Comparison of Yield Response and Nutrient Use Efficiency between Urea Deep Placement Technology and Farmers' Practice of Surface Broadcasting Urea on Transplanted Lowland Rice in Myanmar

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Abstract

Urea deep placement (UDP) adaptation trials in randomized complete block design with four treatments and three replications were conducted in two wet seasons (2014 and 2015) and two dry seasons (2105 and 2016) at selected sites in the Delta Region of Myanmar to study yield comparison and nutrient use efficiency between UDP and surface broadcasting urea on transplanted lowland rice. The four treatments were: (1) control (0 N), (2) farmers' practice of urea application with farmers' rate (FP), (3) urea broadcasting (UB) with the same rate as UDP, and (4) UDP. A Generalized Linear Mixed Model was used to analyze variances among treatments, locations, and interaction of location by treatment for each year/season. Yield superiority of UDP over other treatments and nutrient use efficiency (NUE) for each urea applied treatment were calculated. Significant differences at $P_{(0.01)}$ were observed among treatments and locations in every year/season. Significant differences of interaction of treatments by locations at $P_{(0.05)}$ were found in wet season trials only. UDP gave the highest yield at all times. It was significantly higher than FP treatment and often higher than UB treatment. Yield superiority of UDP over UB and FP was 16-18% in the wet season and 24-28% in the dry season. Nutrient use efficiency with UDP was double the NUE with other N-applied treatments. UDP produced 30 kg of rice grain for every kg of N applied while other treatments produced 14-17 kg of rice grain per kg of N applied. UDP is therefore the more effective technology to apply N fertilizer on transplanted lowland rice, and dry season results indicated that yield with UDP could be expected more with best management practices under favorable water conditions and proper water management.

Key Words

Transplanted lowland rice, urea deep placement, nutrient use efficiency, yield superiority

Introduction

Urea is widely used as a source of a nitrogen fertilizer in lowland rice cultivation around the world. In Asia, where rice is mainly grown under lowland conditions, most farmers are surface broadcasting to apply urea in rice fields with more or less standing water. Surface broadcasting urea onto lowland rice fields with standing water is a very wasteful practice (Dong et al., 2012). To reduce nitrogen losses, farmers need to apply urea two to three times during the growing season. The crop gets only onethird of the applied urea, and two-thirds is lost through various ways, such as ammonia volatilization, surface runoff, leaching, and denitrification processes (Dong et al., 2012; Watanabe et al., 2009; Zhao et al., 2009). In addition to nutrient losses, this practice can also harm the environment by contamination of river/stream water through runoff and emission of nitrogenous oxides into the atmosphere through nitrification-denitrification.

Urea deep placement (UDP) is a proven climate-smart technology, which involves point placement of urea briquettes of 1.8 g or 2.7 g at 7-10 cm depth below the soil surface where no oxygen is present and close to the root zone of the crop (IFDC, 2017). By a process of hydrolysis, the nitrogen in urea transforms to ammonium cations (NH_4^+). The N remains as ammonium in the soil because no nitrification process takes place due to lack of oxygen in the anaerobic zone. Plants can gradually absorb readily available ammonium nitrogen from the soil. Single application of UDP is enough for a rice crop of early to medium-maturing varieties. With this technology, plants can better utilize the nitrogen applied and produce more yield with less impact on the environment (Kapoor et al., 2008; Gaihre et al., 2015, 2016).

Therefore, it can be said that Myanmar rice farmers are wasting urea by practicing surface broadcasting. Compared to other Asian countries, such as Bangladesh, Indonesia, and Malaysia, the amount of fertilizer used in Myanmar rice cultivation is low (FAO, 2015). Less urea is applied in the wet season in the Delta Region, when water levels are deep, than in the dry season. More urea is applied in the dry season rice crop, and higher yields can be obtained than in wet season rice. However, the amount and type of fertilizer used vary among farmers. Urea fertilizer is a very common fertilizer applied by most rice farmers due to its visible response (IFDC, 2016). All is broadcast onto the soil surface. UDP technology can increase rice yield with less urea applied. Coupled with a balanced application of phosphorus, potassium, and secondary and micronutrients as required by soil, UDP would be the best practice for rice growing in Myanmar. This paper presents the results of UDP adaptation trials in farmer fields that measure yield and nitrogen use efficiency of UDP technology when compared with farmers' practice of broadcasting urea.

