

IMPACT OF NITRIFICATION INHIBITOR WITH ORGANIC MANURE AND UREA ON NITROGEN USE EFFICIENCY AND YIELD PERFORMANCE OF MR219 RICE IN ACID SULPHATE SOIL

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Abstract

A glasshouse experiment was designed to study the effects of nitrification inhibitor (Dicyandiamide; DCD) with organic manure and urea on nitrogen use efficiency (NUE), growth performance and yield of MR219 rice. DCD along with N source increased NUE and apparent N recovery over that of sole application of urea. Application of DCD along with urea and oil palm compost (OPC) resulted in the highest NUE (25.94 kg/ha) and fertilizer N recovery by rice (61.75%) together with the highest increase of panicles/hill (17.43%) and filled grains/panicle (9.42%) over urea alone. The highest grain (21.95%) and straw (13.86%) yield increase over control was achieved from DCD with urea and OPC reflecting as the most potential combination to improve NUE and rice yield in acid sulphate soil.

Introduction

Nitrogen is the most important nutrient for rice but it is the most limiting element in almost all soils (Shukla *et al.* 2004). Cereals including rice accounted for approximately 50% of the worldwide N fertilizer utilized (IFA 2009), but nitrogen recovery efficiency (REN) in rice plant is low. Based on a worldwide evaluation, REN has been observed to be around 30% in rice (Krupnik *et al.* 2004). This low REN is associated with large loss of N fertilizer from the soil plant system (Houshmandfar *et al.* 2008). Significant N losses can occur through NO_3^- leaching, NH_4^+ runoff and gaseous emissions of NH_3 and N_2O (Jing *et al.* 2007).

Nitrogen can be applied in inorganic forms such as commercial fertilizers, organic forms such as manure or crop residues, or in a combination of them. If N is applied in the form of organic N, short-term N loss could be reduced because the mobility of organic N is relatively low in soil. However, if N is applied in the form of inorganic fertilizer N, the synchronization of N supply with crop demand can be relatively easily achieved. This can also minimize N loss into the environment. Many scientists have found out that application of NPK fertilizers alone does not sustain productivity under continuous intensive cropping system (Yaduvanshi 2003), whereas inclusion of organic manures improves physical properties (Li and Zhang 2007), increased NUE, reduced the risk of environmental pollution (Ming-gang *et al.* 2008), and soil fertility and crop yields (Yang *et al.* 2008, Ming-gang *et al.* 2008).

To increase NUE and minimize N losses from agricultural soils numerous nitrification inhibitors of different chemical origins have also been tested. Among these inhibitors, DCD reduced NO_3^- leaching and N_2O emission substantially when combined with urea. Dicyandiamide

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effectively decreased gross N nitrification rates in the paddy soils, but did not affect N mineralization and inorganic immobilization. Thus, the addition of DCD with N fertilizer would, in practice, be useful for reducing the availability of NO_3^- for denitrification and leaching (Lan *et al.* 2013). In addition, use of the nitrification inhibitor 2-chloro-6-(trichloromethyl)-pyridine (CP, N-serve) improved the NUE, increased rice tiller number, panicle number and the rice grain yield for the 180 kg N/ha rate (Suna *et al.* 2015). The use of enhanced efficiency nitrogen fertilizers (nitrification inhibitor with urea) led to an 8.0% increase in N uptake and a 5.7% increase in yield (Linquist *et al.* 2013). Most of the above mentioned studies only looked at the effect of DCD with urea or OM separately on NUE and yield of rice. Therefore, the objective of this study was to investigate the effect of DCD in combination with OM and urea on NEU and yield of MR219 rice in acid sulphate soil.

Material and Methods

The experiment was conducted at experimental farm (Ladang 10) of Universiti Putra Malaysia, Serdang, Selangor, Malaysia. It is geographically situated at 3.30°N latitude and 101.50°E longitudes with an elevation of 21 m (71 ft) from sea level at the west coast of Peninsular Malaysia. The local climate is hot humid tropic with high humidity and abundant rainfall.

