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Research Paper

Comparative assessment of urea briquette applicators on greenhouse gas emission, nitrogen loss and soil enzymatic activities in tropical lowland rice

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ABSTRACT

Suitable method of application of urea briquette in flooded rice (*Oryza sativa* L.) not only increases nitrogen use efficiency, but at the same time sustain yield and reduce greenhouse gas emission in general and nitrous oxide emission in particular. Keeping this hypothesis, seven different treatments including manual and mechanical mode of application with two different type of applicators were tested in field in consecutive wet (2015) and dry (2016) seasons. Three row briquette applicator (TRBA) and top dressing applicator (TDA) were used in combination for basal and top dressing application along with prilled urea broadcasting and without application as well. It was observed the use of TRBA at basal with first top dressing by TDA and manual placement of urea briquette at second top dressing (TRBA + TDA) yielded highest @ 6.71 t ha^{-1} and 5.47 t ha^{-1} in the wet and dry seasons, respectively, with the highest agronomic use efficiency (36.3 kg kg^{-1}). Average emission of methane from all treatments were higher (19.2–27.1%) during wet season than the dry season and *vice versa* in case of nitrous oxide (3.6–11.8%). Among the treated plots, TRBA + TDA recorded the lowest emission of nitrous oxide. The largest amount of ammonia was lost through volatilization after basal application of urea, followed by top dressing at the end of maximum tillering stage and panicle initiation stage. As a whole, volatilization loss of N was lowest in control (3.3–3.4 mg NH_3-N m^{-2} d^{-1}), followed by mechanical (27.6–33.9 mg NH_3-N m^{-2} d^{-1}) and manual (49.1–55.3 mg NH_3-N m^{-2} d^{-1}) method of urea briquette application. The population of nitrite oxidizers and heterotrophs were highest in prilled urea broadcasting. Soil dehydrogenase activity was the highest in urea briquette manual placement + top dressing applicator (UBMP + TDA, 148.0 μg–160.0 TPF g^{-1} soil d^{-1}) treatment, while the urease activity was less was in urea applicator treated plots. Subsurface application of larger size urea (urea briquette) and applicator based precise placement of urea reduced the lossess of nitrogen through ammonia volatilization and nitrous oxide emission, thus enhanced nitrogen use efficiency. Apart from that, issue of adequate skilled labour for precise depth of application could be tackled by effectively adopting mechanical placement of urea briquette. The mechanical placement of briquette (relatively larger size particle) in tropical flooded rice is more precise and less labour intensive, hence this is an efficient environment friendly approach of N management.

1. Introduction

Rice (*Oryza sativa* L.) is the major staple food crop in tropics. The production of rice needs to increase annually by 1.2–2.4% during the next decade to meet global demand of world population (Ray et al., 2013). Rice needs 15–20 kg nitrogen (N) to produce one ton of rice grain when all other factors for are not limiting (Dobermann, 2004). Increase in N application can increase the yield of rice, but may aggravate the environmental pollution through denitrification (N_2 and N_2O), leaching (NO_3^-) and volatilization (NH_3) (Watanabe et al., 2009; Zhao et al., 2009). Gaseous N_2O, NH_3 and NOx have large potentials for global warming, stratospheric ozone layer depletion and acid deposition (Khalil, 2010).

Urea is the cheapest N fertilizer and most commonly used. Being an alkaline-hydrolyzing fertilizer, application of urea raised the pH of the soil zone of its contact and intensify the denitrification process to release of large volumes of N_2O as well as NH_3 and NOx (Mulvaney et al., 1997; Khalil et al., 2009). Having larger surface area, the use of prilled urea (PU) increases the problem. Only 30–45% of the applied prilled urea is used by the plant and the remaining part is lost in air or water

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(Dong et al., 2012). Various types of losses are also influenced by the method of application of urea. Broadcasting of PU results in higher amounts of ammonium (NH_4^+) N in floodwater compared with deep placement of PU which inturn increases NH_3 volatilization (Kapoor et al., 2008; Huda et al., 2016). Deep placement of urea has not only enhanced its use efficiency, but also provide an environmental benefit by reducing runoff and volatilization losses of nitrogen. Moreover, emission of nitrous oxide is also reduced by curbing nitrification-denitrification resulted from placement of the nitrogen in the oxygen-depleted soil layer. However, the problem associated with deep placement of urea is this method is a labour intensive process (Rahman et al., 2016).

In the past, various types of N fertilizers and different types of deep placement or slow release form (e.g. supergranules, mudballs, briquettes, coated urea) were developed to increase N use efficiency. However, problems with these technologies were their ineffectiveness of deep placement and at the same time higher cost involvement prevented the technologies to reach at farmers' field and commercialization. In case of briquetted urea due to its less reactive surface area it is hydrolyzed slowly by enzyme-catalysed process and also diffuse slowly outward under aerobic conditions (Khalil, 2010). Deep placement of urea briquette reduces the nitrogen concentration in the floodwater, thereby reduces various losses like ammonia volatilization and runoff and increases the use efficiency of applied urea. On an average deep placement of urea briquette saves about 35% of urea fertilizer and provides additional yield to the tune of 15%–25% (Savant et al., 1992). However, there is a limitation of additional labour costs involved in the manual deep placement of urea briquette in rice crop (Savant and Stangel, 1998; Wohab et al., 2017). Therefore, the use of briquette applicator at basal before planting and at top-dressing could be an easy, less labour intensive, precise (free of human error) and very effective method of urea briquette placement. Keeping view of experiences of past researches and climate change scenario in present time, we have developed and tested different urea briquette applicator for its easy operation, high N use efficiency and less N losses.

