

**Fertilizer Sector Improvement Project
Report of 2015-2016 Dry Season Trials**

**Trials with the Urea Deep Placement Technique
on Transplanted Rice, Broadcast Rice, and
Rice-Gram System in Myanmar**

Funded by



Implemented by



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www.ifdc.org

October 2016

Table of Contents

	Page
Introduction.....	1
Trials Tested in 2016 Dry Season	2
Materials and Methods.....	3
Site Selection.....	3
Trial Failures	3
Varieties and Farmers.....	3
Experimental Design.....	4
Basal Fertilizers.....	4
Treatments for UDP Adaptation Trials on Transplanted Rice.....	5
Treatments for N-Rate Trials on Transplanted Rice	6
Treatments for UDP Before Broadcasting Seed	6
Treatments for UDP Spacing Trial on BR	7
Treatments for Nitrogen x Potassium on TPR	7
Treatments for Plant Spacing x Nitrogen Trials on TPR.....	8
Treatments for Fertilizer Management in the Rice-Gram System.....	8
Treatments for Different Seed Rates on BR using UDP.....	9
Treatments for N-Rate Trial on Black Gram Using UDP and Prilled Urea.....	9
Plot Size and Spacing.....	10
Weeds and Water Problems	10
Results and Discussion	11
UDP Adaptation Trials.....	11
Yield (mt/ha)	11
Dry Grain Weight of Biomass (g/25 plants).....	11
Number of Panicles per Hill.....	14
1,000-Grain Weight (g)	15
Agronomic Efficiency (AE) – Yield Grain per kg N Applied	15
UDP, Yield Parameters, and Yield.....	16
N-Rate Trial at Myaungmya	16
UDP Before Seed Broadcasting Trials.....	19
UDP Spacing Trials on Broadcast Rice	21
Nitrogen x Potassium on TPR at Chantharkone, Letpadan.....	24
Plant Spacing x Nitrogen Rate Trial on TPR at Thewatchaung, Letpadan.....	25
Fertilizer Management Trials on Rice-Gram Cropping System	26
Different Seed Rate Trial on BR.....	28
N-Rate Trial on Black Gram Using UDP and Prilled Urea	29
Conclusion	29

UDP Adaptation Trials	29
N-Rate Trial.....	30
UDP Before Broadcasting Trial on BR.....	30
UDP Spacing Trials on BR	31
Nitrogen x Potassium Trial on TPR	31
Plant Spacing and N Rate Trial on TPR.....	31
Fertilizer Management Trials on Rice-Gram Cropping System	32
Different Seed Rates Trial.....	32
Appendix 1. Data Sheets.....	38
Eingyi, Twantay	38
Inglone, Kunchangone	39
Pyinmalwin, Daik-U.....	40
Zaybine, Thanatpin.....	41
Research Farm, Myaungmya.....	42
Yindaikkwin, Taikkyi.....	43
Kanyingae, Kyaiklat.....	44
Yindaikkwin, Taikkyi.....	45
Kanyingae, Kyaiklat.....	46
Chantharkone, Letpadan.....	47
Thewatchaung, Letpadan	48
Tharkwin, Einme	49
Paramidaunt, Einme	50
Ashaebine, Kyauktan	51
Seed Rate Trial at Eingyi, Twantay	52
Photos.....	53

List of Tables

	Page
Table 1. Locations and Coordinates of Field Trials, Dry Season 2016	3
Table 2. Varieties, Trial Types, and Collaborating Farmers for the 2016 Dry Season Trials	4
Table 3. Experimental Designs Used for 2016 Dry Season Trials	5
Table 4. Plot Size and Spacing Used for Specific Trial, 2016 Dry Season Trials.....	10
Table 5. Locations, Varieties, and Dates of All Trials	34
Table 6. Test of Significant Levels of Plant Characteristics and Biomass Yield for All Locations.....	35
Table 7. Average Yield (mt/ha) of Different Treatments at All Locations	35

Table 8.	Percent Yield Superiority of UDP Over Other Treatments	35
Table 9.	Biomass Grain Weight (g/25 plants) of Different Treatments at All Locations...	36
Table 10.	Number of Panicles per Hill of Different Treatments at All Locations	36
Table 11.	1,000-Grain Weight (g) of Different Treatments at All Locations.....	36
Table 12.	Agronomic Efficiency Values of Treatments at All Locations	36
Table 13.	Analysis of Variance on Yield (t/ha) and Other Characteristics of N-Rate Trial at Myaungmya	37
Table 14.	Test of Significant Level for Yield and Component Characteristics of Fertilizer Management Trial on Rice-Gram Cropping System	37

List of Figures

Figure 1.	Paddy Yield Comparison of Different Treatments by Location.....	14
Figure 2.	Response of Plant Height (cm) on Different N Rates.....	17
Figure 3.	Response of Number of Panicles per Hill on Different N Rates	18
Figure 4.	Response of Biomass Straw Weight on Different N Rates	18
Figure 5.	Yield Comparison of UDP Application, FP, and Zero N at Kanyingae and Yindaikkwin	21
Figure 6.	Yield Response to Different UDP Spacing by Locations.....	23
Figure 7.	Yield Response (mt/ha) on Different Rates of Nitrogen and Potassium	25
Figure 8.	Yield Response (mt/ha) on Different Plant Spacing and Nitrogen Rates.....	26

List of Photos

Photo 1.	Layout and Land Leveling on UDP Spacing Trial at Kanyingae, Kyaiklat, Ayeyarwady, on December 1, 2015	53
Photo 2.	Strengthening Separated Bunds Just Before Urea Application on UDP Adaptation Trial at Inglone, Kunchangone, Yangon, on January 28, 2016.....	53
Photo 3.	Transplanting UDP Adaptation Trial at Eingyi, Twantay, Yangon, on January 27, 2016.....	54
Photo 4.	Sample Area for Crop Cut Harvesting Seed Rate Trial at Eingyi, Twantay, Yangon, on April 22, 2016 (Note: crop lodging)	54
Photo 5.	Harvesting UDP Adaptation Trial at Eingyi, Twantay, Yangon, on April 22, 2016	55
Photo 6.	Green Gram Crop from Fertilizer Management Trial on Rice-Gram System at Ashaebine, Kyauktan, Yangon, on February 2, 2016 (just before harvest).....	55

Acronyms and Abbreviations

AE	Agronomic Efficiency
ANOVA	Analysis of Variance
BR	Broadcast Rice
Ca	Calcium
cm	centimeter
CV	Coefficient of Variation
ft	foot
FP	Farmer's Practice
FSI	Fertilizer Sector Improvement
g	gram
ha	hectare
HYV	High-Yielding Variety
IFDC	International Fertilizer Development Center
in	inch
K	Potassium
kg	kilogram
lb	pound
LSD	Least Significant Difference
m	meter
MOP	Muriate of Potash
mt	metric ton
N	Nitrogen
P	Phosphorus
PU	Prilled Urea
RCB	Randomized Complete Block
S	Sulfur
TSP	Triple Superphosphate
TPR	Transplanted Rice
UB	Urea Broadcast
UDP	Urea Deep Placement
USAID	United States Agency for International Development

Conversions

To Convert	To	Multiply by
acre	hectare	0.4047
hectare	acre	2.471
U.S. ton/acre	mt/ha	2.24
lb/acre	kg/ha	1.12
kg/ha	lb/acre	0.89
K ₂ O	K	0.83
K	K ₂ O	1.2047
P ₂ O ₅	P	0.4364
P	P ₂ O ₅	2.2915

Trials of Urea Deep Placement Technique on Transplanted Rice, Broadcast Rice, and Rice-Gram System in 2015-2016 Dry Season, Myanmar

Introduction

Urea deep placement (UDP) technology is a proven technology that can increase the yield of transplanted lowland rice by 15-20% with less use of urea (up to 40%) compared to broadcast application of urea. This has been proven in Bangladesh and in sub-Saharan African countries.

A number of UDP trials, with transplanted rice (TPR), were conducted at selected locations in Yangon, Bago, and Ayeyarwady regions in Myanmar, during the 2014 wet season to 2015 wet season by the International Fertilizer Development Center (IFDC) through the Fertilizer Sector Improvement (FSI) project, funded by the United States Agency for International Development (USAID).

In the **2014 wet season**, UDP technology, using the same or a lesser rate of nitrogen (N), showed superiority over urea broadcasting (UB) at rates recommended by the Department of Agriculture and at rates used by local farmers (farmer's practice, FP). Average yield increased by 11.57%, ranging from 3.06% to 24.92%.

In the **2015 dry season**, UDP adaptation trials were run again, and it was found that the UDP treatment out-yielded the FP treatment and the UB treatment by up to 29.55% and 36.73%, respectively. The average yield superiority of the UDP treatment across all locations over the second highest yield of FP was 11.10%, which was nearly the same as the average increase during the 2014 wet season. Nitrogen rate trials carried out at two locations showed significant response to N rates and between the type of application (UDP and broadcast). Broadcast prilled urea (PU) produced a significantly higher yield of up to 104 kilograms (kg) N per hectare (ha). For UDP, the yield differences were significant at up to 78 kg N/ha.

In the **2015 wet season**, UDP adaptation trials continued in new locations. The yield increments from UDP varied from 3.36% to 18.95%, with an average yield increase over all locations; UDP resulted in a yield increase of 7.37% over UB and 14.70% over FP. UDP technology was also evaluated on broadcast rice (BR) since farmers practiced the broadcast

seeding method more than the transplanting method for rice cultivation in this season. Other trials relating to N rate, potassium (K) rate, time of application, and plant spacing, and fertilizer management on the rice-gram system was also tested. The results showed the possibilities of applying UDP technology on BR. UDP could be applied just before seed broadcasting and gave higher yield than FP urea application and UDP application 26 days after seed broadcasting with a very early variety (75 days to maturity). The trial has to be repeated using a popular early maturing high-yielding variety (HYV) rather than using a very early variety, which is not popular. Significant yield results between treatments were observed in an N x K trial and a plant spacing x UDP rate trial. Confirmation of those results is still needed with additional trials. No significant result was observed with long-term fertilizer management trials on the rice-gram cropping system.

In this **2016 dry season**, all trials of the 2015 wet season were repeated. Within the long-term fertilizer trial on the rice-gram system, this was the first test on the second crop, gram. All trials were conducted at selected locations in the three project regions, i.e., Yangon, Bago, and Ayeyarwady. The trials established are listed below.

Trials Tested in 2016 Dry Season

<u>Sr. No.</u>	<u>Trials</u>	<u>Number of Trials</u>
1.	UDP adaptation trials on TPR	4
2.	Different N-rate trial using UDP on TPR	1
3.	UDP before seed broadcasting trial on BR	2
4.	UDP spacing trial on BR	2
5.	Nitrogen x potassium trial on TPR	1
6.	Plant spacing x nitrogen trial on TPR	1
7.	Fertilizer management trial on rice-gram cropping system	4
8.	Different seed rate trial on BR using UDP	1
9.	Different N-rate trial using UDP and prilled urea on black gram	1
	TOTAL	17

Materials and Methods

Site Selection

During the 2016 dry season, almost all sites and farmers were newly selected, except the Research Farm in Myaungmya, where the N-rate trial with higher rates was tested, and the long-term fertilizer management trials on the rice-gram system, which continued at their same locations. The coordinates of the selected sites with the number of trials are given in Table 1. Soil samples taken from each location were dried and stored for later testing to identify initial soil condition.

