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# Accessing Role of Urea Briquettes Fertilizer for Enhancing Nitogen Use Efficiency and Crop Productivity

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Enhancing nitrogen efficiency in lowland rice cultivation while mitigating environmental impacts is imperative. Traditional urea application methods lead to significant nitrogen losses. Urea briquettes offer a solution by gradually releasing nitrogen in the ammonium form, minimizing losses through leaching, volatilization, and denitrification. Field trials demonstrate their superiority over prilled urea, with higher yields and increased nitrogen uptake. Binding agents like neem and karanj oils enhance briquette strength, allowing for mechanical applicator use. Utilizing local industrial wastes as filler materials improves briquette quality. To address adoption barriers, National Rice Research

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Institute, Cuttack has developed and evaluated five mechanical applicators. These include continuous and non-continuous types, each designed for specific application scenarios. Extensive testing assessed their performance in terms of speed, capacity, and placement uniformity. The development of user-friendly, cost-effective applicators is a critical step towards wider adoption of urea briquettes. These innovations streamline the labor-intensive application process and cater to the needs of smallholder farmers. Future research should focus on refining applicator designs for varied soil conditions and crop stages. Additionally, optimizing briquette formulations based on local resources can further enhance efficiency and reduce costs. Overall, urea briquettes coupled with efficient applicators represent a promising approach for sustainable rice cultivation. By reducing nitrogen losses and improving efficiency, they contribute to higher yields and environmental preservation. Continued efforts in research, development, and promotion are essential to realize the full potential of this technology and ensure its widespread adoption among farmers.

*Keywords: Briquettes; denitrification; Karanj oil; nitrogen use efficiency; urea; volatilization.*

## 1. INTRODUCTION

Rice cultivation stands as a cornerstone of food production in Southeast Asia, but meeting the escalating global demand necessitates a 1.2-2.4% yearly increase in rice yields. However, conventional methods of nitrogen (N) application, essential for rice growth, often result in environmental degradation. While each kilogram of rice grain typically requires 15–20 grams of nitrogen, excessive nitrogen application can lead to pollution. Nitrogen deficiency poses a significant challenge to lowland rice production, exacerbated by the inefficient use of nitrogen fertilizers due to losses through leaching, volatilization, and denitrification, especially in flooded rice soils. The unique soil environment of flooded lowland rice, characterized by alternating aerobic and anaerobic conditions, accelerates nitrogen loss processes. Although urea is commonly used due to its affordability and high nitrogen content, its rapid hydrolysis upon application results in nitrogen losses through nitrification and volatilization. This contributes to low nitrogen recovery efficiencies, typically ranging from 30–50%. Despite extensive research, the efficiency of nitrogen fertilizer utilization in lowland rice remains relatively low due to losses through leaching, volatilization, and denitrification, particularly in flooded rice soils. Urea, favored for its high nitrogen content, affordability, and favorable physical properties, is widely used in rice cultivation. Nonetheless, a significant drawback of urea application lies in its rapid hydrolysis upon broadcasting in rice fields, leading to nitrogen losses through nitrification. Prilled urea, with its larger surface area, exacerbates these losses, with 55–70% of applied nitrogen escaping into the atmosphere or leaching into water bodies. To mitigate such losses and enhance nitrogen use efficiency, there is growing interest in the deep placement of larger-sized urea granules. This approach not only boosts fertilizer efficiency but also offers environmental benefits by reducing nitrogen runoff and volatilization.

Different strategies have been explored to improve the efficiency of nitrogen utilization in rice cultivation, including the use of deep placement or slow-release formulations such as super granules, mudballs, briquettes, and coated urea. Specifically, researchers have investigated the efficacy of urea briquettes, which are formulated by blending urea with low-cost filler materials and binding agents. In efforts to optimize the application of urea briquettes, various mechanical applicators have been developed by ICAR-NRRI, Cuttack, including single-row, two-row, and three-row models, as well as injector-type and top-dressing mechanical applicators. These innovations aim to enhance the precision and effectiveness of urea briquette placement in rice fields, ultimately improving nitrogen use efficiency and reducing environmental impact.

## 2. UREA BRIQUETTES/UREA PELLETS/ UREA SUPER GRANULES

Urea super granules, typically produced through either melt granulation or mechanical compaction methods, contain 46% nitrogen in the form of amide. These super granules, shaped like oval pellets or briquettes weighing 1-2 grams, are created using a briquette or pellet making machine. Research indicates that depending on the agricultural climate and nitrogen application rates, deep-placed urea super granules can significantly outperform traditional prilled urea fertilizer. Studies have demonstrated that these super granules have the potential to save up to

65% of urea fertilizer while also boosting grain yields by up to 50%, particularly when used at lower nitrogen application rates [1]. This suggests a promising avenue for enhancing agricultural productivity and efficiency.