Rice (*Oryza sativa* L.) cv. MR 219 was used in the trial. Treatments comprised of four nitrogen source: $N_1=100\%$ N of recommended dose from urea, $N_2 = 75\%$ N of recommended dose from urea + 25% N from rice straw (RS), $N_3 = 75\%$ N of recommended dose from urea + 25% N from poultry dung (PD), and $N_4 = 75\%$ N of recommended dose from urea + 25% N from oil palm compost (OPC), and two levels of nitrification inhibitor (NI): without inhibitor (NoNI) and with inhibitor (NI). A 20 litre plastic bucket was filled with 14 kg air-dry soil. Organic manure: RS, PD, and OPC were applied as per treatments one week before final land preparation. Phosphorous (30 kg/ha) from triple super phosphate (TSP) and K (60 kg/ha) from muriate of potash (MOP) were applied before one day of transplanting. Nitrogen (120 kg/ha) from urea was top dressed in three equal splits at the time of TSP and MOP application, maximum tillering stage and at panicle initiation stage of crop growth. DCD was applied at the rate of 15% of N with urea. The 15 days old seedlings were transplanted into bucket with two hills in each bucket and three seedlings per hill. The bucket was flooded and rice management was conducted following standard practices (MARDI 2002). Plant height (cm) and tiller number (tillers/hill) at 30, 45 and 60th day of transplanting and growth, yield attributes and yield harvest were measured. Sample panicles were hand-threshed; filled grains were separated from unfilled grains and counted to calculate average filled grains/panicle. Panicle length and thousand-seed weight were determined. Thousand-seed weight and grain yield were adjusted to 14% moisture content. Grain and straw sample were dried in an oven at 65°C for 48 hrs and then ground by a grinding machine to pass through a 20 mesh. Nitrogen contents in grain and straw were determined by $\text{H}_2\text{O}_2\text{-H}_2\text{SO}_4$ digestion (Ohyama *et al.* 1991) using a Kel Plus auto N analyzer for N.

Nitrogen use efficiency (NUE) in terms of agronomic efficiency (kg increase in grain yield/kg N applied) and apparent nitrogen recovery (%) of applied N were calculated as:

Agronomic efficiency (AE) = [Grain yield in N applied (kg)-Grain yield in N control (kg)]/N applied (kg).

Apparent N recovery (ANR) = $100 \times [\text{N uptake in N applied (kg)} - \text{N uptake in N control (kg)}] / \text{N applied (kg)}$.

All data were subjected to a two-way ANOVA using the PROC GLM function of the SAS statistical programme (SAS2003). Significant treatment effect, means were compared using DMRT. Treatment comparisons were deemed significant at $p < 0.05$.

Results and Discussion

Agronomic efficiency and ANR of MR219 rice was significantly influenced by the sources of N, DCD levels and their interaction (Table 1). The average higher AE values of 23.72 kg/ha and ANR values of 53.91% were recorded in the presence of DCD. The interaction effects of DCD with N source on AE and ANR were the highest in DCD with urea + OPC (25.94 kg/ha and 61.75%, respectively). The AE and ANR from DCD with urea, urea + RS, urea + PD and urea + OPC were 22.37, 22.41, 24.20, 25.94 kg/ha and 44.84, 50.83, 58.23, 61.75, respectively. The value of AE and ANR were always lowest (16.49 kg/ha and 33.62 %, respectively) for the application of urea alone. Abalosa *et al.* (2014) implied that the commonly used nitrification inhibitors (DCD) can increase NUE by 12.9%. Coating of periled urea (PU) with different neem products slows down the availability of N from PU since neem products act as nitrification inhibitors, which results in increased NUE in different crops (Prasad 2005). The ANR across N rates ranged from 33.62 to 61.75%. This result is consistent with previous studies. The ANR across N rates ranged from 37 to 46%, which is still well below the average of many developed countries (Kumar *et al.* 2010). Application of coated calcium carbide along with urea significantly improved the fertilizer N recovery by the crop (24.4%) over that of sole application of urea (Bandyopadhyay and Sarkar 2005).

