Improving nitrogen use efficiency of irrigated rice (*Oryza sativa* L.): use of Stabilized Urea

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Abstract
Agronomic efficiency of N (AE_N) in rice cultivation ranges from 20-40 % due to heavy losses of applied N. Dicyandiamide (DCD) and N-(n-butyl) thiophosphorictriamide (NBPT) are used for some crops to enhance the efficiency of urea fertilizer and reduce ammonia volatilization, respectively. The DCD and NBPT were evaluated in combination with different levels of the recommended rate of urea by the Department of Agriculture (DOA), Sri Lanka to examine the (AE_N) in irrigated rice (*Oryza sativa* L.), conducting a pot experiment. As treatments, three levels of urea (100 % (225 kg Urea/ha), 75 % and 50 % of the DOA recommended rate) in the form of urea, and inhibitor compound with four levels (no compound, only NBPT, only DCD and combination of NBPT + DCD) and a control of no urea applied, were arranged in a Completely Randomized Design (CRD) with three replicates. The DCD and NBPT rates were 10 % and 1 % of the amount of urea used, respectively. Results showed that 50 % urea with inhibitors had no significant yield reduction ($P>0.05$) compared to 100 % urea alone, with a greater AE_N. Thus, application of urea with DCD and NBPT lead to a significant reduction in amount of urea application.

Key Words
Agronomic efficiency of nitrogen, nitrification inhibitors, urease inhibitors, DCD, NBPT, rice

Introduction
Sri Lanka has imported 624,491 mt of solid fertilizer in 2012 and amount of urea was 302,831 mt (Weerarathne, 2014). The recovery of applied nitrogen (N) to wetland rice is around 20-40% (Vlek *et al.*, 1986). Addition of grain yield per kg N applied, over no N is as low as 10 kg kg^{-1}N (Sirisena *et al.*, 2001). Considerable amount of N is lost through volatilization, nitrification and de-nitrification when compared to that of leaching (Nielsen, 2006). In this scenario stabilized N fertilizers can be adopted effectively to minimize N losses. Stabilized N fertilizers are products, where a substance is added to the fertilizer which can extend the time that the nitrogen component of the fertilizer remains in the soil in urea or ammonium form, (Watson, 2013). Although there are many compounds available as urease or nitrification inhibitors, only few meet the requirement of being effective at low concentrations, nontoxic, stable, inexpensive and compatible with standard N fertilizers (Watson, 2013). Urease inhibitors delay the rate of urea hydrolysis to NH_4^+ and prevent high pH and NH_4^+ concentrations in soil which are conducive to NH_3 volatilization (Watson, 2013). Nitrification inhibitors slow down the rate of biological oxidation of NH_4^+ to NO_3^- and thereby reduce NO_3^- leaching and the production of NO and N_2O by both nitrification and de-nitrification (Watson, 2013).Thus, this study was focused on increasing agronomic efficiency of N (AE_N) in rice by the use of stabilized urea treated with NPBT and DCD as N stabilizers.

Materials and Methods
Glasshouse pot experiment was conducted at the University Experimental Station, Dodangolla, Kundasale in the Mid Country Intermediate Zone (IM3a) of Sri Lanka during July-November, 2015. Location coordinates are N 7' 10' E 80' 38' and elevation is 580 m above mean sea level with mean maximum and minimum temperatures of 33 ºC and 22.3 ºC, respectively. The experiment was a two factor factorial where factors were N fertilizer with three levels (50%, 75% & 100% of the Department of Agriculture (DOA), recommended rate) in the form of urea, and inhibitor compound with four levels (no compound, only NBPT, only DCD and combination of NBPT + DCD) and a control of no urea and inhibitors applied, arranged in a Completely Randomized Design (CRD) with three replications. DOA recommendation (100%) for rice used in the experiment was, urea 225 kg ha^{-1}, TSP 55 kg ha^{-1} MOP 60 kg ha^{-1} and $ZnSO_4^{2-}$ 5 kg ha^{-1}. Three month duration rice variety CIC 3-1 was grown in pots (20 *l*) filled with Low Humic Gley (LHG) soils.