Both urea super granules and urea briquettes outperformed sulfur-coated urea, neem cake-coated urea, and prilled urea in terms of crop yield and nitrogen uptake [2]. Additionally, deep placement of urea super granules resulted in an 8 to 18% increase in grain yield compared to broadcasting prilled urea [3].Urea super granules were also observed to inhibit nitrification for up to seven weeks and significantly reduce emissions of both ammonia (NH) and nitrous oxide (NO), by up to 94%, in comparison to regular urea .The recovery efficiencies of applied nitrogen (N) for lowland rice in tropical regions typically fluctuate between 30% and 50%, depending on factors such as the season, yield level, and the rate and timing of N application [4].

With support from the International Fertilizer Development Center (IFDC), the technology for urea super granules has been extensively trialed and endorsed across various regions of South Asia, notably in Bangladesh, where it is commonly referred to as Guti urea technology. According to a study, lands treated with Guti urea technology yield three times better results compared to lands where urea is manually sprayed using traditional methods. This not only enhances agricultural productivity but also leads to significant profits for farmers [5].

## 3. MECHANISM OF UREA BRIQUETTES

Transplanting and simultaneous deep placement of fertilizer were conducted, where the coated fertilizer exhibited gradual dissolution of N granules at a depth of 3-5 cm into the soil and positioned 4-5 cm away from the seedlings [6]. Urea briquettes are a form of controlled-release nitrogen fertilizer designed to enhance nitrogen use efficiency in lowland rice cultivation. When urea briquettes are placed at a depth of 5-7 cm in the soil, they release nitrogen gradually over an extended period. This gradual release mechanism works as follows:

1. The compacted urea briquettes dissolve slowly in the soil moisture, releasing urea into the soil solution.

2. The urea undergoes hydrolysis, converting it into ammonium ($NH_4^+$) ions.

3. Since the briquettes are placed in the reduced zone of the soil (below the oxidized surface layer), the ammonium ions are protected from rapid nitrification (conversion to nitrate) and subsequent denitrification losses.

4. The ammonium ions are gradually made available to the rice plants through diffusion and cation exchange with the soil particles, ensuring a steady supply of nitrogen throughout the crop growth period.

This slow release and controlled availability of nitrogen from urea briquettes reduce losses through leaching, volatilization, and denitrification, which are common in traditional broadcast application of prilled urea in lowland rice fields. Consequently, urea briquettes improve nitrogen use efficiency, increase crop yields, and minimize environmental pollution.

## 4. PREPARATION OF UREA BRIQUETTES

**Raw Material Procurement:** The first step involves procuring the raw materials required for making urea briquette fertilizers. The primary ingredient is urea, which is a common nitrogenous fertilizer and the desired filler material (e.g., phosphogypsum, fly ash, silica powder, neem cake, or rice husk) in the required proportions.

**Selection of Binders and Additives:** Binders and additives are selected based on their compatibility with urea and their ability to form stable briquettes. Common binders include bentonite, lignosulfonates, and starch**.** Addition of commercially available biodegradable and water-soluble binder at the rate of 10-15% of the total solid material.

**Mixing:** Urea is mixed thoroughly with the selected binders and additives in a mixing chamber. The proportions are carefully controlled to ensure uniform distribution of ingredients. If oils like neem or karanj are used as binding agents, thoroughly mix the oil (at a rate of 40 ml per 1 kg urea) with the granular urea before compaction.

**Moistening:** The mixture is moistened to achieve the desired consistency for briquetting. The moisture content is critical for the binding process and determines the strength of the briquettes.

**Briquetting:** The moistened mixture is fed into a briquetting machine where it is compressed under high pressure to form briquettes of uniform size and shape. The pressure applied during this process ensures proper binding of the ingredients**.**

**Drying:** The freshly formed briquettes are transferred to a drying chamber where they are dried to remove excess moisture. Proper drying is essential to prevent the briquettes from crumbling and to enhance their shelf life.

**Cooling:** After drying, the briquettes are cooled to room temperature to stabilize their structure and improve handling characteristics.

**Sizing:** The cooled briquettes may undergo sizing to ensure uniformity in shape and size. This step involves removing any oversized or irregularly shaped briquettes.