Nitrogen source and DCD exerted significant influence on plant height (Fig. 1) and tiller number per hill (Fig. 2) at tillering, panicle initiation and heading stages. Application of DCD significantly increased plant height and tiller number with the advancement of growth stages and reached the peak at heading stage. At all growth stages, DCD resulted in taller plants (62.33, 81.04 and 91.29 cm, respectively) and higher tiller number (5.90, 9.63 and 13.31, respectively), while without DCD resulted in shorter plant (60.00, 78.79 and 91.29 cm, respectively) and lower number of tiller (5.10, 8.85 and 12.35, respectively). Among the N sources, urea + OPC and urea + PD produced higher and statistically similar plant height and tiller number at different growth stage.

Table 1. Nitrogen use efficiency and apparent N recovery of rice variety MR219 as influenced by DCD with organic manure and urea.

N source	N use efficiency (kg/ha)		Apparent N recovery (%)	
	Without DCD	With DCD	Without DCD	With DCD
N ₁	16.49 ± 0.88f	22.37 ± 0.95c	33.62 ± 1.48g	44.84 ± 2.00d
N ₂	16.95 ± 0.29f	22.41 ± 1.13c	38.82 ± 1.31f	50.83 ± 1.97c
N ₃	17.97 ± 0.79e	24.20 ± 1.07b	41.11 ± 1.77ef	58.23 ± 1.69b
N ₄	19.14 ± 0.86d	25.94 ± 0.98a	44.32 ± 2.30d	61.75 ± 3.22a
Mean	17.64b	23.72a	39.47b	53.91a
CV (%)		2.06		4.01

Means followed by the same letter for the same parameter are not significantly different ($p > 0.05$) using DMRT.

At all growth stages, urea + RS and urea alone produced shorter plant height and lower number of tiller. There was no significant effect of DCD with nitrogen source on the growth attributes of MR219 rice variety. It has been reported that farm yard manure or straw along with inorganic fertilizer increased microbiological activities (Liu *et al.* 2010), which directly and

indirectly improved plant growth (Marris 2006). In an earlier study Myint *et al.* (2010) observed that urea with PM showed higher tiller number/hill due to higher decomposable nutrient content and urea with RS showed lower tiller number/hill due to N immobilization. The results of this study are also in agreement with the findings of other researchers (Parvez *et al.* 2008), who reported that application of organic and inorganic fertilizers significantly increased plant height and number of effective tillers per hill of rice compared to application of inorganic or organic manures alone.

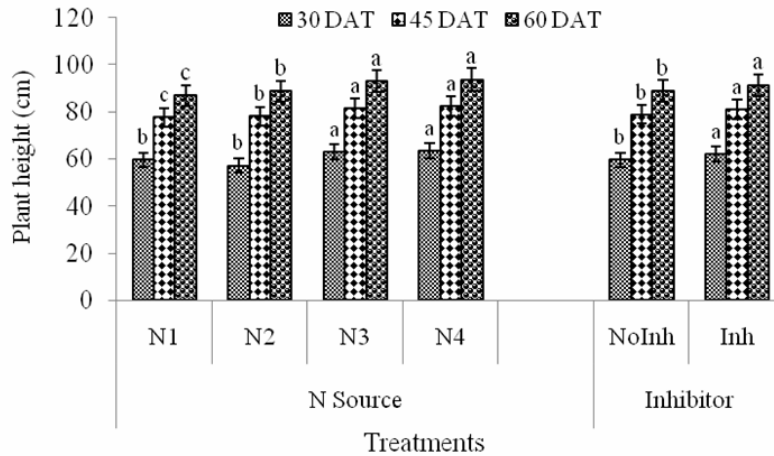


Fig. 1. Effect of DCD with organic manure and urea on plant height of rice variety MR219 at different growth stages. Vertical bars represent \pm standard error of mean.

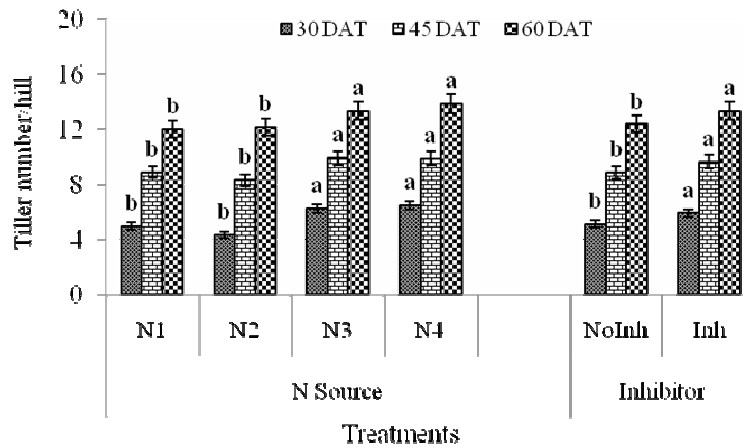


Fig. 2. Effect of DCD with organic manure and urea-N on tiller number of rice variety MR219 at different growth stages. Vertical bars represent \pm standard error of mean.