Table 1. Locations and Coordinates of Field Trials, Dry Season 2016

Region	Township	Village	Latitude	Longitude	Elevation	Trial Type
Yangon	Kyauktan	Ashaebine	16° 38.765' N	96° 20.645' E	44 ft	7
	Thanlyin	Nyaungthonebin ^a	16° 45.630' N	96° 17.305' E	51 ft	7
	Twantay	Eingyi	16° 46.273' N	96° 01.748' E	18 ft	1
		Eingyi	16° 46.257' N	96° 01.782' E	11 ft	8
	Kunchungone	Inglone	16° 28.552' N	96° 03.244' E	48 ft	1
	Taikkyi	Yindaikkwin	17° 20.525' N	95° 55.248' E	30 ft	9
		Yindaikkwin	17° 20.513' N	95° 55.573' E	56 ft	3
Yindaikkwin		17° 20.513' N	95° 55.573' E	56 ft	4	
Bago	Thanatpin	Zaybine	17° 18.371' N	96° 33.393' E	35 ft	1
	Daik-U	Pyinmalwin	17° 41.978' N	96° 35.256' E	62 ft	1
	Letpadan	Chantharkone	17° 46.452' N	95° 46.692' E	75 ft	5
		Thewatchaung	17° 50.048' N	95° 45.402' E	94 ft	6
Ayeyarwady	Kyaiklat	Kanyingae	16° 26.958' N	95° 41.917' E	23 ft	3
		Kanyingae	16° 26.958' N	95° 41.917' E	23 ft	4
	Einme	Tharkwin	16° 44.336' N	95° 05.527' E	36 ft	7
		Paramidaunt	16° 55.007' N	95° 09.416' E	28 ft	7
	Myaungmya	Research Farm	16° 36.824' N	94° 55.000' E	17 ft	2

^a - Failed trial due to poor germination.

Trial Failures

A new trial on fertilizer management in green gram at Nyaungthonebin, Thanlyin, in this season had poor germination due to late sowing and poor land preparation. As the crop progressed, it showed large variations between and within plots. Sensible crop cuts were not possible, and the trial was abandoned.

Varieties and Farmers

Varieties and farmers for all locations are given in Table 2.

Table 2. Varieties, Trial Types, and Collaborating Farmers for the 2016 Dry Season Trials

Township	Village	Farmer	Variety		Remark
Kyauktan	Ashaebine	U Aung Myo	Shwewar	Improved	Green gram
Thanlyin	Nyaungthonebin	Daw Zin Mar Kyaw	Shwewar	Improved	Green gram
Twantay	Eingyi	U Aung Myint	Theedatyin	HYV	UDP adaptation trial
	Eingyi	U Aung Myint	Theedatyin	HYV	Seed rate trial
Kunchungone	Inglone	U Than Hla	Theedatyin	HYV	UDP adaptation trial
Taikkyi	Yindaikkwin	U Zaw Min Htwe	Yezin - 2	Improved	Black gram
	Yindaikkwin	U Zaw Min Htwe	Theedatyin	HYV	UDP before sowing
	Yindaikkwin	U Zaw Min Htwe	Theedatyin	HYV	UDP spacing trial
Thanatpin	Zaybine	U San Shwe Oo	Sinthukha	HYV	UDP adaptation trial
Daik-U	Pyinmalwin	U Tin Win Naing	Thai Manaw	HYV	UDP adaptation trial
Letpadan	Chantharkone	U Naing Tun	Yadanartoe	HYV	N x K trial
	Thewatchaung	U Thein Hlaing	Yadanartoe	HYV	TPR space x N rate
Kyaiklat	Kanyingae	U Aye Than	Theedatyin	HYV	UDP before sowing
	Kanyingae	U Aye Than	Theedatyin	HYV	UDP spacing trial
Einme	Tharkwin	U Aung Htay Win	Yezin - 3	Improved	Black gram
	Paramidaunt	U Thet Naing Soe	Yezin - 3	Improved	Black gram
Myaungmya	Research Farm	U Htain Lin Tun	Theedatyin	HYV	N-rate trial

Experimental Design

A Randomized Complete Block (RCB) design with four treatments by three replications was used in most of the trials (Table 3). An RCB with six treatments by three replications was used in the N rate trial. An RCB with five treatments and three replications was used in the two UDP spacing trials. A factorial experiment with RCB and three replications was used for the nitrogen x potassium trial at Chantharkone, Letpadan. A 2 x 2 split plot design with three replications was used for the plant spacing x nitrogen trial. The UDP before seed broadcasting trial was simply sown in a large plot for each treatment, and data were taken from three random samples within the plot. A different N-rate trial on black gram has four treatments with three replications, and there were two separate trials, one with UDP and one with prilled urea. A detailed plan for each trial is available in protocols, retained in a separate document.

Basal Fertilizers

In all the trials, a basal fertilizer of triple superphosphate (TSP), muriate of potash (MOP), and gypsum is used as the source of phosphorus (P), K, and sulfur (S). In calculating the rates, it is assumed:

$$\text{TSP} = 45\% \text{ P}_2\text{O}_5 \text{ or } 20\% \text{ P}$$

$$\text{MOP} = 60\% \text{ K}_2\text{O} \text{ or } 50\% \text{ K}$$

$$\text{Gypsum} = 18\% \text{ S and } 23\% \text{ Ca}$$

Table 3. Experimental Designs Used for 2016 Dry Season Trials

No.	Trial Name	Treats x Reps	Design
1	UDP adaptation trial on TPR	4 x 3	RCB
2	Different N-rate trial using UDP on TPR	6 x 3	RCB
3	UDP before seed broadcasting trial on BR	4 x 1	Simple Four treatments, no reps but three random samples
4	UDP spacing trial on BR	5 x 3	RCB
5	Nitrogen x potassium trial on TPR	2 x 2 x 3	Factorial
6	Plant spacing x nitrogen trial on TPR	2 x 2 x 3	Split plot
7	Fertilizer management trial on rice-gram cropping system	4 x 3	RCB
8	Different seed rate trial on BR using UDP	5 x 3	RCB
9	Different N-rate trial on black gram using UDP and PU	4 x 3	RCB

Treatments for UDP Adaptation Trials on Transplanted Rice

There are four treatments, as usual, in this trial, and treatments are given below. Rice is transplanted with 20 x 20 cm spacing.

Treatment 1 = Zero N.

Treatment 2 = Farmer's Practice (FP) – urea broadcast with two or three splits.

Treatment 3 = Urea Broadcast (UB) (77.6 kg N/ha) – urea with three splits.

Treatment 4 = Urea deep placement¹ (UDP) (77.6 kg N/ha).

After discussion with farmers at each location, there were two different doses of urea application in FP, depending on location. One dose was 50 kg urea per acre (56.8 kg N/ha) (at Eingyi and Pynmalwin), and the other dose was 75 kg urea per acre (85.2 kg N/ha) at Inglone and Zaybine. There were three split applications of urea at all sites: first application at seven days after transplanting, second application at 35-40 days after transplanting, and third application at just before flowering.

As basal fertilizer application on FP treatment, 25 kg TSP/acre was applied at all four sites and 12.5 kg MOP/acre was applied at only two sites where a higher rate of urea was applied. A blanket basal fertilizer of P at the rate of 80 kg TSP/ha, K at the rate of 40 kg MOP/ha, and Ca and S at the rate of 25 kg gypsum/ha were applied in other treatments, control, UB, and UDP.

¹ 2.7-g briquette size.

UDP was applied only one time at seven days after transplanting and also for the first urea application of UB treatment and FP treatment. The second application of urea was applied at 40 days after transplanting, and the third application of urea was applied at flowering time for both UB and FP treatments. Sowing dates, transplanting dates, UDP dates, and harvesting dates are given in Table 5.

Treatments for N-Rate Trials on Transplanted Rice

This trial was conducted with the same six treatments (control and five different nitrogen rates), with three replications, as the 2015 wet season. Treatments are as follows:

1. Zero N (control)
2. UDP with 2.7 grams (g) x 1 briquette (Urea 66 kg/acre)
3. UDP with 1.8 g x 2 briquettes (Urea 88 kg/acre)
4. UDP with (1.8 + 2.7) g x 1 briquette (Urea 110 kg/acre)
5. UDP with 1.8 g x 3 briquettes (Urea 132 kg/acre)
6. UDP with (1.8 g x 2) + (2.7 g x 1) (Urea 154 kg/acre)

Triple superphosphate at 50 kg/acre (56 kg P₂O₅/ha or 25 kg P/ha), MOP at 25 kg/acre (37 kg K₂O/ha or 30 kg K/ha), and gypsum at 10 kg/acre (4.5 kg S/ha) were applied as basal fertilizer at plot layout time, just before transplanting.

Treatments for UDP Before Broadcasting Seed

This trial was repeated with the same treatments as in the wet season 2015, but using a popular early variety, Theedatyin, and 2.7-g urea briquettes. Urea rate was 1.5 times that of the wet season. There are four treatments:

1. UDP just before sowing (100.8 kg urea/acre = 114.6 kg N/ha)
2. UDP at 20-25 days after sowing (100.8 kg urea/acre)
3. Control (Zero N)
4. Farmer's dose of urea broadcast (75 kg urea/acre = 85.2 kg N/ha)

Triple superphosphate at 50 kg/acre (56 kg P₂O₅/ha or 25 kg P/ha), MOP at 25 kg/acre (37 kg K₂O/ha or 30 kg K/ha), and gypsum at 10 kg/acre (4.5 kg S/ha) were applied as basal fertilizer for all treatments just before seed broadcasting.

A briquette size of 2.7 g was applied at a spacing of 14 x 12 inches on UDP plots. UDP was applied just before seed broadcasting for Treatment 1 (UDP before sowing) and 20-25 days

after sowing for Treatment 2 (UDP after sowing). There were three split applications in equal amounts of urea for Treatment 4 (total farmer's rate of urea is 75 kg/acre), one at 20-25 days after sowing, one at 40-45 days after sowing, and another at flowering time.

The trial was simply sown in a large (35 x 60 ft) plot. At harvesting time, three representing samples were taken from each treatment to get three replications for analysis of variance (ANOVA).

Treatments for UDP Spacing Trial on BR

UDP application at 16 x 16 inch spacing seemed wider on broadcast rice since yellow lines are left between UDP rows. Therefore, this trial was tested with closer UDP spacing than 16 x 16 inches. There are five treatments in this trial. Four spacings of UDP application were compared with farmer's practice broadcast urea application rate.

1. Farmer's practice (75 kg urea/acre = 84 kg N/ha)
2. UDP with 16 x 14 inch spacing (75.6 kg urea/acre or 85.9 kg N/ha)
3. UDP with 16 x 12 inch spacing (88.2 kg urea/acre or 100.3 kg N/ha)
4. UDP with 14 x 14 inch spacing (86.4 kg urea/acre or 98.2 kg N/ha)
5. UDP with 14 x 12 inch spacing (100.8 kg urea/acre or 114.6 kg N/ha)

Triple superphosphate at 50 kg/acre (56 kg P₂O₅/ha or 25 kg P/ha), MOP at 25 kg/acre (37 kg K₂O/ha or 30 kg K/ha), and gypsum at 10 kg/acre (4.5 kg S/ha) were applied as basal fertilizer for all treatments just before seed broadcasting.

UDP was applied one time only at 20-25 days after sowing by placing one 2.7-g urea briquette at 3-4 in deep in the soil. There were three split applications in equal amounts of urea for Treatment 1 (total farmer's rate of urea is 75 kg/acre), one at 20-25 days after sowing, one at 40-45 days after sowing, and another at flowering time.