Fertilizer was broadcast sown evenly throughout the pots in split applications. DCD and NBPT were mixed thoroughly with urea granules using a mixer. Proximate soil analysis was done to identify the initial soil nutrient content. Growth parameters at regular intervals and grain yield and yield components were recorded. AE_N was calculated as, AE_N = kg grain yield increase kg^{-1} N applied.

Results and Discussion

Yield components

Significant interaction effect of urea level and inhibitor compounds indicated that different inhibitors responded differently to different rates of urea with respect to number of panicles/m^2 (Fig. 1), number of spikelets/panicle (Fig. 2) and filled grain percentage (Fig. 3).

With the urea alone treatment, the number of panicles/m^2 increased linearly with the increasing rate of urea (from 50% to 100%) indicating a high level of response to added N. When both DCD and NBPT were added to urea, a significant increase in number of panicles/m^2 at 50% rate of urea was observed and as a result, rate of increase in panicles/m^2 when increasing the rate of urea from 50% to 100% was marginal. Thus, applying 50% urea amended with DCD and NBPT showed a comparable number of panicles/m^2 to that achieved by applying 100% urea alone.

With no-inhibitors, increasing urea level (from 50% to 100%) increased the number of spikelets per panicle linearly. This is in agreement with Dobermann *et al.* (2000) who reported that N is an essential constituent to increase spikelets per panicle and percentage filled spikelets in each panicle. However, in this study even when urea application rate decreased down to 50% level with inhibitors, spikelet number per panicle increased to the value at 100% urea alone.

Increasing urea level (from 50% to 100%) with no inhibitors showed a slight reduction in grain filling whereas 50% urea mixed with DCD and DCD + NBPT had higher percentages of grain filling than that of 100% urea alone. Sturm *et al.,* (1994) reported that Nitrification Inhibitors (NI) when added to N fertilizers and applied to the soil delayed the transformation of ammonium to nitrite by inhibiting or at least by slowing the action of *Nitrosomonas* spp. Therefore, when NI is present it may favour the partial ammonium nutrition. Urea rate, inhibitors and urea × inhibitor interaction effects were found to be not significant with respect to thousand grain weight at moisture content of 13%.

Grain yield

Grain yield responded significantly to urea addition where without urea application yield was 3.32 t ha^{-1}.Significant interaction effect of urea level and inhibitor compound indicated that different inhibitors responded differently to different levels of urea (Fig. 4). Urea alone treatment increased grain yield with increasing level of urea from 50 to 100% indicating a high level of response to added N, conforming the need of N application. All the inhibitor treatments increased grain yield when urea level increased from 75 to 100% indicating more N available for the crop. At 50% urea level, grain yield was considerably increased with added inhibitors over no inhibitor treatments recording the highest grain yield in the DCD + NBPT treatment. The grain yield of DCD + NBPT treatment at 50% urea rate was similar to that of 100% urea alone indicating that recommended rate of urea can be cut down by 50% without affecting grain yield if urea is amended with DCD + NBPT. However, adding both DCD + NBPT to 50% urea level performed greater than adding DCD and NBPT alone. Increasing availability of N to the plants through decreasing N losses by inhibitors may be the reason for the above observations. This is in agreement with Trenkel (2010) who cited that rice yield was increased by 9% when DCD + Triazole was used when compared to urea alone. Author also reported that there was a significant reduction in N_2O emissions. Byrnes *et al.* (1995) reported that the use of urease inhibitors added to urea increased the efficiency and reduced ammonia volatilization when surface applied on flooded rice.

