planting density.

"Several hundred field trials have been conducted in south and southeastern Asia by rice agronomists of national and international institutions and networks to evaluate the performance of deep-placed USG," says Dr. Ray B. Diamond, an IFDC agronomist, who is coordinating a project that is promoting the adoption of urea deep placement technology in Bangladesh, Nepal, and Vietnam. "In most cases, the agronomic performance of deep-placed USG was superior to that of two or three split broadcast applications of prilled urea. UDP resulted in an average saving of urea fertilizer of about 35% and an average additional yield of 15%-25%."

Socioeconomic Performance

"On average from a hectare of land, UDP provides an additional 3.2 persons with the annual rice requirement above the poverty level established by the Government of Bangladesh," says Dr. Thomas P. Thompson, IFDC Senior Sociologist. A survey conducted in Bangladesh produced these findings:

- Compared with nonusers, the standard of living among UDP users was improved significantly because the ownership of radios (19%), televisions (109%), and bicycles (30%) increased significantly.
- Income from paddy sales by UDP users increased by 11%, compared with a decrease of 16% among nonusers.

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Benefits of Deep Placement of Urea Supergranules

- Reduces expenditures for urea by 20%-25%.
- Increases paddy yields by 15%-25%.
- Reduces expenditures for hired weeding labor by 26%-35%.
- Increases efficiency of fertilizer use in flooded rice due to reductions of loss through gaseous emissions and floodwater runoff. (With broadcast application of urea, volatilization losses alone could account for 30%-50% of applied fertilizer.)

- Encourages algal biological nitrogen fixation because of low floodwater nitrogen concentration.
- Encourages better water management and line transplanting (instead of random), thus, weeding and pest control is made easier.
- Reduces phosphorus runoff when urea-diammonium phosphate is deep placed.
- Minimizes ammonium and phosphate fixation and immobilization.
- Reduces the number of ineffective tillers in rice plants and results in bigger panicles.
- Ensures nitrogen availability beyond the flowering stage when applied at an appropriate rate.

Contribution of UDP to Income and Employment Generation in Bangladesh

Year (July-June)	UDP Briquette Sales (tons)	UDP Area Coverage (ha)	UDP[a] Employment Generation (person years)	Increased Paddy Production (tons)	Gross Value of Increased Paddy ('000 US $)	Briquetter Machines Sold
1995-96	0.3	2	0.5	2	0.3	-
1996-97	98	610	16	744	88	2
1997-98	1,639	10,180	271	12,419	1,471	20
1998-99	15,691	108,434	2,892	132,290	15,667	212
1999-00	83,000	335,158	8,938	408,893	48,425	303
2000-01	91,840	379,056	10,108	462,448	54,768	116

a. Eight days/ha, one person year = 300 person days.

Source: Bangladesh Department of Agricultural Extension.

- The percentage of UDP users occupying mud houses decreased by 42%, compared with a decrease of 23% among nonusers.
- For the total sample of UDP users, increased rice storage, thus food security, represented the greatest percentage (16.2%) of all 542 benefits expressed. Other benefits and the represented percentages include: payment of educational expenses (12.9%), improved housing (11.8%), improved finances (10.0%), purchases of animals (8.5%), purchases of agricultural equipment (6.5%), purchases of new clothing (5.9%), new or improved small businesses (4.1%), purchases of household appliances (3.3%), improved household furnishings (3.0%), and installation of tube wells (3.0%). These benefits represent 85.0% of all qualitative benefits expressed by UDP users in the post-intervention period and represent fulfilled life wishes.
- Marginal net benefits from the trials were found to average $103/ha during the dry season and $80/ha during the rainy season.

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Environmental Impact

Deep placement of urea fertilizer has not only a positive agronomic and socioeconomic impact but also an environmental benefit. The observed environmental benefits are as follows:

- Runoff loss of nitrogen was reduced as indicated by negligible amounts of nitrogen measured in the floodwater although broadcast or incorporated prills continued to produce high amounts of nitrogen in the floodwater.
- Measurements of nitrogen in the floodwater showed that ammonia volatilization losses were practically eliminated with deep placement. Broadcasting or incorporating prills continued to produce high amounts of nitrogen in the floodwater.
- Reduced nitrification-denitrification resulted from placement of the nitrogen in the oxygen-depleted soil layer; thus, emission of nitrous oxide was reduced.