Treatments for Nitrogen x Potassium on TPR

This trial was an RCB factorial experiment in rice transplanted with 20 x 20 cm spacing. Two factors were tested with three replications. Treatments are as follows:

Factor A - Nitrogen (2 doses)

1. UDP (with 1.8 g size) (44 lb urea/acre or 51.6 kg N/ha)
2. UDP (with 2.7 g size) (66 lb urea/acre or 77.6 kg N/ha)

Factor B - Potassium (2 doses)

3. Muriate of potash 25 kg/acre (37 kg K₂O/ha)
4. Muriate of potash 50 kg/acre (74 kg K₂O/ha)

Triple superphosphate at 50 kg/acre (56 kg P₂O₅/ha or 25 kg P/ha) and gypsum at 10 kg/acre (4.5 kg S/ha) were applied as basal fertilizer at plot layout time, just before transplanting.

Treatments for Plant Spacing x Nitrogen Trials on TPR

This trial was split plot design with two factors, main plot with plant spacing and sub-plot with different nitrogen rates:

Main Plot - Spacing (S)

1. 20 x 20 cm spacing
2. 20 x 15 cm spacing

Sub-Plot - UDP (2 rates)

3. Using 1.8-g briquette
4. Using 2.7-g briquette

The urea rates were 44.1 kg/acre (51.8 kg N/ha) with 20 x 20 cm spacing and 58.8 kg/acre (69 kg N/ha) with 20 x 15 cm spacing using a 1.8-g urea briquette. By using a 2.7-g urea briquette, the rates were 66.2 kg/acre (77.6 kg N/ha) with 20 x 20 cm spacing and 88.2 kg/acre (103.5 kg N/ha) with 20 x 15 cm spacing.

Triple superphosphate at 50 kg/acre (56 kg P₂O₅/ha or 25 kg P/ha), MOP at 25 kg/acre (37 kg K₂O/ha or 30 kg K/ha), and gypsum at 10 kg/acre (4.5 kg S/ha) were applied as basal fertilizer at plot layout time, just before transplanting.

Treatments for Fertilizer Management in the Rice-Gram System

This trial is a long-term trial that extends across the rice crop and the gram crop at the same location. It is a 4 x 3 RCB design with four treatments as follows:

Treatments on Rice

1. P₂O₅ 40 kg/ha + K₂O 40 kg/ha
2. P₂O₅ 20 kg/ha + K₂O 20 kg/ha
3. P₂O₅ 0 kg/ha + K₂O 0 kg/ha
4. P₂O₅ 0 kg/ha + K₂O 0 kg/ha

Treatments on Gram

1. P₂O₅ 0 kg/ha + K₂O 0 kg/ha
2. P₂O₅ 20 kg/ha + K₂O 20 kg/ha
3. P₂O₅ 40 kg/ha + K₂O 40 kg/ha (No residue)
4. P₂O₅ 40 kg/ha + K₂O 40 kg/ha (+crop residue)

The trials were tested with gram crops. There were two trials with black gram and two trials with green gram. One trial with green gram at Nyaung Thone Bin, Thanlyin, was just started this season but failed due to poor germination.

Treatments for Different Seed Rates on BR using UDP

This is a new trial testing different seed rates of BR using UDP for nitrogen fertilizer.

Farmers are broadcasting at a high seed rate (40-60 kg seed per acre) to get a dense population and reduce the weed problem. This trial was conducted to determine yields with lower seed rates combined with balanced nutrients with UDP in broadcast seeded rice. Five different seed rates were tested with three replications. Treatments are:

1. 20 kg dry seed per acre (nearly one basket)
2. 25 kg dry seed per acre (nearly 1.25 baskets)
3. 30 kg dry seed per acre (nearly 1.5 baskets)
4. 35 kg dry seed per acre (nearly 1.75 baskets)
5. 40 kg dry seed per acre (nearly two baskets)

Triple superphosphate at 50 kg/acre (56 kg P₂O₅/ha or 25 kg P/ha), MOP at 25 kg/acre (37 kg K₂O/ha or 30 kg K/ha), and gypsum at 10 kg/acre (4.5 kg S/ha) were applied as basal fertilizer at plot layout time, just before transplanting. UDP was applied.

UDP was applied one time only 20-25 days after seed broadcasting by placing 2.7-g briquettes at a depth of 3-4 in.

Treatments for N-Rate Trial on Black Gram Using UDP and Prilled Urea

This is a new trial with the gram crop to test different N rates using UDP and prilled urea.

Two trials, one with UDP and one with prilled urea, were tested side by side. Nitrogen rates were the same for both trials and there were four treatments.

With Briquette Urea

1. Control (Zero N)
2. UDP with 1.8 g x .25 briquette
3. UDP with 1.8 g x .50 briquette
4. UDP with 1.8 g x 1 briquette

With Prilled Urea

- Control (Zero N)
Urea 12.5 kg N/ha
Urea 25.0 kg N/ha
Urea 50.0 kg N/ha

UDP was applied just after sowing by placing a specific sized briquette for Treatments 2, 3, and 4 at 16 x 16 inch spacing. Prilled urea was applied along with basal fertilizers just before sowing with last tillage.

Triple superphosphate at 25 kg/acre (28 kg P₂O₅/ha) and MOP at 12.5 kg/acre (18 kg K₂O/ha) were applied as basal fertilizers.

Plot Size and Spacing

There are variations in plot size between trials according to the type of trial and the kind of treatments. Many trials were conducted with a plot size of 16 x 16 ft. Plot sizes used in each trial are given Table 4. A detailed plan can be seen in the protocols.

Table 4. Plot Size and Spacing Used for Specific Trial, 2016 Dry Season Trials

No.	Trial Name	Plot Size	TPR Spacing
1	UDP adaptation trial on TPR	28 x 24 ft	8 x 8 in
2	Different N-rate trial using UDP on TPR	16 x 16 ft	8 x 8 in
3	UDP before seed broadcasting trial on BR	35 x 60 ft	Broadcast
4	UDP spacing trial on BR	28 x 28 ft	Broadcast
5	Nitrogen x potassium trial on TPR	16 x 16 ft	8 x 8 in
6	Plant spacing x nitrogen trial on TPR	16 x 16 ft	2 spacings tested
7	Fertilizer management trial on rice-gram cropping system	16 x 16 ft	Broadcast (gram)
8	Different seed rate trial on BR using UDP	21 x 18 ft	Broadcast
9	Different N-rate trial on black gram using UDP and PU	20 x 20 ft	Broadcast (gram)

Trial descriptions about varieties used, sowing dates, UDP dates, and harvest dates can be seen in Table 5.

Weeds and Water Problems

Dry season rice often has weeds and water problems. Rice is mostly grown under insufficient water conditions in the dry season. Though expecting more yields in the dry season, farmers are always looking for cost reduction cultivation practices to minimize the cost of cultivation.

Water management practice was poor on many farmers' fields regardless of water availability. Farmers are keeping standing water very deep where availability of water is not limited and not putting much effort to irrigate when there is no water in the field for a period of time.

Weeds are normally a problem in rice fields with lack of water. A weed problem was noted particularly at Pynmalwin, Daik-U, and Thewatchaung, Letpadan.

Results and Discussion

UDP Adaptation Trials

Yield (mt/ha)

The results showed that the UDP treatment gave the highest yield at all four locations. UDP yields ranged from 4.36 mt/ha at Pynmalwin to 5.77 mt/ha at Eingyi. However, the differences were only statistically significant at Eingyi, Inglone, and Pynmalwin. There was no significant difference among treatments at Zaybine. The second highest yield was observed with UB treatment at Eingyi and Pynmalwin, where N rate with UB (77.6 kg N/ha) was higher than that with FP (56.8 kg N/ha). At Inglone and Zaybine, the second highest yield was observed with the FP treatment in which the rate (85.2 kg N/ha) was higher than the UB rate (77.6 kg N/ha). Control plots with Zero N had the lowest yields at all locations (Table 7) (Figure 1).

Among all trials, the Pynmalwin trial gave the lowest yield for all treatments, since soil fertility in the location is the poorest, with very sandy soil. The average yield at Pynmalwin was only 3.42 mt/ha, while other locations gave more than 4.50 mt/ha (Figure 1).

Among the three locations where significant differences were found, UDP yields were significantly higher than all other treatments at two locations (Eingyi and Inglone). At Pynmalwin, the UDP yield was the highest but not statistically different from the UB treatment (Table 7).

Dry Grain Weight of Biomass (g/25 plants)

Dry grain weights of biomass with UDP were highest at three locations (Eingyi, Inglone, and Pynmalwin), and statistical differences were also found. Dry grain weight of biomass with

UDP was significantly higher than all other treatments at Eingyi. However, there were no statistical differences between any N-applied plots at the other locations. Only the control treatment was statistically lower. At Zaybine, there was no significant difference between treatments, and the UDP treatment did not give the highest grain weight. The UB treatment had the highest biomass grain weight (762 g/25 plants), whereas UDP had 738 g/25 plants (Table 9).

Eingyi (Twantay) – A popular variety of dry season rice, Theedatyin was used in this trial. Significant differences were found in yield and all other component characteristics, except 1,000-grain weight and panicle length. The UDP treatment gave the highest yield (5.77 mt/ha) and highest values for other characteristics, which were statistically higher than other treatments. The UB treatment, which used the same N rate as UDP and a higher rate than the FP treatment, gave the second highest yield (4.29 mt/ha) but was not significantly different from the FP treatment. The control plot gave a significantly lower yield of 3.45 mt/ha (Table 7). Significant differences between treatments were also observed on biomass yield (straw and grain and wet and dry). UDP gave the significantly highest biomass than any other treatment, which indicates UDP application could increase both yield and straw for animal feed. Among the yield contributing characteristics, the number of tillers per hill was the most determining factor to increase yield. The UDP treatment had 21.3 panicles per hill (Table 11), which was significantly higher than other treatments. The number of spikelets and grains per panicle could be secondary determinants for yield. The UDP treatment had the highest number with those characteristics (157 spikelets/panicle and 119 grains/panicle), which were significantly higher than other treatments (Refer to the Eingyi, Twantay data sheet in Appendix 1).

Inglone (Kunchangone) – The Theedatyin variety was also used in this trial. Significant differences were found in yield and other characteristics, except 1,000-grain weight and panicle length. The number of grains per panicle and dry grain of biomass were significant at $P_{(0.05)}$ level, and others were highly significant at $P_{(0.01)}$ level. The UDP treatment gave a significantly higher yield (5.70 mt/ha) than other treatments. The UB and FP treatments were not different, with nearly equal yield (4.86 and 4.87 mt/ha, respectively). Zero N treatment gave a significantly lower yield of 3.38 mt/ha. Biomass straw weights, both wet and dry, with UDP were significantly higher than other N-applied treatments (2,192 g wet straw weight and 650 g dry straw weight), while there was no statistical difference in biomass grain weight among N-applied plots. Though no differences, UDP gave the highest biomass grain weights

(672 g wet grain and 617 g dry grain weight) among treatments. The determinant for yield was the number of panicles per hill. UDP was the highest (17.8) and significantly different than other treatments (Refer to the Inglone, Kunchangone data sheet in Appendix 1).