Materials and Methods

On-farm UDP adaptation trials were conducted at selected locations in four continuous seasons, two wet seasons and two dry seasons starting from the wet season of 2014 and ending after the dry season of 2016. Trial locations were from Yangon, Bago, and Ayeyarwady regions, where rice is the main crop. The trial sites in farmer fields and villages changed from season to season. There were three trials in each wet season and four trials in each dry season. Trial locations, villages, townships, and regions for each year and season are given in Table 1. The farmers' preferred variety was used in each trial. These were mostly high-yielding medium-maturing varieties in the wet season and early maturing varieties in the dry season. Varieties included Sin

Thu Kha, Manaw Thu Kha 2, Thee Dat Yin, Shwe Pyi Htay, and Yadanar Toe as improved varieties. Hybrid rice varieties, Pale Thwe and GW 1, were also used for some trials. See Table 1.

Table 1. Locations, test varieties, and farmers' practice N rates for each year and season.

Year/ Season	Village	Township	Variety	N Rate with FP (kg/ha)	Basal in FP
2014 WS	Sat Ka Lay	Htandabin	Sin Thu Kha	57	No
	Sar Ma Lauk	Nyaungdon	Pale Thwe hybrid	57	No
	Ohn Hnae Gone	Hlegu	Manaw Thu Kha 2	28	No
2015 DS	Ein Lay Lone	Htandabin	Shwe Pyi Htay	57	Compound
	Nga Pa	Thanlyin	Thee Dat Yin	114	Compound
	Ohn Hnae Gone	Hlegu	Pale Thwe hybrid	57	Compound
	U To	Taikkyi	Yadanar Toe	114	Compound
2015 WS	Too Chaung	Nyaungdon	Sin Thu Kha	57	No
	Wagon Gayet	Maubin	Sin Thu Kha	28	No
	Gyoe Phyu	Taikkyi	GW 1 hybrid	57	No
2016 DS	Ein Gyi	Twantay	Thee Dat Yin	57	TSP only
	Inglone	Kunchangone	Thee Dat Yin	85	TSP + MOP
	Pyin Ma Lwin	Daik-U	Thai Manaw	57	TSP only
	Zay Bine	Thanatpin	Sin Thu Kha	85	TSP + MOP

Four fertilizer treatments, namely Zero N (control), farmers' practice of fertilizer application (FP), urea surface broadcasting practice (UB), and UDP were tested in a randomized complete block design with three replications. For the UDP treatment, the size of the urea briquette was 1.8 g in the wet season trials and 2.7 g in the dry season trials. One briquette was deep-placed one time only at the center of four alternate rice hills with a spacing of 20 cm x 20 cm, seven days after transplanting. This produced a nitrogen rate of 52 kg N/ha in the wet season and 78 kg N/ha in the dry season. To get precise place and depth of application, UDP was applied by hand. With the UB treatment, the same N rate as UDP was applied. But it was applied as three split doses in equal amounts. The first application was at the same time as UDP, the second application was at the panicle initiation stage, and the last application was just before flowering. In the FP treatment, N rates varied from one farmer to another, year to year, and season to season. Normally, the N rate was lower in the wet season and higher in the dry season. N rates of FP ranged from 28 kg N/ha to 57 kg N/ha in the wet season and 57 kg N/ha to 114 kg N/ha in the dry season. It was also applied in three split applications as for the UB treatment for all N rates except the lowest N rate. With the lowest N rate (28 kg N/ha), it was applied as two split applications in equal amount. With the lowest N rate, no nitrogen was applied at the flowering stage.

A basal fertilizer of triple super phosphate (TSP) 80 kg/ha (36 kg P_2O_5/ha), muriate of potash (MOP) 40 kg/ha (24 kg K_2O/ha), and gypsum 25 kg/ha (4.5 kg S/ha) were applied on all treatments except the FP treatment. Basal fertilizer application for the FP treatment differed from season to season. No basal fertilizer was applied on the FP treatment in the wet season trials. In the dry season of 2015, compound fertilizer with a nutrient ratio of 15:15:15 ($N:P_2O_5:K_2O$) was applied at the rate of 25 kg/acre (or 61.8 kg/ha). In the dry season of 2016, TSP 25 kg/acre, or 61.8 kg/ha, was applied on all trials. And MOP 12.5 kg/acre, or 31 kg/ha, was applied on the trials with higher FP N rates (Table 1).

Raising the nursery, management, and field land preparation was done by farmers. Plots were pegged one day before transplanting. Each experimental plot with a size of 24 feet x 28 feet was separated by bunds about 12 inches high and 12 inches wide. Basal fertilizer was applied to each plot after bunding and incorporated with soil, and the plot was re-leveled. Transplanting was done the following day using 25-day-old seedlings at two to three per hill. Crop management, such as weed, pest, and water management, was carried out by the farmers.