**Quality Control:** Quality control measures are implemented at various stages of the manufacturing process to ensure that the final product meets the required standards. This may include testing for moisture content, binding strength, and nutrient composition.

**Packaging:** Once the briquettes pass quality control checks, they are packed into appropriate packaging materials such as plastic bags or sacks. Proper packaging helps protect the briquettes from moisture and contamination during storage and transportation.

**Labelling:** Each package is labelled with relevant information such as product name, nutrient content, usage instructions, and manufacturer details. Clear labelling helps consumers identify and use the product correctly.

**Storage:** The packaged urea briquette fertilizers are stored in a dry, well-ventilated warehouse to maintain their quality and freshness. Proper storage conditions help prevent moisture absorption and degradation of the product.

## 5. SPECIAL PROTOCOLS FOLLOWED IN NRRI, CUTTACK FOR PREPARATION OF BRIQUETTES

Enhancing fertilizer utilization efficiency can be achieved by coating synthetic fertilizers with a substance designed to delay the release of nutrients, known as slow-release fertilizer [7,8]. Nutrient release from coated fertilizers primarily happens via a diffusion process that traverses permeable or semi-permeable coatings [7,9]. The physical attributes of coating materials, such as their size, shape, and surface, also influence the patterns of nutrient release [7,10]. At NRRI, urea briquettes were prepared using a mechanical compaction method with a specialized urea briquetting machine. To enhance the strength of the briquettes and reduce their susceptibility to breaking, urea was thoroughly mixed with neem (*Azadirachta indica*) and karanj (*Pongamia pinnata*) oils at a rate of 40 ml per 1 kg of urea before compaction. These oils not only serve as effective binding agents but also contain active ingredients known to inhibit nitrification activity in the soil. The addition of oil resulted in a significant decrease in the percentage of broken briquettes, reducing it to only 2-5% compared to 25-30% for urea pellets without a binding agent.

Organic materials possess attributes that make them highly promising as fertilizer coating materials. Organic acids can directly or indirectly bind nutrients from fertilizers through chemical reactions or microbial activity and the decomposition of microbial biomass [11,12,13]. Organic matter is recognized for its ability to retain water effectively [14]. On the other hand, Coal fly ash, being a mineral, is acknowledged for its relatively lower water retention capacity [15,16]. Various materials such as phospho-gypsum, fly ash, silica powder, azolla, neem cake, and rice husk have been utilized as amendments. These amendments were combined with urea using a commercially available biodegradable and water-soluble binder. Increasing the proportion of fly ash or decreasing the proportion of azolla biomass tends to enhance the compressive strength and bulk density, while simultaneously reducing the water holding capacity and porosity of the resulting briquette fertilizers [17]. The proportions of urea, amendments, and binder were carefully measured out. In a tray, urea fertilizer and the selected amendment were mixed together according to specified ratios. The binder was then added at a rate of 10-15% of the total solid material. After thorough mixing, the materials were allowed to sit for one hour before preparing the briquettes. However, in the case of a mixture of urea and rice husk, the materials were left for one day after the binder was added before forming the briquettes.

## 6. METHOD OF APPLICATION OF UREA BRIQUETTES

Urea briquettes or pellets are typically manually placed at a depth of 7-10 cm in the soil, with one briquette near the centre of every four rice hills, following IFDC guidelines. Non-continuous injector-type urea briquette applicators are generally less labour-saving compared to continuous operation-type applicators. IFDC has developed a non-continuous injector-type applicator made from polyvinyl chloride (PVC) pipe, which is lightweight, simple to use, and cost-effective However, this type of applicator often faces operational challenges due to soil clogging at the injector mouth, hindering the smooth release of briquettes into the soil.

Until now, there hasn't been an applicator readily available that is both easy to use and efficient for deep placement of urea briquettes in rice fields with varying soil conditions. Therefore, further research is needed to develop and standardize user-friendly, cost-effective applicators suitable for different rice-growing regions, taking into account factors such as soil type, rice variety, and crop growth stage.

Additionally, the effectiveness and efficiency of briquettes depend on various other factors, including the strength and durability of the briquette to prevent breakage during application, the urea concentration in the briquette to ensure even distribution of nitrogen to crops without causing burning injury, and the rate of nitrogen release to meet the crop's timely requirements**.**

## 7. UREA BRIQUETTE APPLICATORS DEVELOPED AND EVALUATED BY NRRI, CUTTAK

Recognizing the challenges of labor-intensive manual application and lack of user-friendly applicators as major bottlenecks for wider adoption of urea briquettes, researchers at NRRI undertook efforts to develop and evaluate efficient mechanical applicators. A total of five hand-operated applicators were designed and tested, three being continuous-type applicators and two non-continuous injector-type applicators.