Pyinmalwin (Daik-U) – Farmers’ preferred variety, Thai Manaw, was used in this trial. It is not an improved variety and, unfortunately, had poor purity. Off-type plants were observed during the vegetative stage and rogued out. Due to impurity of seed and poor soil fertility (light sandy soil), the yield at Pyinmalwin was the lowest among all test sites. Average paddy yield was only 3.42 mt/ha, whereas other sites produced about 4.50 mt/ha. Nevertheless, significant yield differences were found among treatments. The UDP treatment gave the highest yield (4.36 mt/ha), which was not statistically different from the second highest yield (3.77 mt/ha) with UB treatment. The yields of UB treatment and FP treatment were also not significantly different. Zero N treatment gave a significantly lower yield. Significant difference at $P_{(0.05)}$ level was found on biomass yield of straw and grain but only between N-applied plots and Zero N. The UDP treatment did have a higher biomass yield than other N-applied plots (UB or FP), but the difference was not significant. There were no treatment differences in other characteristics (Refer to Pyinmalwin, Daik-U data sheet in Appendix 1).

Zaybine (Thanatpin) – The trial used a high-yielding, medium-maturing variety, Sinthukha (140 days), with a higher rate of urea (75 kg urea/acre or 85.2 kg N/ha) on the FP treatment. The soil is comparatively fertile since only one rice crop is grown in the dry season and the land is flooded during the rainy season. The soil is clay meadow, which is suitable for a rice crop. No significant difference was found on yield and many component characteristics. However, the highest yield (5.39 mt/ha), highest number of panicles per hill (14.5), and highest number of spikelets per panicle (203) were produced with UDP. Significant difference at $P_{(0.05)}$ was found only on dry straw weight of biomass, but differences were between the N-applied plots and control plot only (Refer to the Zaybine, Thanatpin data sheet in Appendix 1).

Analysis of variance among treatments across all four locations showed highly significant ($P_{(0.01)}$) differences in yield. The UDP treatment produced the highest yield with 5.31 mt/ha, and it was statistically different from the yields of all other treatments. The UB treatment gave the second highest yield with 4.26 mt/ha, a little higher (but not significantly) than the third highest yield with FP, which produced 4.23 mt/ha. Zero N treatment was the lowest with 3.30 mt/ha (Figure 1).

The yields with UDP were the highest in all locations. Yield superiority of UDP over other treatments varied from 11.07% over FP at Zaybine, Thanatpin, to 78.92% over the control at Pynmalwin, Daik-U. The UDP treatment could out-yield other treatments on both fertile soil at Zaybine and poor soil at Pynmalwin. The yield superiority of UDP over FP at Eingyi and Pynmalwin was higher than it was over UB, since the N rate with FP was lower than that with UB. As an average across all locations, yield superiority of UDP was 24.67% over UB and 25.30% over FP (Table 8).

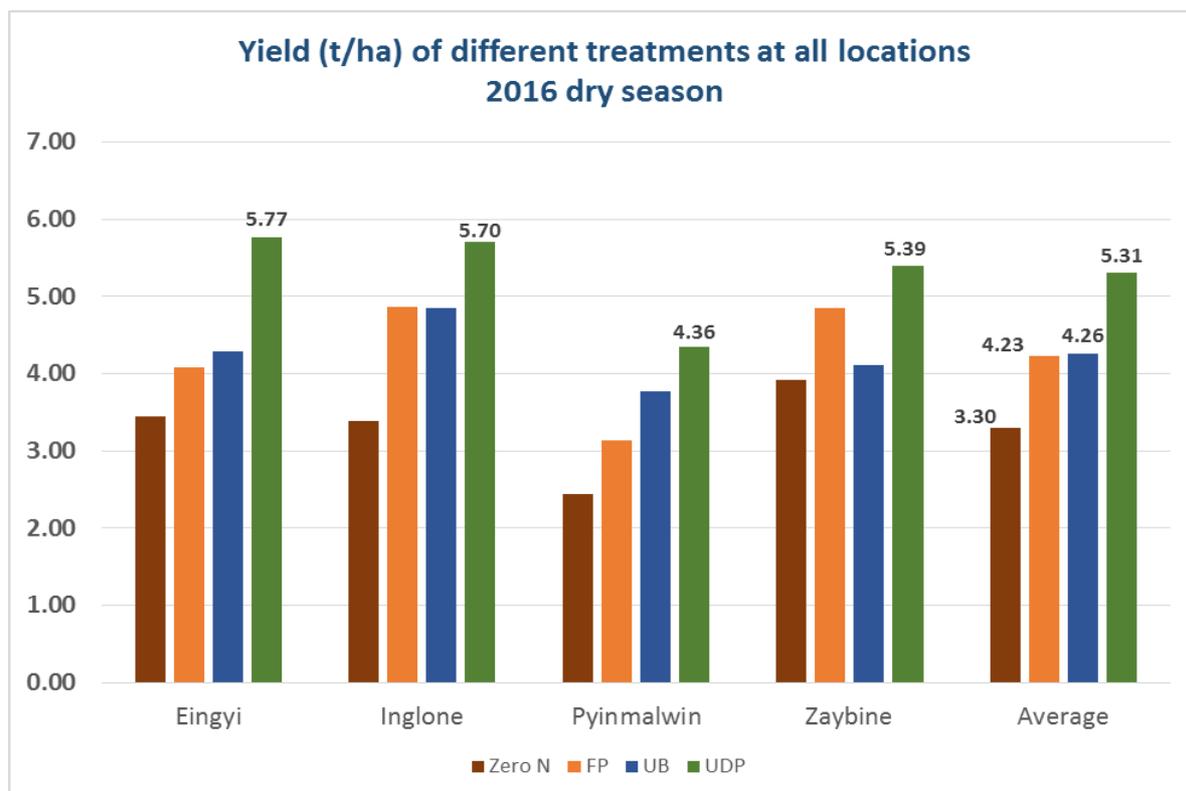


Figure 1. Paddy Yield Comparison of Different Treatments by Location

Number of Panicles per Hill

The highest number of panicles per hill with UDP were observed at three out of four locations. UDP did not produce the highest number of panicles per hill at Pynmalwin. The UB treatment produced the highest with 15.7 numbers of panicles per hill, and UDP gave a comparably high number of panicles with 15.3 per hill. Significant differences ($P_{(0.05)}$) of treatments on the number of panicles per hill were found at two locations only, Eingyi and Inglonge (Table 6). At both locations, the UDP treatment gave a significantly higher number than all other treatments. The UDP treatment at Eingyi produced the highest number of panicles per hill with 21.3, and it was significantly higher than other treatments. At Inglonge,

the highest number of panicles per hill (17.8) in the UDP treatment was also significantly higher than other treatments. There were no differences between treatments at the other two locations. Though not significant, UDP did produce the highest number of panicles per hill at Zaybine but not at Pyinmalwin. At Pyinmalwin, the UB treatment produced the highest number of panicles per hill with 15.7, but this was only slightly higher than the UDP treatment, which produced 15.3 panicles per hill (Table 10).

According to ANOVA across all four locations, there was significant difference at $P_{(0.05)}$. The UDP treatment gave the highest number of panicles per hill with 17.2, and it was statistically higher than all other treatments. FP produced the second highest with 14.3 panicles, UB was third with 13.3 panicles, and Zero N produced the lowest with 12.0 panicles per hill. There was no significant difference between those three treatments (Table 10).

1,000-Grain Weight (g)

There was no significant difference in 1,000-grain weight among treatments in all locations. Variations in 1,000-grain weight within treatments were observed at all locations. The UDP treatment did not give the highest grain weight. The highest 1,000-grain weight with UDP (26.1 g) was obtained at Pyinmalwin only. The UB treatment gave the highest grain weight at three locations, Eingyi, Inglone, and Zaybine. ANOVA across locations by treatments also showed no differences between treatments (Table 11).

Agronomic Efficiency (AE) – Yield Grain per kg N Applied

In the 2016 dry season, UDP showed the highest agronomic efficiency² (AE) at all four locations, which means UDP was the most effective application method of nitrogen application. The highest AE (29.94 kg/kg N) with UDP was calculated at Eingyi, which was slightly higher than the second highest AE (29.86 kg/kg N) at Inglone. The lowest AE (18.88 kg/kg N) with UDP was found at Zaybine.

As an average over all locations UDP is the most effective method of urea application among all application methods and can give 25.86 kg rice by applying one kg of urea. The second effective application was FP, which gave 12.93 kg rice yield per kg of urea. However, it was only slightly higher than UB, which also gave 12.33 kg/kg urea (Table 12).

² (Yield of fertilized crop – yield of control)/amount of fertilizer applied.

UDP, Yield Parameters, and Yield

In the 2016 dry season, UDP treatment gave the highest yield at all four locations, and it was significantly different at three locations, Eingyi, Inglone and Pyinmalwin. Only one location, Zaybine, did not show significant differences among treatments, but the UDP treatment still gave the highest yield (Table 7). Rice is grown one time only in the dry season at Zaybine due to deep water conditions in the wet season. Soil is fertile since nutrient replacement occurs due to precipitation of nutrients from floodwater. That may be the reason for no differences between N-applied treatments and control. According to an analysis of locations by treatments, it was found that the UDP treatment produced a significantly higher yield than all other treatments with 5.31 mt/ha, followed by UB and FP. UB and FP treatments were not different from one another, with 4.26 mt/ha and 4.23 mt/ha, respectively. Zero N gave significantly lower yield with 3.30 mt/ha (Table 7 and Figure 1). Yield superiority of UDP, on average, was 24.67% over the second highest treatment (UB), 25.30% over FP treatment, and 60.85 % over Zero N treatment (Table 8).

Among the yield contributing characteristics, a significant difference was found in the number of panicles per hill, followed by the number of grains per panicle at locations that corresponded with yield differences. It is concluded that UDP could improve the number of productive tillers over other urea application practices. This was clearly visible at the maximum tillering stage. The number of grains per panicle may be a second characteristic that could improve yield with UDP application, since it showed significant differences at two locations (Table 6). Since there was no difference in 1,000-grain weight at any location, it is assumed UDP does not improve this characteristic.

N-Rate Trial at Myaungmya

In the 2016 dry season, the N-rate trial at Myaungmya showed no significant differences for yield. Among the plant characteristics, significant differences were observed for plant height ($P_{(0.05)}$), ($P_{(0.05)}$), number of panicles per hill ($P_{(0.01)}$), fresh straw weight ($P_{(0.01)}$) and dry straw weight ($P_{(0.01)}$) ($P_{(0.01)}$) (

Table 13). Only one yield component characteristic, the number of panicles per hill, showed significant difference among treatments. Biomass straw weight also showed significant difference. This is important for animal feed. The maximum yield and highest values of most parameters were found with the second highest N rate (155.3 kg N/ha), whether it was significant or not. Only two characteristics, number of spikelets per panicle and 1,000-grain weight, did not give the highest value with the second highest N rate (Refer to the Research Farm, Myaungmya data sheet in Appendix 1).

Response curves of significant parameters (plant height, number of panicles per hill, and biomass straw weight) are given in Figure 2, Figure 3, and Figure 4, which all show highest values with the second highest N rate (155.3 kg N/ha).

Plant height – Significant differences were found between treatments. The highest N-rate treatment (181.1 kg N/ha) did not give the tallest plant. It was nearly the same height as the control (Zero N), and they are not statistically different. The second highest N rate (155.3 kg N/ha) gave the tallest plant with 103 cm, and it was not different from the heights with the two lowest N rates (77.6 kg N/ha and 103.5 kg N/ha) (Figure 2).