At maturity, a crop cut was taken from 100 square feet (10 feet x 10 feet) inside each plot, leaving at least six border rows. Moisture content (%) was measured at harvest. Crop cut wet yield was recorded as kilograms. Paddy yield (t/ha) was adjusted to 14% moisture content using the formula:

$$\text{Yield (t/ha)} = \frac{\text{Crop cut yield (kg) x (100 – MC\%) x 43,560 x 2.471}}{\text{1,000 x 100 x 86}}$$

Where:

Crop cut yield	= actual grain weight (kg) from crop cut area at harvest
MC%	= Moisture content (%) at harvest
43,560	= square feet of 1 acre
2.471	= Conversion from acre to hectare
1,000	= Conversion from kg to ton
100	= Crop cut area (sq. ft.)
86	= Adjustment of moisture content to 14%

Analysis of variance was conducted by each year/season. Within each of the four years/seasons, the effect of treatments, locations, and interaction of location by treatment were used as the sources of variation in the analysis of variance. A Generalized Linear Mixed Model was used for the analysis of variance. Treatment and location were handled as fixed effects and the error Rep (Treatment*Location) as random effect. When the interaction location by treatment was significant in the analysis of variance, treatment means were compared within each location. When the interaction location by treatment was not significant, average treatment means across locations were compared. Least Significant Difference (LSD) was run to compare treatment means.

Superiority of UDP over other fertilizer application practices (FP and UB) was also calculated as a percentage to express what yield increase could be obtained using UDP compared with other N application practices. Nutrient use efficiency (NUE) of each application practice was also calculated to see how many kilograms of grain were produced by applying a kilogram of nitrogen by the practice. Both calculations were done for wet and dry season separately using average yield across locations and years. The following formulas were used to calculate the above parameters.

$$\text{\% superiority of UDP over other practice} = \frac{\text{(Yield with UDP} - \text{Yield with other practice)}}{\text{Yield with other practice}} \times 100$$

$$\text{NUE (kg)} = \frac{\text{(Yield with treatment, kg} - \text{Yield with Zero N, kg)}}{\text{kg of N applied with treatment}}$$

Results and Discussion

There was some variability in yields from year/season to year/season and from location to location. Analysis of variance showed highly significant difference at $P_{(0.01)}$ among both treatments and locations. Interaction of location by treatment showed significant difference at the $P_{(0.05)}$ level in the wet season trials. It was not significant in the dry season trials. A significant effect of interaction in the wet season indicates that the yield responses to treatments, especially urea broadcast treatments (FP and UB), are not consistent among locations. This is explained by the poor water control and heavy rain in lower parts of Myanmar. In the dry season, water management is better than in the wet season; hence, the yield responses to treatments are similar at all locations and show no significant interaction of locations by treatments (Table 2).

Table 2. Significance tests of sources of variation for each year and season.

Effect	2014 Wet Season		2015 Dry Season		2015 Wet Season		2016 Dry Season	
	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
Treatment	22.19	< .0001	30.92	< .0001	14.90	< .0001	17.58	< .0001
Location	154.51	< .0001	23.14	< .0001	19.67	< .0001	8.34	< .0003
Location*Treatment	3.59	0.0111	0.39	0.9303	2.97	0.0261	0.89	0.5423

UDP consistently produced the highest yield at all locations in every year and season. The treatment that gave the second highest yield differed from year to year, season to season, and location to location. Sometimes, it was the FP treatment and sometimes it was the UB treatment, regardless of N rates for both treatments. The zero N treatment gave the lowest yield in most locations in every year/season. Comparing treatment means in 2014 wet season trials, two of the three locations showed the UDP treatment was significantly better than other fertilizer application practices. UDP yields ranged from 4.59 t/ha to 6.86 t/ha (Table 3). UDP yield at Sar Ma Lauk was the highest with 6.86 t/ha. But yields with other treatments were also high at Sar Ma Lauk, and there was no significant difference between treatments. The high yield may be attributed to the use of the high-yielding hybrid variety Pale Thwe. Since hybrid varieties require high amounts of nitrogen, the high yield of 6.38 t/ha from the control plot with zero N suggests that either the soil N supply was very high or additional urea might have been applied.

In the 2015 wet season trials, UDP treatment produced the highest yield (5.93-6.53 t/ha) at all three locations, and it was significantly higher than FP and control (Table 3). However, it was statistically higher from the UB treatment only at Too

Chaung. As evident from the yields of the control plots (Table 3), soil N supply at Too Chaung (3.13 t/ha) was lower than Wayon Gayet (4.65 t/ha) and Gyoe Phyu (5.54 t/ha). The soil of Too Chaung is more sandy and classified as sandy loam. (Land Use Map, 2017).

Table 3. Comparison of treatment means of each location for wet season.