Panicles/hill and filled grains/panicle were significantly influenced by N source, DCD and their interaction (Table 2). These attributes attained their higher values in the presence of DCD and lower ones in the absence of DCD. With DCD, the number of panicles/hill and filled grains/panicle ranged from 11.25 - 12.33 and 73.58 - 77.85, respectively and it varied from 10.50 - 11.73 and 71.59 - 75.94, respectively without DCD across the N sources. The highest value of

panicles/hill (12.33) and filled grains/panicle (77.85) were obtained from DCD with urea + OPC which were statistically similar to DCD with urea + PD filled grain per panicle (76.97). All these attributes were the lowest (10.50 and 71.59, respectively) for urea alone. This agrees with Suna *et al.* (2015) who reported that use of the nitrification inhibitor increased rice panicle number for the 180 kg N/ha, which achieved the same value as the 240 kg N/ha with or without CP. Ming-gang *et al.* (2008) reported that application of organic manure combined with chemical fertilizer had higher total panicles and filled grains per panicle. In addition, filled grain rate was higher in the NPK with organic manure treatment, to which high photosynthetic rates in late growth period of rice were related, than that of NPK treatment (Khan *et al.* 2004).

Table 2. Effect of DCD with organic manure and urea on yield attributes of rice variety MR219.

N source	Number of panicle (No./hill)		Filled grain (No./panicle)	
	Without DCD	With DCD	Without DCD	With DCD
N ₁	10.50 ± 0.50e	11.25 ± 0.53c	71.59 ± 3.01f	73.58 ± 2.93d
N ₂	10.83 ± 0.29d	11.42 ± 0.38c	72.36 ± 2.96e	74.91 ± 1.97c
N ₃	11.83 ± 0.29b	12.00 ± 0.50b	75.86 ± 2.24b	76.97 ± 2.43a
N ₄	11.73 ± 0.24b	12.33 ± 0.28a	75.94 ± 2.19b	77.85 ± 3.54a
Mean	11.25b	1.75a	73.93b	75.74a
CV (%)		1.27		1.49

Means followed by the same letter for the same parameter are not significantly different ($p > 0.05$) using DMRT.

Panicle length and 1000-seed weight were significantly influenced by N source and DCD (Table 3). In the presence of DCD those attributes attained their higher values than the absence of DCD. With DCD, panicle length and 1000-seed weight were 19.02 cm and 23.30 g, respectively and it were 17.89 cm and 22.89 g, respectively without DCD. Among the N source, higher values of panicle length (19.03 cm) and 1000-grain weight (23.30 g) were obtained from urea + OPC which were statistically similar to urea + PD. All these attributes were the lowest (17.74 cm and 22.84 g, respectively) for urea alone. Dicyandiamide with N source had no significant effect on the

Table 3. Effect of DCD with organic manure and urea on yield attributes of rice variety MR219.

Treatments	Panicle length (cm)	1000-grain weight (g)
N source		
N ₁	17.74±0.76b	22.84±0.41b
N ₂	18.09±0.45b	23.02±0.29b
N ₃	18.95±0.33a	23.20±0.28ab
N ₄	19.03±0.74a	23.30±0.33a
Inhibitor		
No Inh	17.89±0.75b	22.89±0.33b
Inh	19.02±0.64a	23.30±0.27a
CV (%)	2.57	2.44

Means followed by the same letter within the same column are not significantly different ($p > 0.05$) using DMRT.

panicle length and 1000-seed weight of MR219 rice variety. Similar results were reported by Rahman *et al.* (2007) who found that panicle length increased with the application of manures and fertilizers. Verma *et al.* (2001) also reported that application of FYM @ 10 t/ha coupled with 50% recommended N recorded higher panicle lengths compared to control. Banik and Bejbaruah (2004) found that combined application of 40 per cent recommended dose of N as vermicompost + 60 per cent recommended dose of N as urea produced the highest level of yield attributes as compared to 100 per cent recommended dose of N entirely from urea.