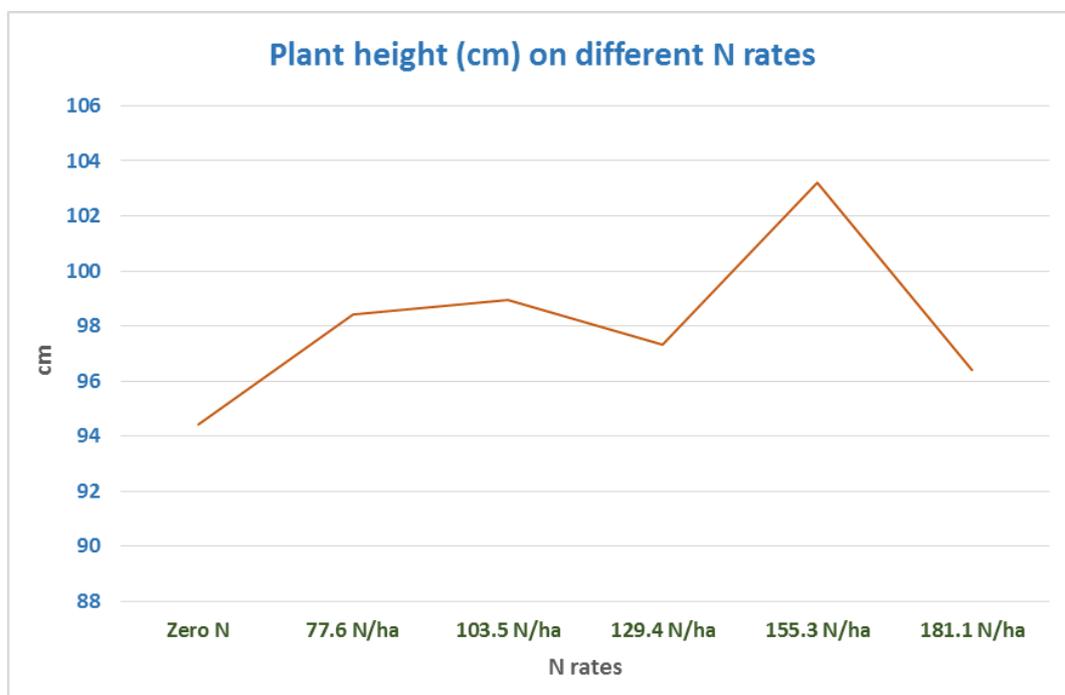


Figure 2. Response of Plant Height (cm) on Different N Rates

Number of panicles per hill – Analysis of variance shows significant differences in the number of panicles per hill. This difference was between the control (11.4 panicles per hill)

and the N-rate treatments only. There were no significant differences among different N-rate treatments. The highest N rate (181.1 kg N/ha) did not give the highest number of panicles per hill (19.7). However, it was second in the group. The second highest N rate (155.3 kg N/ha) gave the highest number of panicles (19.8) per hill. There were some variations in the number of panicles per hill among the three lowest N rates. It did not follow as the N rate increased (Figure 3).

Biomass straw weight – Significant differences were observed on both fresh and dry straw weight. The trend was similar to plant height and number of panicles per hill. The highest N-rate did not give the highest biomass straw weight. The second highest dose of nitrogen gave the highest biomass straw weight. However, biomass straw weights of the top three N rates were not significantly different (Figure 4).

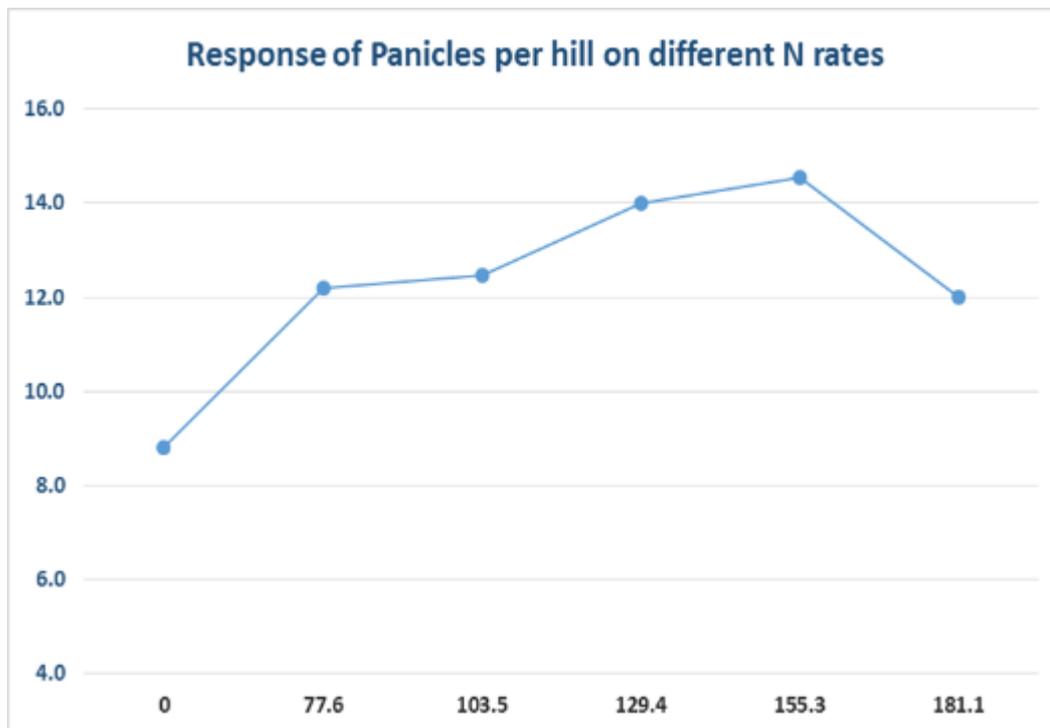


Figure 3. Response of Number of Panicles per Hill on Different N Rates

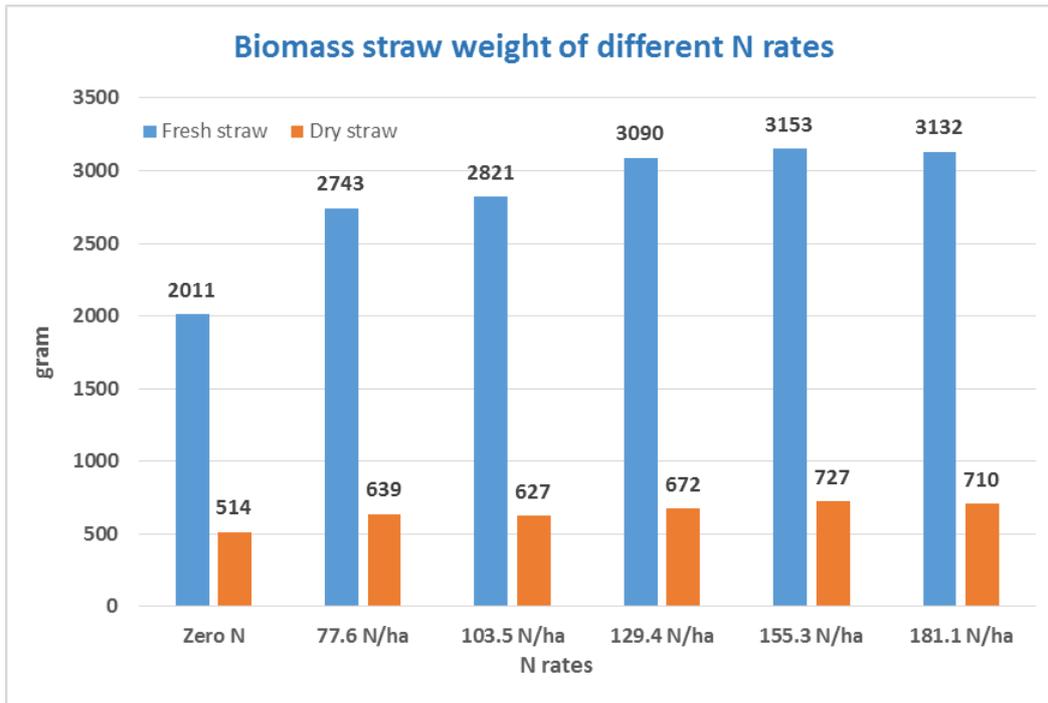


Figure 4. Response of Biomass Straw Weight on Different N Rates

Yield – There were variations in yield among treatments and the ANOVA did not show a statistical difference among the treatments. Rather, a high yield (5.86 mt/ha) was obtained even with Zero N treatment. However, similar to other significant characteristics, the second highest N rate (155.3 kg N/ha) produced the highest yield with 6.12 mt/ha. The highest N rate (181.1 kg N/ha) produced the lowest yield with 5.03 mt/ha (

Table 13).

In this trial, it was noticed at harvesting time that grains from N-applied plots were less filled compared to that of the Zero N plot. Although disease was not serious in the dry season, it was observed that sheath rot disease was slight on most of N-applied plots. Grain discoloration was also observed on N-applied plots. Because of the lowest biomass straw weight, the Zero N treatment had the highest grain-straw ratio among all treatments.

This trial was conducted to identify the highest N rate that gives the peak yield. Based on the similar result of yield to the significant results of plant height, panicles per hill, and biomass straw weight, the highest yield could be obtained with a N rate of 155.3 kg N/ha, and the yield would decline beyond that rate.

UDP Before Seed Broadcasting Trials

These trials were conducted to determine possible alternatives for applying UDP technology on broadcast rice at two locations, one at Yindaikkwin, Taikkyi township, Yangon region, and one at Kanyingae, Kyaiklat township, Ayeyarwady region. It used a popular early maturing variety (Thee Dat Yin – 110 days to maturity) to compare yield response to UDP application before seed broadcasting (Treatment 1) and after seed broadcasting (Treatment 2) with Zero N (Treatment 3) and surface broadcasting of urea as FP (Treatment 4).

Yindaikkwin (Taikkyi) – It was found that yield, plant height, number of grains per panicle, and biomass straw and grain weights were significantly different between treatments. The yield, plant height, and biomass straw weights were significant at $P_{(0.01)}$ level and others were significant at $P_{(0.05)}$ level. UDP application after seed broadcasting produced the highest yield with 6.30 mt/ha, and it was statistically different from yields in other treatments. UDP application before seed broadcasting gave the second highest yield (5.11 mt/ha), but this was not significantly different from FP treatment, which gave 4.90 mt/ha. Zero N treatment had the significantly lowest yield with 2.90 mt/ha. Similar to yield response, plant height (cm), number of grains per panicle, and biomass straw and grain weight had the highest value with Treatment 2 (UDP after seed broadcasting).

Plant heights of UDP treatments were significantly higher than that of other treatments. UDP after sowing treatment had a height of 86 cm, which was not different from plant height (82 cm) of UDP before sowing treatment. The Zero N treatment had significantly shorter

plant height with 70 cm. The number of grains per panicle of UDP after sowing was the maximum with 110, but not significantly different from that of UDP before sowing, which had 93 grains per panicle. The number of grains per panicle of UDP before sowing, FP, and Zero N were not statistically different. UDP after sowing treatment produced the highest biomass weights of both straw and grain (Refer to Yindaikkwin, Taikkyi data sheet in Appendix 1).

Kanyingae, Kyaiklat – In this trial, significant differences among treatments were found in yield and all other characteristics except 1,000-grain weight. Plant height, number of spikelets per panicle, and biomass straw weight were highly significant ($P_{(0.01)}$), and yield and other characteristics were significant at $P_{(0.05)}$ level. Treatment 1 (UDP application before seed broadcasting) produced the highest yield with 5.67 mt/ha, followed by Treatment 2 (UDP application after sowing) with 4.95 mt/ha, and Treatment 4 (FP prilled urea application) with 4.10 mt/ha yield. Zero N treatment gave the lowest yield with 2.90 mt/ha. However, the significant difference was between urea-applied treatments and Zero N treatment only. There was no statistical difference among urea-applied treatments (Refer to Kanyingae, Kyaiklat data sheet in Appendix 1).