**Manually pulled two-row briquette applicator (UBA-I):** The manually pulled two-row briquette applicator (UBA-I) consists of two hoppers, a frame, two cup-type metering rollers, one axle, one ground wheel, and one handle. It is constructed using angle iron and GI sheets. This applicator can be utilized for both basal and top-dressing applications. Removable furrow openers are fitted for both rows, and the row-to-row spacing is adjustable between 350-400 mm. During operation, the skids work in the middle of alternate plant rows, distributing briquettes evenly between rows.

**Manually pulled three-row urea briquette applicator (UBA-II):** The manually pulled three-row urea briquette applicator (UBA-II) features three hoppers, a frame, three cup-type metering rollers, one axle, one ground wheel, and one handle. Made from angle iron and GI sheets, this applicator is suitable for basal application only. Removable furrow openers are fitted for all three rows, and two ground wheels support the applicator from both ends. The four cups in the metering unit ensure uniform placement of urea briquettes.

**Manually pulled four-row drum-type urea briquette applicator (UBA-III):** The manually pulled four-row drum-type urea briquette applicator (UBA-III) comprises two drums, a frame, one axle, two ground wheels, and one handle. Constructed using angle iron, GI sheets, and MS flats, this applicator is useful for basal application. Its working principle is similar to a drum seeder, where the operator pulls the applicator, causing the urea briquettes filled in the drums to drop onto the field uniformly. Two ground wheels support the applicator from both ends, and a float enables easy movement in puddled field conditions.

**The urea briquette applicator mounted on a conoweeder (UBA-IV):** The urea briquette applicator mounted on a conoweeder (UBA-IV) is an attachment designed for top-dressing. It consists of two cones, one float, one briquette hopper, a briquette delivery control system, and one handle, made from angle iron, GI sheets, and MS flats. This applicator allows for simultaneous weeding between rows and urea briquette application. The operator pushes the weeder and engages a clutch fitted on the handle at intervals to drop one or two urea briquettes at a time.

**Injector-type briquette applicator (UBA-V):** The injector-type briquette applicator (UBA-V) is a simple hand-held device suitable for both basal and top-dressing applications. It comprises a funnel, delivery tube, plunger assembly, and depth control ring made from PVC pipes and MS flats. The operator places urea briquettes in the funnel and pushes the handle to inject them 5-6 cm deep into the soil. This light-weight and easy-to-carry applicator is particularly beneficial for small landholding farmers.

## 8. ENHANCING NITROGEN USE EFFICEINCY IN LOWLAND RICE CULTIVATION USING UREA BRIQUETTES

Based on data provided by National Rice Research Institute, Cuttack, application of urea briquettes enhances nitrogen use efficiency in lowland rice cultivation through several mechanisms:

**Controlled release:** When urea briquettes are placed at a depth of 5-7 cm in the reduced soil zone, the urea dissolves and hydrolyses gradually, releasing ammonium ions over an extended period. This controlled release prevents the rapid conversion of ammonium to nitrate, reducing losses through leaching, volatilization, and denitrification.

**Reduced nitrogen losses:** Field trials showed that deep placement of urea briquettes significantly reduced nitrogen losses compared to broadcasting prilled urea. For instance, nitrous oxide emissions were reduced by 17.7-23.1%, and ammonia volatilization was lowered by up to 61.6% when using urea briquettes.

**Improved nitrogen uptake and recovery:** The controlled release and reduced losses result in improved nitrogen uptake by the rice plants. Field trials demonstrated 8.7-22.8% higher nitrogen uptake with urea briquettes compared to prilled urea broadcasting. The nitrogen recovery efficiency, which measures the proportion of applied nitrogen taken up by the crop, was also substantially higher, ranging from 42.8-54.7% with briquettes, compared to 26.8-38.3% with prilled urea.

**Higher yields:** The enhanced nitrogen use efficiency translates into increased grain yields. Across multiple field trials, the yield increase with urea briquettes ranged from 16.8-19.7% over broadcasting prilled urea and 8.2-12.6% over neem-coated urea.

**Agronomic efficiency:** The agronomic nitrogen use efficiency, which measures the yield increase per unit of applied nitrogen, was significantly higher with urea briquettes, ranging from 23.6-30.2 kg grain per kg N applied, compared to 13.1-19.7 kg grain per kg N with prilled urea broadcasting.