AE_N (Agronomic efficiency of nitrogen)

There were no significant difference in AE_N at 75 and 100% N levels when they were applied alone or with different inhibitors. However, the highest AE_N was recorded at 50% urea level amended with both DCD and NBPT while the lowest was recorded in urea alone at 50% urea level, indicating that there is a significant efficiency improvement at 50% urea level with inhibitors, further considerable amount of added N is made available by preventing from losing. At 75% and 100% urea levels rice plant is getting adequate amount of N even with N losses so that saving N by inhibitors has no use. Thus, with respect to $AE_{N,}$ 75% urea level appeared to be the appropriate level of urea for the rice variety CIC 3-1 when cultivated in pots without inhibitors. The reason for this may be that the N loss in pots may be lower than that of in the field so that 75%

of the recommended urea rate may be adequate to fulfil the N requirement of the rice plant cultivated in the pots.

Conclusions

Application of 50% of the recommended rate of urea treated with inhibitors could attain a grain yield similar to that of at 100% of the recommended rate of urea so that 50% of the recommended rate of urea could be saved if urea is applied with DCD and NBPT. AE_N in rice could be increased by reducing N losses through treating urea with inhibitor/s (DCD and/or NBPT) when 50% of the recommended rate of urea is applied

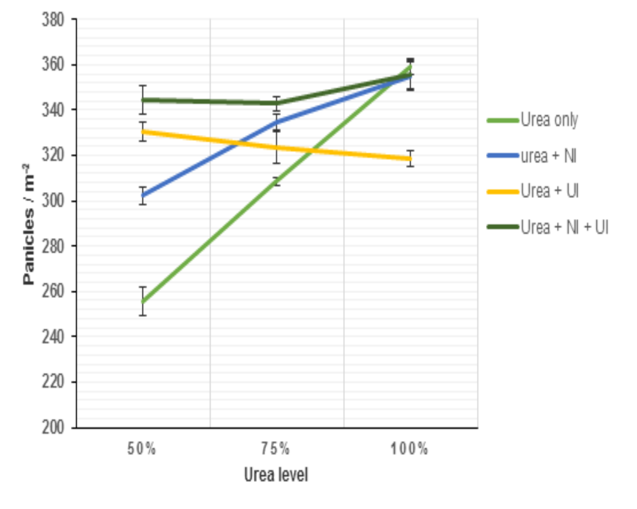

Figure 1Responses of different inhibitors and different rates of added urea on panicles/m^{-2} in rice.

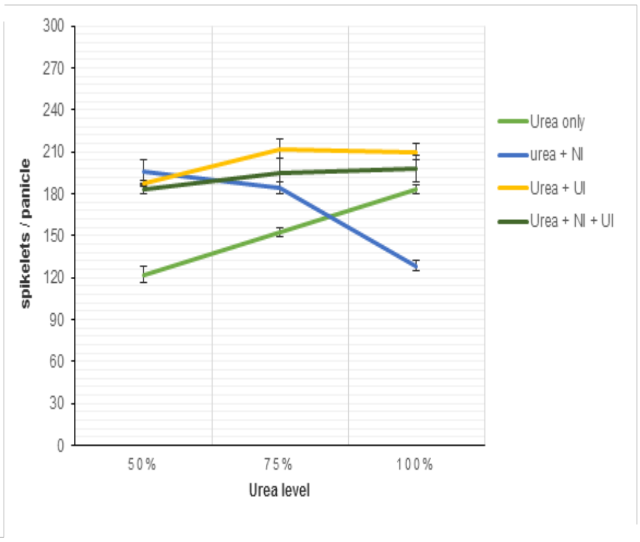

Figure 2 Responses of different inhibitors and different rates of added urea on spikelets per panicle in rice.