Unlike yield results, other plant characteristics gave the highest values with UDP after sowing. Plant height with UDP treatments (before and after sowing) was significantly higher than that with other treatments. Plant height with UDP after sowing treatment was 92 cm and not different from that of UDP before sowing treatment, which had a plant height of 91 cm. The FP treatment had 80-cm plant height, and Zero N had the significantly shortest plant height with 68 cm.

The number of panicles per square meter of UDP after sowing treatment was the maximum, with 502, and significantly different from all other treatments. The FP treatment produced the second maximum number of panicles per square meter (415) followed by UDP before sowing (383) and Zero N (362), which are not different from each other.

The difference in biomass grain weight (g/m^2) was significant at $P_{(0.05)}$, and this difference was between urea-applied treatments and Zero N treatment only (Refer to Kanyingae, Kyaiklat data sheet in Appendix 1).

According to yield results from both locations, UDP-applied plots gave higher yield than FP treatment, although there were some inconsistent results within UDP-applied plots. UDP before sowing produced the highest yield at Kanyingae, while UDP after sowing produced the highest yield at Yindaikkwin. It suggests that UDP can be applied before or after seed broadcasting. In this trial, UDP was applied at 14 x 12 inch spacing, at a rate of 114.6 kg N/ha, which was higher than the rate of FP (85.2 kg N/ha), which may be the reason for the higher yield with UDP (Figure 5).

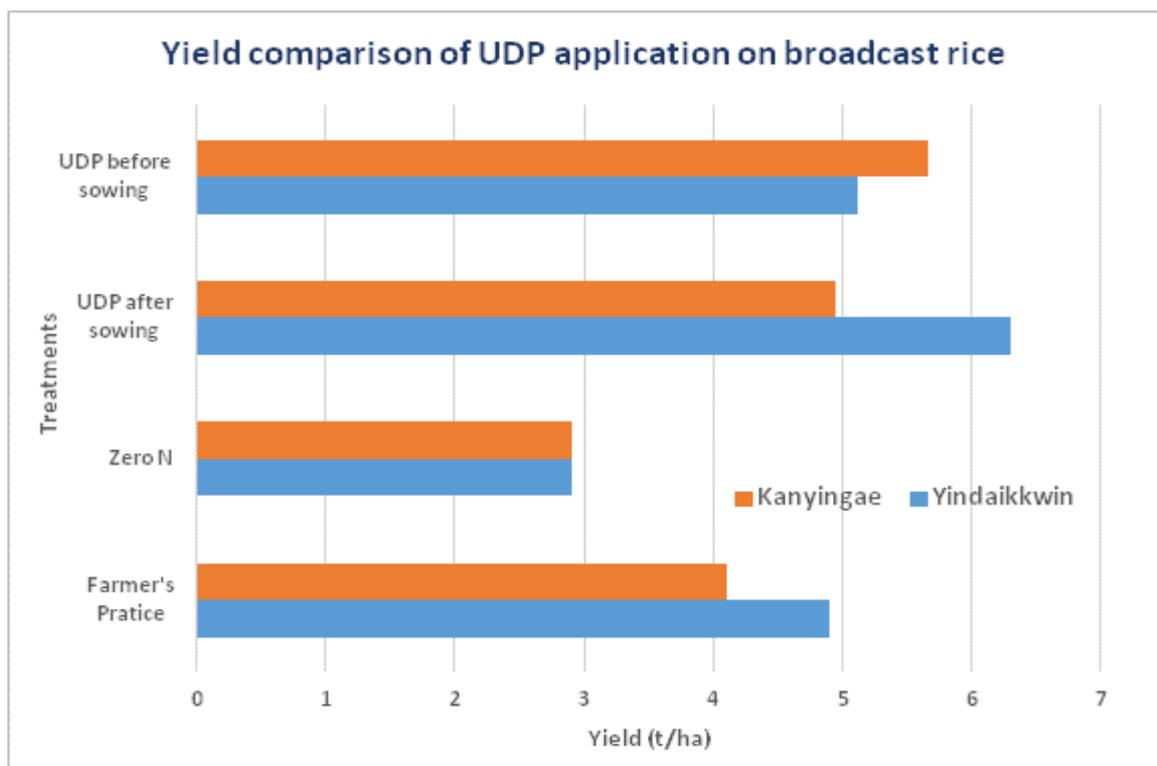


Figure 5. Yield Comparison of UDP Application, FP, and Zero N at Kanyingae and Yindaikkwin

UDP Spacing Trials on Broadcast Rice

These trials were designed to determine the best spacing for UDP application on broadcast rice, since the UDP spacing (16 x 16 inches) on broadcast rice seemed wide, leaving thin yellow lines between points of placement of urea briquettes. This was interpreted as a sign that the plants were not getting enough N. Trials were conducted at two locations, one at Taikkyi township, Yangon region, and one at Kyaiklat township, Ayeyarwady region, using a popular early maturing variety (Thee Dat Yin – 110 days to maturity). UDP spacing treatments were 16 x 14, 16 x 12, 14 x 14, and 14 x 12 inches. A check treatment was FP with broadcast prilled urea split surface application as Treatment 1. Nitrogen rates were

therefore 85.9 kg/ha with 16 x 14 inch, 100.3 kg/ha with 16 x 12 inch, 98.2 kg/ha with 14 x 14 inch, and 114.6 kg/ha with 14 x 12 inch spacing. FP treatment had 84 kg N/ha.

Yindaikkwin, Taikkyi – In this trial, yield and most characteristics were not significantly different among treatments. Significant differences were found only on plant height and biomass straw weights, both fresh and dry. The results showed some variations between treatments. Yield and most of characteristics gave the highest value, with 16 x 12 inch UDP spacing. The number of spikelets per panicle and biomass grain weight were the highest with the narrowest UDP spacing (14 x 12 inch). The tallest plant height (88 cm) was observed with 14 x 14 inch UDP spacing. Significant characteristics, plant height, and dry biomass straw weight showed differences between UDP-applied plots and FP plot only. There were no statistical differences between UDP-applied plots with different UDP spacing. There was no difference on fresh straw weight between UDP-applied treatments, and the weight of closer spacing of UDP was also not different from that of Zero N treatment (Refer to Yindaikkwin, Taikkyi data sheet in Appendix 1).

Kanyingae, Kyaiklat – Analysis of variance showed significant differences among treatments on yield and most characteristics, except dry biomass grain weight and 1,000-grain weight. The highest yield (8.26 mt/ha), the tallest plant (93 cm), and the largest panicle (20.2 cm) with a large number of spikelets and grains (126 and 98, respectively) were observed with UDP spacing of 14 x 14 inches. However, biomass yields and a large number of panicles per square meter were produced with 16 x 12 inch spacing.

The highest yield, with 14 x 14 inch UDP spacing, was 8.26 mt/ha, not statistically different from that with 16 x 12 inch or 14 x 12 inch spacing. UDP spacing of 16 x 14 inches gave the lowest yield (6.44 mt/ha) among the UDP-applied treatments and was not statistically different from the FP treatment. It can be said that UDP application with closer spacing, which means a higher N rate, could give higher yield than UDP application with 16 x 14 inch spacing, with a consequently lower N rate.

In most of the plant characteristics (plant height, panicle length, number of spikelets, and number of grains per panicle), UDP with 14 x 14 inch spacing gave the highest values. But the number of panicles per meter square and biomass yields were highest with UDP and spacing of 16 x 12 inches. However, differences were mostly between FP and UDP plots only. When comparing the N rate, UDP with 16 x 12 inch spacing (88.2 kg urea/acre or

100.3 kg N/ha) and 14 x 14 inch spacing (86.4 kg urea/acre or 98.2 kg N/ha) did not differ significantly (Refer to Kanyingae, Kyaiklat data sheet in Appendix 1).

Analysis of variance across locations showed no difference between treatments. This may be due to different trends in yield at each location. The highest yield was observed with 16 x 12 inch UDP spacing at Yindaikkwin, whereas it was observed with 14 x 14 inch UDP spacing at Kanyingae. Significant difference at Yindaikkwin was between UDP-applied plots and FP plot and that at Kanyingae was between the three closest UDP spacing treatments and FP and 16 x 14 inch. As an average over locations, 16 x 12 inch UDP spacing showed the highest yield with 7.51 mt/ha. It could be said that UDP could be applied at 16 x 12 inch or 14 x 14 inch spacing since 16 x 14 inch spacing gave similar yield to FP treatment at Yindaikkwin. The N rate of those two spacings was not very different, 100.3 kg N/ha with 16 x 12 inch spacing and 98.2 kg N/ha with 14 x 14 inch spacing (Figure 6).

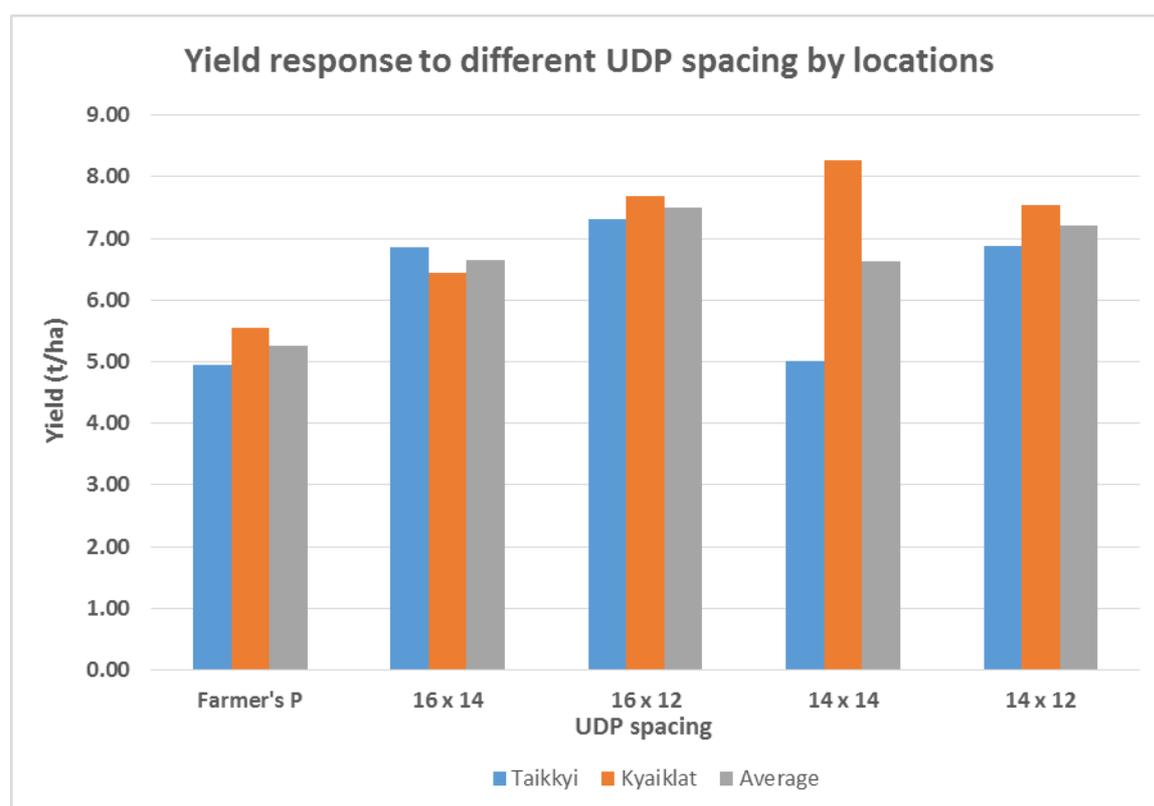


Figure 6. Yield Response to Different UDP Spacing by Locations

Nitrogen x Potassium on TPR at Chantharkone, Letpadan

Two different rates of nitrogen (51.7 kg N/ha and 77.6 kg N/ha) using two different sizes of urea briquettes and two different rates of potassium (37 kg K₂O/ha and 74 kg K₂O/ha) were tested with three replications. There were some variations in plant performance and yield

among trial plots. There were no significant differences between treatments. However, significant difference $P_{(0.05)}$ was observed for potassium rates.