Conditions That Make Urea Deep Placement Highly Beneficial

- **Labor is readily available and economical.**
- **The soil has low permeability and percolation (<1 cm per day).**
- **The soil has high clay content (associated with percolation).**
- **The soil has moderate-to-high cation exchange capacity.**
- **The soil exhibits neutral or alkaline pH (common with flooded conditions).**
- **The location has high rainfall (monsoon season) that can lead to high potential for runoff loss.**

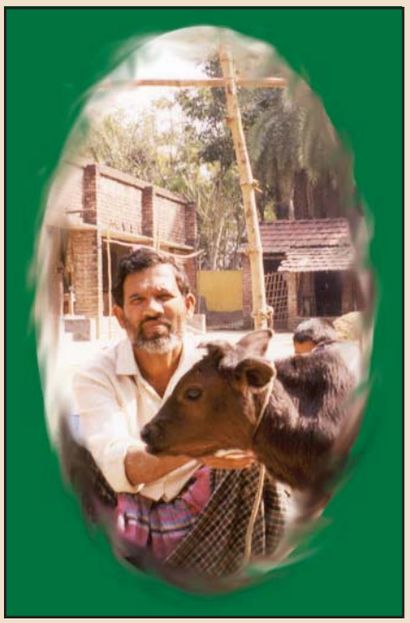
Urea Deep Placement—The Answer for Small, Poor Farmers Like Abdul Jalil

IFDC has demonstrated that a wide range of benefits can be expected from the use of UDP in appropriate locations. The approach brings about a 25% increase in urea efficiency that leads to approximately 35% improvement in revenues as compared with prilled urea.

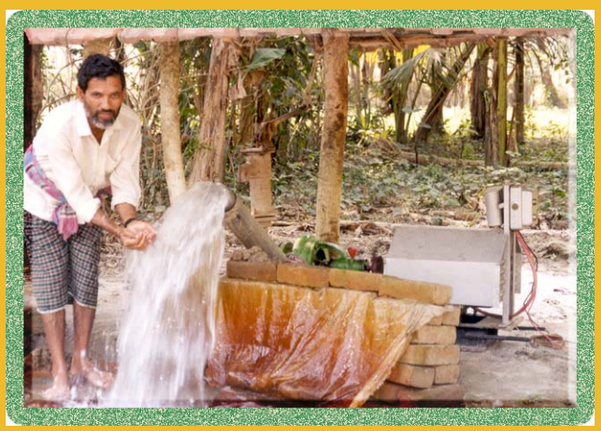
IFDC has objectively demonstrated that UDP can help poor rural farmers improve rice yields, for example, 1,000 kilograms more per hectare during irrigated dry seasons and 750 kilograms more per hectare during wet seasons. These yield increases can be gained by using one-third less urea than the recommended rate. For many small landholders, that means food self-sufficiency and food security.

Once households are food secure, increased productivity can contribute to improvements in the quality of life (for example, increased educational opportunities for children, improvement in housing, crop diversification, and increased livestock numbers).

Many small landholders like Bangladeshi rice farmer Abdul Jalil are adopting the practice. In Bangladesh UDP technology has been adopted on about 350,000 hectares over a period of 8 years. To meet the demand for producing USG, local entrepreneurs are fabricating the village-level briquetters, and there are more than 1,000 locally manufactured machines that can be used to produce USG briquettes.



Targeted Benefits of Adoption of UDP Technology



- **For Farmers:** UDP technology decreases production costs, increases yield, improves household food security, and increases profit.
- **For Entrepreneurs:** The technology provides a new profitable business and opportunity to contribute to economic development.
- **For the National Economy:** UDP increases rural employment and paddy production, saves urea, and increases gross domestic product.
- **For the Environment**: The technology decreases air and water pollution.

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