2014 Wet Season			2015 Wet Season		
Location Treatment	Mean Yield (t/ha)	Comparison using LSD	*Location* Treatment	Mean Yield (t/ha)	Comparison using LSD
Sat Ka Lay			*Too Chaung*		
Control (0 N)	3.97	c	Control (0 N)	3.13	c
FP (57 kg N)	5.49	b	FP (57 kg N)	4.99	b
UB (52 kg N)	4.87	b	UB (52 kg N)	4.04	c
UDP (52 kg N)	6.38	a	UDP (52 kg N)	5.93	a
Sar Ma Lauk			*Wayon Gayet*		
Control (0 N)	6.38	ns	Control (0 N)	4.65	c
FP (57 kg N)	6.58	ns	FP (28 kg N)	5.35	bc
UB (52 kg N)	6.28	ns	UB (52 kg N)	5.92	ab
UDP (52 kg N)	6.86	ns	UDP (52 kg N)	6.12	a
Ohn Hnae Gone			*Gyoe Phyu*		
Control (0 N)	3.06	b	Control (0 N)	5.54	b
FP (28 kg N)	3.55	b	FP (57 kg N)	5.44	b
UB (52 kg N)	3.67	b	UB (52 kg N)	6.13	ab
UDP (52 kg N)	4.59	a	UDP (52 kg N)	6.53	a

Since there was no significant interaction of location by treatment in dry season trials, a comparison of treatment means was made using average values across all locations. Both dry seasons (2015 and 2016) showed UDP treatment produced the highest yield, and it was significantly higher than all other treatments. The yield with the FP treatment, which used a little higher N rate in 2015 and slightly lower in 2016, was not significantly different from the UB treatment (Table 4).

Table 4. Comparison of average treatment means across locations and years for the dry season.

Treatment	2015 Dry Season		Treatment	2016 Dry Season	
	Mean Yield (t/ha)	$LSD_{(0.05)}$ Comparison		Mean Yield (t/ha)	$LSD_{(0.05)}$ Comparison
Control (0 N)	3.29	c	Control (0 N)	3.30	c
FP (95 kg N)	4.85	b	FP (71 kg N)	4.23	b
UB (78 kg N)	4.53	b	UB (78 kg N)	4.26	b
UDP (78 kg N)	5.93	a	UDP (78 kg N)	5.31	a

The results clearly indicate that UDP technology is better than surface-broadcasting urea and can increase the yield of transplanted lowland rice in Myanmar. This is consistent with findings in other countries (Bandaogo et al., 2014; Miah et al., 2016). Percent yield increase of UDP over broadcast fertilizer practices were calculated by using overall average yield of the wet and dry season as given in Table 5. The data showed UDP can increase yield by 16-18% over FP and UB in the wet season and 24% to 28% over FP and UB in the dry season. This indicates UDP is more responsive on dry season rice than on wet season rice. Overall, the increase in yield of 16-28% on application of UDP is similar to results from Bangladesh and Africa (Miah et al., 2016). Nutrient use efficiency (NUE) is not much different between the wet and dry season. With urea surface-broadcasting practices, 13-16 kg of rice grain are produced by applying one kilogram of nitrogen (Table 5). But with UDP practice, NUE is twice as high as other practices (30-31 kg rice grain per kg N applied). The effect of N application on yield increase is twice as high in the dry season compared to the wet season, validating why farmers apply more in the dry season.

Table 5. Percent yield superiority of UDP over other practices and NUE of fertilizer practices.

Treat.	Wet Season				Dry Season			
	N Rate (ave) (kg/ha)	Yield (t/ha)	% of UDP Over	NUE kg/kg N	N Rate (ave) (kg/ha)	Yield (t/ha)	% of UDP Over	NUE kg/kg N
Zero N	0	4.46	36	-	0	3.30	70	-
FP	47	5.23	16	16	83	4.54	24	15
UB	52	5.15	18	13	78	4.39	28	14
UDP	52	6.07	-	31	78	5.62	-	30

Conclusion

These rice trials were conducted on transplanted rainfed lowland rice in the lower part of Myanmar and run for both the wet and dry season. Although there were variations in rice yield from year to year, season to season, and location to location, UDP treatment produced the highest yield at all times among all other treatments. It was often significantly higher than other urea application practices. With UDP technology, rice yield can be improved by at least 18% in the wet season and 28% in the dry season compared with broadcasting urea at the same N rate. Yield increase with UDP is due to an increase in nutrient use efficiency. UDP can double the NUE over urea surface-broadcasting practices. It is concluded that UDP technology is a highly effective method of urea application on rainfed lowland rice. The best result from UDP can be obtained in lowland rice cultivation under favorable water condition or good irrigation and best management practices.

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