Nitrogen – The higher nitrogen rate (77.6 kg N/ha) gave higher yield of 6.59 mt/ha compared to 6.42 mt/ha with the lower nitrogen rate (51.7 kg N/ha). But they were not statistically different.

Potassium – In this trial, it seemed potassium was more limiting than nitrogen. Significant difference at $P_{(0.05)}$ was observed between high K rate and low K rate. The higher K rate gave higher yield (6.73 mt/ha) than the low K rate, which gave 6.28 mt/ha.

N x K interaction – There was no interaction between N and K rate. Higher rates gave higher yields for both N and K. However, the yield with high K rate was significantly higher than the low K rate (Figure 7).

In this trial, there was no visual difference between N rates at early stages. Plants were equally healthy and green. No difference was observed between N rates though the higher N rate gave higher yield than the lower N rate. N may not be a limiting nutrient on this soil. There was no clear visual difference between K rates before harvest. However, yields with different K rates were significantly different at $P_{(0.05)}$. The higher K rate produced higher yield than the lower K rate. K may therefore be more limiting than N (Refer to Chantharkone, Letpadan data sheet in Appendix 1).

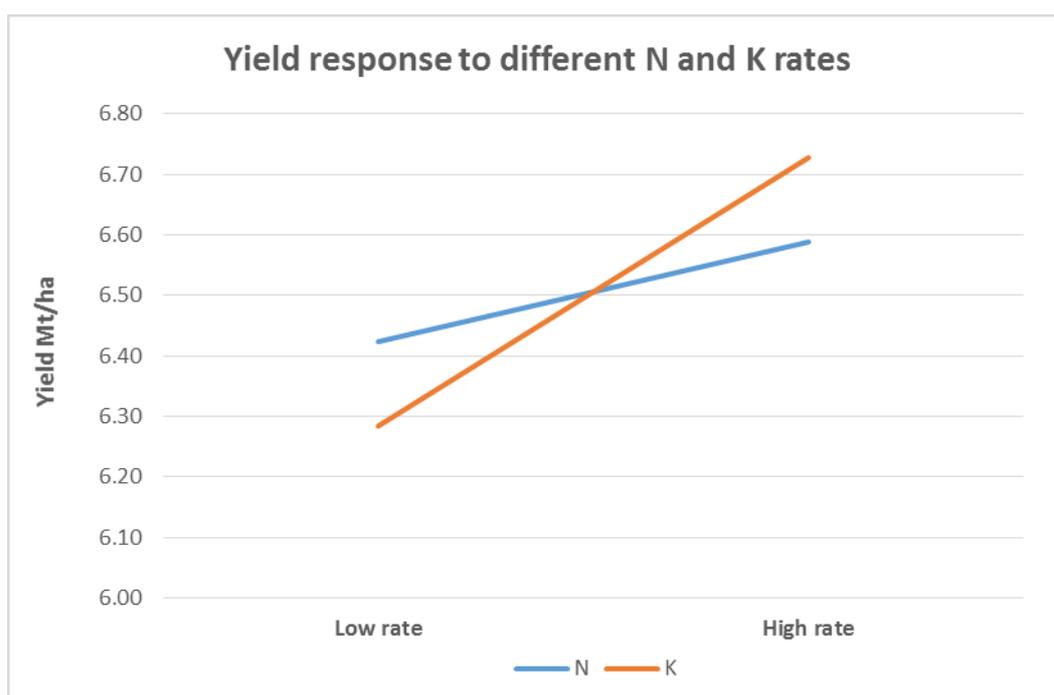


Figure 7. Yield Response (mt/ha) on Different Rates of Nitrogen and Potassium

Plant Spacing x Nitrogen Rate Trial on TPR at Thewatchaung, Letpadan

Two different plant spacings (S1=20 x 20 cm and S2=20 x 15 cm) were tested as the main factor, and two different sizes of urea briquette were tested as the sub-factor in a split plot design with three replications. Nitrogen rates were therefore 51.8 kg N/ha (20 x 20 cm spacing) and 69.0 kg N/ha (20 x 15 cm spacing) for 1.8-g briquette, and 77.6 kg N/ha (20 x 20 cm spacing) and 103.5 kg N/ha (20 x 15 cm spacing) for 2.7-g briquette. According to statistical analysis, there were no significant yield differences for both factors and no significant interaction was observed.

However, closer spacing (20 x 15 cm) gave a slightly higher yield (5.79 mt/ha) than wider spacing (20 x 20 cm), which gave 5.75 mt/ha for low N rates. With higher N rates, 20 x 20 cm spacing gave higher yield (5.86 mt/ha) than 20 x 15 cm spacing (5.78 mt/ha). As an average, wider spacing gave more yield than closer spacing. But according to ANOVA, the difference was not significant (Figure 8). This is because plants sown in wider spacing having more productive tillers (17.6 panicles per hill) than plants with closer spacing, which have only 14.3 panicles per hill.

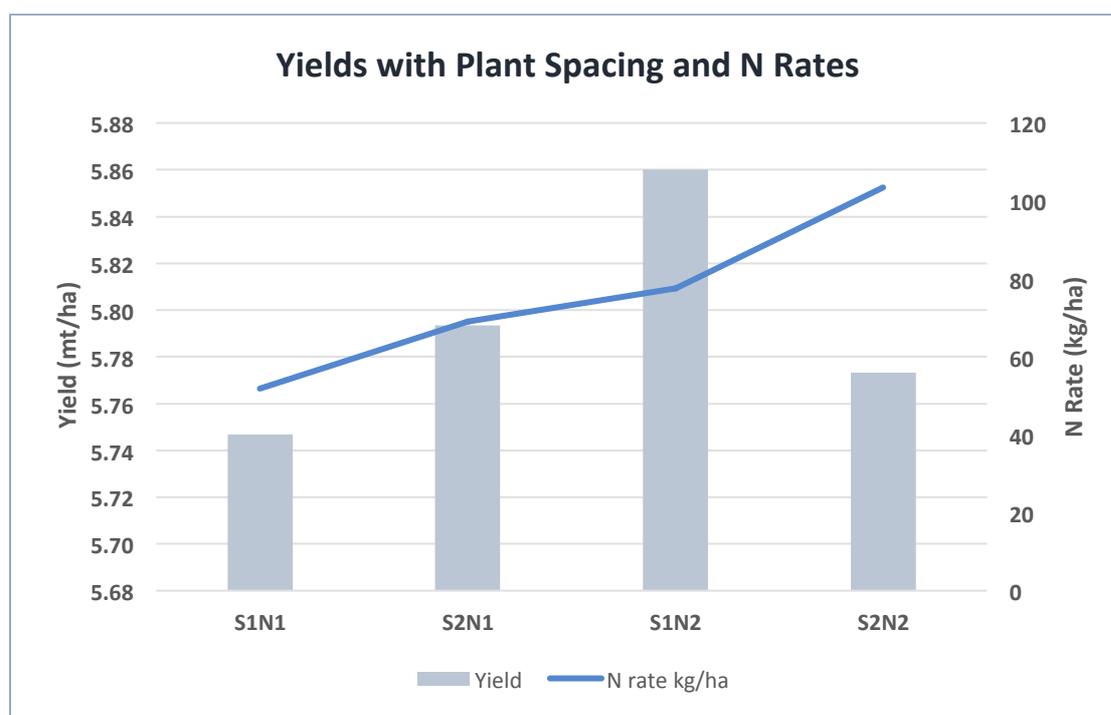


Figure 8. Yield Response (mt/ha) on Different Plant Spacing and Nitrogen Rates

There was no significant yield difference between N rates. With wider spacing, the higher N rate produced more yield than low N rate (5.86 mt/ha and 5.75 mt/ha, respectively). With closer spacing, the yields with lower N rate and higher N rate were similar (5.79 and 5.78 mt/ha, respectively). As an average over two spacings, the lower N rate gave lower yield (5.77 mt/ha) and higher N rate gave higher yield (5.82 mt/ha) (see Figure 8).

Fertilizer Management Trials on Rice-Gram Cropping System

Different amounts of P and K on rice or gram were tested in the rice-gram cropping system. This is a long-term experiment to study the carryover effect of P and K on the subsequent crop (gram or rice).

In the 2016 dry season, the gram crop was grown for the first time after harvesting the wet season rice crop. With Treatment 1, zero P and zero K were applied on the gram crop, and both P and K had been applied on the rice crop. With Treatment 2, half the amount of P (20 kg P₂O₅/ha) and half the amount of K (20 kg K₂O/ha) were applied, which was the same amount applied on rice. The full amount of P (40 kg P₂O₅/ha) and the full amount of K (40 kg K₂O/ha) were applied on Treatments 3 and 4. After harvesting the gram crop, all crop residue will be added for the next rice crop on Treatment 4. No N was applied on the gram crop. The trials were conducted on the same plot as rice at all locations.

The significant test of yield and all component characteristics for all three locations are given in Table 14. According to the ANOVA, there were no significant differences between treatments on almost all component characteristics and yield. Significant difference at $P_{(0.05)}$ was observed on 100-seed weight at Tharkwin, Einme only.

Thar Kwin, Einme – No significant differences were observed on yield and plant characteristics, except 100-grain weight. Significant difference at $P_{(0.05)}$ was observed on 100-seed weight. Generally, P- and K-applied plots gave heavier seed weight than plots with no P and K, or with half of the P and K applied. The plots that received the full amount of P and K had 100-seed weight of 4.87 g (Treatment 3) and 4.67 g (Treatment 4) and were not statistically different from each other. Zero P and K and half P and K had 100-seed weight of 4.47 g each. The yields of different treatments were inconsistent. The full P and K treatments (Treatment 3) gave 1.15 mt/ha, while another (Treatment 4) gave only 1.05 mt/ha. Zero P and K produced 1.07 mt/ha, while the half P and K treatment produced 0.79 mt/ha. Yield

difference may be due to lack of plant uniformity, which was observed at the growing stage. Some plants were very small while other plants had normal growth (Refer to Tharkwin, Einme data sheet in Appendix 1).

Parami Daunt, Einme – According to ANOVA, there were no differences between treatments on all plant characteristics and yield. The Zero P and K treatment produced the lowest yield with 1.56 mt/ha, and the half P and K treatment gave the second lowest yield 4.66 mt/ha. The full amount of P- and K-applied plots gave higher yields with 1.77 mt/ha (Treatment 3) and 1.68 mt/ha (Treatment 4). But the yields were not significantly different from each other. Other plant characteristics showed no differences between treatments. The number of seeds per pod ranged from 6.5 (Treatment 4) to 6.9 (Treatment 2). P- and K-applied treatments produced heavier grain weight than no P and K treatments. Zero P and K produced 4.60 g of 100-grain weight, and plots that received P and K produced 4.67-4.77 g of 100-seed weight. But there was no significant difference between treatments (Refer to Paramidaunt, Einme data sheet in Appendix 1).