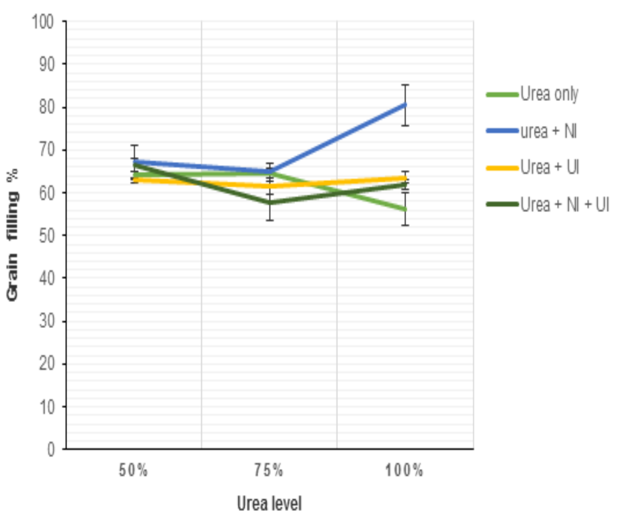

Figure 3 Responses of different inhibitors to different rates of added urea on grain filling percentage in rice.

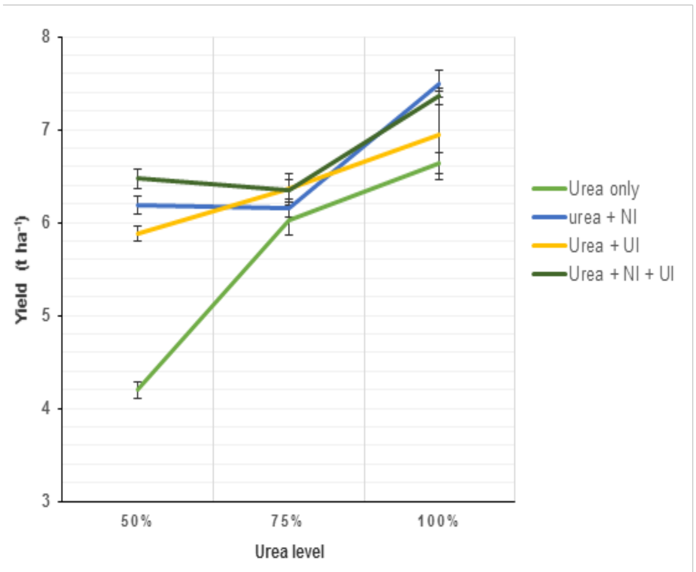

Figure 4 Responses of different inhibitors to different rates of added urea on yield in rice.

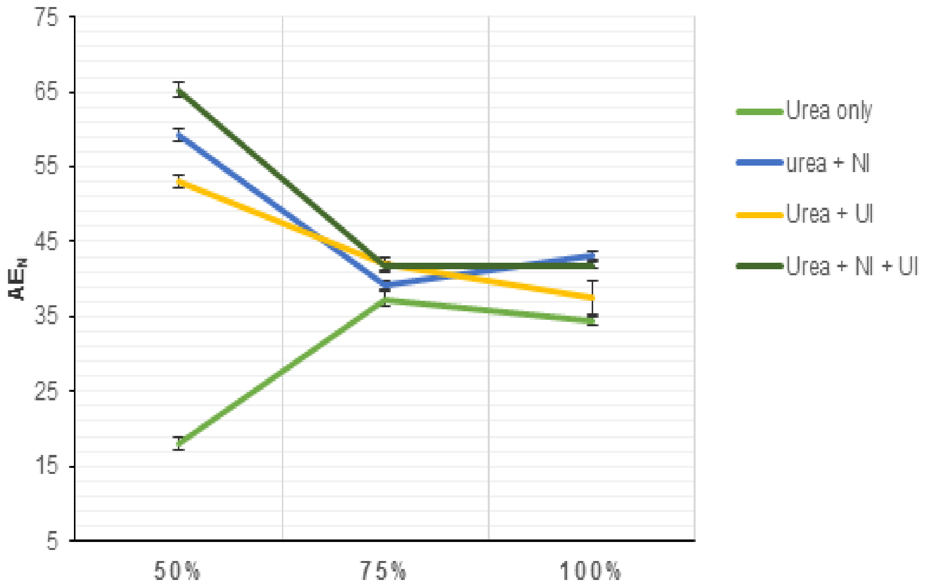

Figure 5 Responses of different inhibitors to different rates of added urea on AEN in rice.

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