Dicyandiamide and N sources responded to the yields differently (Figs 3 - 4). Application of DCD produced significantly higher yield of grain and straw than the absence of DCD. Nitrogen source with DCD resulted 4.76 - 21.95% gain yield and 4.12 - 13.86% straw yield increase over urea, whereas only N source increased 0.00 - 13.39% grain yield and 0.00 - 8.23% straw yield over urea alone. The highest increase 21.95 and 13.86% of grain and straw yield over urea alone was found from urea + OPC with DCD.

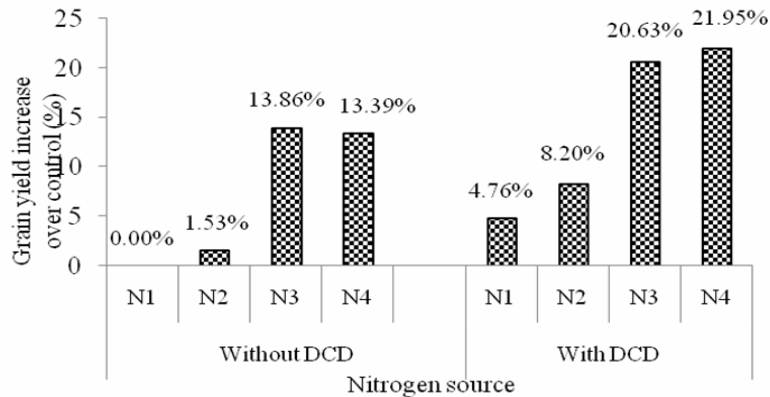


Fig. 3. Grain yield increase over control as influenced by DCD with organic manure and urea.

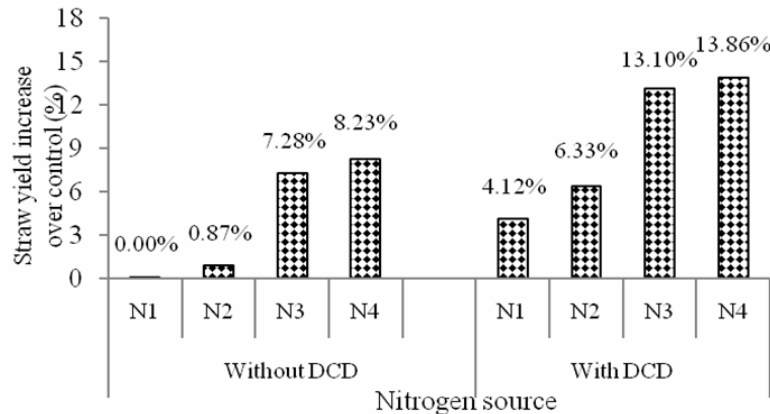


Fig. 4. Straw yield increase over control as influenced by DCD with organic manure and urea.

From a meta-analysis Abalosa *et al.* (2014) showed that the use of DCD can increase crop yields by 7.5%. Addition of DCD with OM and urea increased yield, it was in agreement with the results of Ghosh *et al.* (2003) which showed that addition of DCD with urea and ammonium sulphate resulted in significantly higher grain yield than without DCD. A similar positive response of rice to urea with organic manure has been reported by Myint *et al.* (2010), because application

of organic manure combined with chemical fertilizer increase the yield of rice by adjusting nutrient release rate in soil and fertilizer.

The results of this study showed that DCD with organic manure and urea had a significant impact on the NUE and the yield of MR219 rice. The NUE and performance of MR219 rice was best for the application of DCD with OPC and urea. Hence, combined use of 13.5 kg DCD (15% of applied N) along with 90 kg urea-N (75% N of recommended dose) and 1.75 t/ha OPC (25% N of recommended dose) might be an efficient agricultural strategy for increasing NUE and improving rice yield.

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