On the view point of above literature, we observe a scanty of work, probably none, try to address the briquette applicator for both basal and top dress application of nitrogen in tropical lowland rice soils. Keeping all the above facts in view, a field experiment was conducted with the following objectives: (i) to evaluate the performance of the urea briquette applicator on reduction of N losses, (ii) to assess the effects of deep placement of N on rice yield, N losses and its use efficiency.

2. Materials and methods

2.1. Preparation of urea briquette

Circular shape urea briquettes having diameter 15 mm, thickness 8 mm and weight 1.08 g were used in this experiment. Urea briquette was prepared by mechanical compaction method using a urea briquetting machine. Karanj (*Pongamia pinnata*) oil @ 40 mL per kg of urea was used as binding material to improve the strength (25–30% higher) of briquettes and to reduce the breakability. For uniform and appropriate application of N (80 kg N ha^{-1}), rice husk was used as filler material at the time of briquette preparation in various proportions (Table 1). The ratio of filler material used varied according to the type of applicator i.e. basal or top dressing, enabling to match the rate of application, basal @ 40 kg N ha^{-1} and top dressing @ 20 kg N ha^{-1}. Prepared urea briquettes after adding binder and filler were applied in the field using urea briquette applicator.

2.2. Urea briquette applicators (UBA)

A continuous briquette applicator for basal N i.e. three row urea briquette applicator (TRBA) and one top dressing applicator (TDA) were developed and tested in the study (Fig. 1). The TRBA was fitted with hoppers, frame, cup type metering rollers, one axle, ground wheel and handle fitted in the frame. This applicator operated manually by opening a slit and closes immediately by float after placement of urea briquette. Both side ground wheels in TRBA enabled continuous dropping of urea briquettes, uniformly in all three rows. This applicator placed the briquettes at 5 cm depth from soil surface. For top dressing application of urea, top dressing urea briquette applicator (TDA) was used, which was an attachment behind the cono-weeder to apply urea briquettes simultaneously with weeding operation. It comprised of two cones, one float, one briquette hopper, briquette delivery control system, and one handle fitted in the frame. The TDA work as cono-weeder, but operator has to push the clutch fitted on the handle at fixed interval to place urea briquettes (Fig. 1). The TRBA and TDA worked at average operating speed of 0.92, and 1.4 km h^{-1} and the effective field capacity recorded as 0.082, and 0.025 ha h^{-1}, which can save time up to 82.8%, and 42.8% over hand application respectively (Table 1).

2.3. Experimental set up

Field experiment was conducted during 2015–16 at ICAR-National Rice Research Institute, Cuttack (20° 26′ 58.7″ N latitude, 85° 56′ 3.03″ E longitude and 17 m above mean sea level). The soil of the experimental site is an Aeric Endoaquept with sandy clay loam texture (30.9% clay, 16.6% silt, 52.5% sand), bulk density 1.40 Mg m^{-3}, pH (1:2.5 soil:solution ratio) 6.17, electrical conductivity 227.5 μS m^{-1} and available N 351.2 kg ha^{-1}. Mean annual maximum and minimum temperatures were 32.5 °C and 23.4 °C, respectively during the study period. Annual precipitation was 1290.8 mm of which 87.2% was received during June–September. The experiment was laid out (plot size 30 m^2) in randomized block design with 7 treatments replicated thrice (Table 2). Pooja (150 d) and Naveen (120 d) were the test varieties transplanted during wet and dry season, respectively. Thirty days old seedlings were transplanted at a spacing of 20 cm × 15 cm. A uniform dose of 80, 40 and 40 kg N, P and K ha^{-1} was applied during both the seasons. Full dose of P and K and half of the N was applied as basal at the time of final puddling and remaining N was applied in two equal splits at maximum tillering and panicle initiation stage. The field was continuously flooded (5–6 cm) with water, which was drained 10 days before harvesting. The whole crop growth stages in both the seasons were classified as active tillering (AT), maximum tillering (MT), panicle initiation (PI), flowering (FL), and grain filling (GF) stages based on their critical physiological growth.

2.4. Yield and nitrogen use efficiency

Plant samples were taken from each plot using 1.0 m^2 quadrate for yield at harvest and averaged. The straw and panicles were air-dried for a week and then cleaned and sun-dried. The rice grain yield was determined with the moisture content being adjusted to 14%, while the straw yield was reported on oven dry weight basis. The harvest index (HI) was calculated by dividing economic yield with the biomass yield and was reported as percentage

$$Harvest\ \ Index\ (HI) = \frac{Economic\ yield}{Biomass\ yield}$$

Total N content of the grain and straw were analyzed using the modified microkjeldahl method (Bremner and Mulvaney, 1982). Nitrogen uptake was determined by multiplying the grain and straw yield with their respective nitrogen content and expressed in kg ha^{-1}. Partial factor productivity (PFP), agronomic use efficiency (AEN), physiological efficiency of nitrogen (PEN) and recovery efficiency of nitrogen (REN) were calculated by the procedure stated by Dobermann (2005).