The utilization of deep-placed NPK briquettes results in the accumulation of nutrients within the lower soil layers, facilitating efficient uptake by rice plants, leading to enhanced growth and increased yield. Consequently, the adoption of NPK briquettes promotes balanced fertilization, conserves fertilizers, mitigates environmental pollution, and can be regarded as environmentally friendly technology [18].

## 9. ADVANTAGES OF USING UREA BRIQUETTES/PRILLED UREA

**Enhanced nitrogen use efficiency:** Urea briquettes offer improved efficiency in nitrogen utilization compared to conventional methods, leading to optimal nutrient uptake by crops.

**Reduced nitrogen loss:** Briquettes help minimize nitrogen loss through leaching, volatilization, and denitrification, thereby preserving soil fertility and minimizing environmental pollution.

The deep placement of urea fertilizer emerges as an effective application method for reducing total nitrogen loss in floodwater, with the likelihood of minimizing losses through volatilization and surface runoff [19].

**Controlled release**: Briquettes provide a controlled release of nitrogen, ensuring a steady supply of nutrients to plants over an extended period, promoting sustained growth and development.

**Customizable formulations:** Briquettes can be formulated with various filler materials and binding agents to suit specific soil conditions, crop requirements, and environmental concerns, offering flexibility in application**.**

**Precision placement:** Mechanical applicators allow for precise placement of urea briquettes, ensuring optimal distribution within the root zone of plants for maximum nutrient uptake and minimal waste.

**Cost-effectiveness:** Briquettes offer a cost-effective alternative to traditional nitrogen fertilizers, providing farmers with an economical solution for enhancing crop productivity while reducing input costs**.**

**Environmental sustainability:** By minimizing nitrogen losses and reducing the need for frequent applications, urea briquettes contribute to sustainable agriculture practices and environmental conservation.

**Reduced labour requirements:** Mechanical applicators streamline the application process, reducing the labour intensity associated with traditional broadcasting methods, thereby improving operational efficiency.

**Improved crop yields:** The controlled release of nutrients from briquettes promotes healthier plant growth, leading to increased crop yields and improved overall farm profitability. The application of urea super granules deep placement led to an additional grain yield of 1080, 510, and 350 kg ha-1 compared to prilled urea split in alternate wetting and drying, shallow lowland, and intermediate lowland conditions, respectively [20].

**Adaptability to different crops and soils**: Urea briquettes can be tailored to meet the specific nutrient requirements of different crops and soil types, making them a versatile option for a wide range of agricultural applications.

## 10. CHALLENGES

Despite advantages, challenges with urea briquettes include initial investment for mechanical applicators, complexity in customizing formulations, risk of nutrient imbalances, residual nitrogen pollution, and dependence on machinery prone to breakdowns. Addressing these challenges is vital for ensuring effective and sustainable implementation in agricultural practices.

## 11. CONCLUSION

Urea briquettes offer a ray of hope for better rice farming, promising improved yields and eco-friendly practices. Deep placement of urea briquettes at a depth of 5-7 cm significantly enhances yield and nitrogen use efficiency while substantially reducing nitrogen losses through nitrous oxide emissions and ammonia volatilization. This controlled-release mechanism ensures a steady supply of nitrogen throughout the crop growth period, minimizing environmental pollution and saving on fertilizer costs for farmers. Urea briquettes can be produced at the village level using briquetting machines, making the technology accessible to smallholder farmers. Locally available industrial or biological wastes like fly ash, phosphor gypsum, and neem cake can be utilized as filler materials along with suitable binders to optimize urea concentration and improve briquette strength without compromising efficiency. Though facing hurdles like initial costs and machinery issues, their benefits shine through enhanced efficiency, less nitrogen loss, and controlled release. With innovation and support, these briquettes can truly transform farming, providing farmers with cost-effective and environmentally friendly options to meet the growing demand for food production in Southeast Asia and beyond.

## FUTURE PROSPECTS

Despite the promising agronomic benefits, widespread adoption of urea briquettes has been hindered by the labor-intensive nature of manual deep placement and the lack of user-friendly applicators. Future research should focus on developing power-operated applicators for both basal and top-dressing applications, reducing the drudgery involved in this operation. These applicators should be designed to be cost-effective, easy to use, and capable of uniform placement in varying soil conditions and crop growth stages. Further fine-tuning of briquette formulations with different combinations of filler materials and binders may also be explored to optimize nitrogen release patterns for specific rice-growing regions. Additionally, economic analyses and extensive farmer participatory demonstrations should be conducted to assess the feasibility and promote the adoption of this technology among smallholder rice farmers in different agro-ecological zones.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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