Ashaebine, Kyauktan – It was difficult to interpret P and K response on yield since all treatments gave nearly equal yields ranging from 1.63 mt/ha to 1.88 mt/ha. Zero P and K did not give the lowest yield, and the highest yield was observed with half P and K treatment. They are not significantly different from each other. No differences between treatments were observed on other characteristics. Although no differences, P- and K-applied plots gave a slightly heavier grain weight (8.47 g and 8.53 g) with the full amount of P and K and 8.27 g and 8.47 g with half the amount of P and K and Zero P and K, respectively (Refer to Ashaebine, Kyauktan data sheet in Appendix 1).

This is the first time a gram crop was planted in a rice-gram system. Farmers' practice of land preparation must improve to get proper tillage for the gram crop. Residual moisture content of the soil is also important to get good germination and establishment of the crop. Poor germination and poor crop establishment were noted at all locations. This is evident by how many plants in 100 ft² could be harvested (see the data sheets of all locations in Appendix 1). Final yields are adjusted to the same number of plants. The non-significant result may be because P and K levels applied in this experiment are too low. The trial will continue with higher rates of P and K in coming seasons/years.

Different Seed Rate Trial on BR

Myanmar farmers are practicing broadcast rice using a high seed rate (150-200 kg/ha). UDP application at 25-30 days after sowing on a dense broadcast rice field is difficult since seedlings are too thick to use the push type UDP applicator. This trial was conducted to study yield differences between different seed rates on broadcast rice. There were five treatments with five seed rates (50, 62.5, 75, 87.5, and 100 kg seed/ha). As basal fertilizer, 50 kg TSP/acre, 25 kg MOP/acre, and 10 kg gypsum/acre were applied just before sowing. UDP was applied at 20-25 days after sowing with 14 x 12 inch spacing (100 kg urea/acre).

In this trial, no significant differences were found on yield or any characteristics. There are some variations of results on all parameters. Trends of results are not similar among parameters. The lowest seed rate (50 kg seed/ha) gave the highest yield with 5.82 mt/ha. The lowest yield (4.97 mt/ha) was found with 75-kg seed rate. But with biomass yields per square meter, both straw and grain were the highest with the highest seed rate (100 kg/ha). The number of panicles per square meter also had the same result with biomass yields, which could mean that the highest seed rate may produce the highest yield. Although not a significant difference, the lowest seed rate had the highest number of spikelets and grains. That might be the reason that the highest yield occurred with a lower seed rate and less number of panicle per square meter. The reason the crop cut yield did not agree with the above results may be due to sample size. It was somewhat difficult to get a 100 ft² crop cut sample area that had enough population. The germination of broadcast rice on a farmer's field is often found not uniform due to uneven land preparation. However, from the results of this trial, seed rate on broadcast rice could be reduced down to 50 kg dry seed/ha (Refer to Seed Rate Trial at Eingyi, Twantay data sheet in Appendix 1).

N-Rate Trial on Black Gram Using UDP and Prilled Urea

This trial was conducted for the first time to see the response of N on yield by applying different rates of urea briquettes and prilled urea. Two trials were conducted side by side. There are some constraints with farmers' practice of land preparation and the residual moisture content of soil. It was difficult to deep-place urea briquettes due to uneven tillage. The soil was too hard to apply UDP in many places. Germination and establishment of crop were very poor. Several variations in plant growth and germination were observed. The data was found hard to interpret and not reported.

Conclusion

UDP Adaptation Trials

UDP treatment gave the highest yield at all four locations. It was significantly higher at three locations, but there was no significant difference at Zaybine. Although not significant, the yield with UDP (5.39 mt/ha) was clearly the highest among all treatments (Table 7). The highest yield increase of UDP over other N-applied treatments was 41.69% and observed at Eingyi, where the FP N rate was lower than the UDP rate. The lowest yield increase of 11.07% was calculated at Zaybine, where the FP N rate was higher than the UDP rate. On average, yield superiority of UDP over UB with the same N rate was 24.67%. It was 25.3% over FP, although N rates varied. It is concluded that a 25% yield increase can be expected by applying UDP (Table 7 and Table 8).

The highest yield with UDP was explained by the number of productive tillers since it was significantly the highest at two locations (Eingyi and Inglone). At the other two locations, it was not significant, but panicles with UDP were not the lowest or even more than other treatments, particularly at Zaybine (Table 10).

With UDP technology, 25.86 kg of rice was obtained by applying a kilogram of N, whereas surface broadcasting of prilled urea gave only 12-13 kg of grain per kg of N (Table 12). It is concluded that UDP technology is clearly the most effective use of N fertilizer and needs less fertilizer than urea surface broadcast applications.

N-Rate Trial

There was no significant difference in yield among treatments. However, the highest yield (6.12 mt/ha) was obtained with the second highest N rate of 155.3 kg N/ha. The yield started to decline after that, and the highest N rate (181.1 kg N/ha) did not give the highest yield; it was even lower than the control (Refer to Research Farm, Myaungmya data sheet in Appendix 1). This yield result was similar to the results of the number of panicles per hill and biomass straw weight in which significant differences were observed; the highest number of panicles per hill and highest biomass straw weight were produced with the second highest N rate. Although not significant, other characteristics also had the highest value/amount with the second highest N rate, except the number of spikelets per panicle. The total number of spikelets per panicle was similar for all N rates. Therefore, it can be concluded that the

highest rice yield can be expected with an N rate of about 155.3 kg/ha with balanced fertilization of other important nutrients.

UDP Before Broadcasting Trial on BR

Significant results from test locations showed a possibility of UDP application before seed broadcasting on broadcast rice fields. UDP application just before seed broadcasting gave the highest yield at Kanyin Gae, Kyaiklat, although it was not statistically different from other N-applied treatments (Refer to Kanyingae, Kyaiklat data sheet in Appendix 1). At Yin Daik Kwin, Taikkyi, UDP application after seed broadcasting produced the highest yield, and it was statistically different from all other treatments. UDP before sowing gave the second highest yield at Taikkyi. It seemed that UDP application before sowing did not provide enough N throughout the season at Taikkyi (Refer to Yindaikkwin, Taikkyi data sheet in Appendix 1). It was observed at flowering time that the plant color under UDP in the pre-sowing treatment was not as green as the post-sowing treatment. However, this did not show at Kyaiklat. In these trials, unlike on transplanted rice, UDP spacing of 14 x 12 inches was used and, therefore, the N rate with UDP (114.6 kg N/ha) was higher than the FP treatment (85.2 kg N/ha). It was tested on an early maturing variety, Thee Dat Yin. With normal UDP spacing of 16 x 16 inches and medium-maturing variety, the result may be different.

Based on the trials, it can be concluded that UDP application could be practiced just before seed broadcasting on broadcast rice, especially with early varieties. This is more convenient than applying UDP after seed broadcasting, particularly if application is late and in a dense field.

UDP Spacing Trials on BR

Between Taikkyi and Kyaiklat trials, a significant result was found at Kyaiklat only. Almost all parameters, except 1,000-grain weight and dry grain biomass weight, showed significant differences among treatments. Significant differences in yield were between FP treatment and UDP treatments only. There were no differences between UDP-applied plots. At Taikkyi, significant differences were observed with plant height and wet and dry straw weight only. Other characteristics, including yield, did not show differences. Yield results were not consistent among Taikkyi and Kyaiklat. The Taikkyi trial gave the highest yield with 16 x 12 inch spacing, while the Kyaiklat trial gave the highest yield with 14 x 14 inch

spacing. However, N rates were not much different between 16 x 12 inch and 14 x 14 inch spacing (100.3 kg N/ha and 98.2 kg N/ha, respectively).

Based on the results, which showed no differences between UDP-applied plots, a UDP spacing of 16 x 12 inches or 14 x 14 inches could be applied along with a seed rate of not more than 75 kg/ha. When transplanting, normal spacing of 16 x 16 inches is still recommended.

Nitrogen x Potassium Trial on TPR

According to results, significant difference at $P_{(0.05)}$ was observed with K rates. There was no significant difference between N rates or N x K interaction. However, the higher N rate (77.6 kg N/ha) gave a higher yield of 6.59 mt/ha than the lower N rate, which gave only 6.42 mt/ha. The higher K rate (74 kg K₂O/ha) gave significantly higher yield than the lower K rate (37 kg K₂O/ha), which means K is more limiting a nutrient than N in the soil tested.

Plant Spacing and N Rate Trial on TPR

Although results showed no differences on both factors, plant spacing and N rates, wider spacing of 20 x 20 cm gave higher yield than closer spacing of 20 x 15 cm with a higher N rate. With a lower N rate, closer spacing gave slightly higher yield than wider spacing. This is the dry season, and the result is different from the wet season trial conducted in 2016. In the wet season, wider spacing gave a higher yield with a low N rate than with a high N rate (Refer to the 2016 Wet Season Summary Report), which means that more N fertilizer is needed in the dry season than in the wet season.

Fertilizer Management Trials on Rice-Gram Cropping System

This is a long-term trial on the rice-gram system, testing the carryover effect of N applied as UDP on the rice crop to the gram crop and P and K on subsequent crop, rice or gram.

Different amounts of P and K were applied on the rice or gram crop. The total amount of P and K was 40 kg P₂O₅/ha and 40 kg K₂O/ha, respectively. Treatments on the gram crop were: 0 P and 0 K for Treatment 1 (all P and K were applied on the rice crop). Half of the amount of P and K (20 kg P₂O₅/ha and 20 kg K₂O/ha) was applied for Treatment 2, and the entire amount of P and K (40 kg P₂O₅/ha and 40 kg K₂O/ha) was applied on Treatments 3 and 4.

Among three tested locations, significant difference at $P_{(0.05)}$ was observed only on 100-seed weight at Thar Kwin, Einme only. No significant differences were observed for yield or other characteristics at all locations. This means that P and K applied on the gram crop could improve 100-grain weight at Thar Kwin since P and K applied at the full amount (Treatments 3 and 4) gave statistically higher yield than half of the amount or zero applied plots. Carryover effect was not observed because of non-significant results on yield and other characteristics. This means that the amount of P and K applied appears to be enough for the rice crop only. The trial will be continued with higher amounts of P and K in coming seasons by applying 60 kg/ha each for P_2O_5 and K_2O .

In these trials, poor germination and poor crop establishment were noted, particularly on the black gram crop at Einme. Residual moisture content and land preparation are critical to obtain proper germination and good crop establishment since the gram crop is grown with residual moisture. Unfavorable late rain tends to rush land preparation, which also leads to poor crop establishment and low yield.

Different Seed Rates Trial

The seed rate trial showed no statistical differences on yield or any parameters between treatments. According to results, the lowest seed rate (20 kg seed/acre) gave the highest yield with 5.82 mt/ha. This yield arose with fewer panicles per square meter but with more spikelets and grains per panicle. However, the highest biomass weight, both straw and grain, was produced by the highest seed rate, which came from more panicles per square meter.

Since the yield was not significantly different between seed rates, farmers may have two options. Use a lower seed rate combined with balanced fertilizer management to get high yield with fewer panicles bearing more grains or use a high seed rate with less fertilizer to get a similar yield with more panicles bearing less grains. Currently, farmers are practicing a high seed rate on broadcast rice to ensure germination to get enough plant population in a given area.