Session 2.
Fertilizer Recommendations and Their Extension to and Adoption by Farmers

Urea Deep Placement Technology and Its Extension to Farmers in Myanmar

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Abstract

Urea deep placement (UDP) technology has been introduced to Myanmar by the International Fertilizer Development Center (IFDC) as a science-based technology that can increase nitrogen use efficiency by 40%, allowing less urea to be applied to produce higher yields. Farmers can save money, maintain soil fertility of their lands, and can get higher yields. Through the Fertilizer Sector Improvement (FSI) project, IFDC implemented UDP adaptation trials in the 2014 wet season in Yangon, Bago, and Ayeyarwady regions. Extension activities started among farmer communities in the 2015 dry season through a program of "Balanced Nutrient Management and Urea Deep Placement Technology." This included farmer trainings with field demonstrations that publicized the benefits of the new technology.

Demonstration plots were established during the 2015 dry season to 2016 wet season with three treatments: (1) UDP on transplanted rice; (2) UDP on broadcast-seeded rice; and (3) farmers' practice of planting and fertilizing. The layout of the demonstration was simple, without replication, but there were at least 30 demonstration plots established in each season. According to the results from four seasons, UDP on transplanted rice was the best nitrogen application practice, followed by UDP on broadcast-seeded rice. The FSI project also took crop cuts from a random sample of farmers' fields who apply UDP in each season. UDP plots produced between 750-1,000 kilograms per hectare (15-20 baskets/acre) more yield than non-UDP plots. These results showed farmers that UDP technology can reduce cost of urea and increase income.

Key Words

Urea deep placement technology

Introduction

Most Myanmar farmers normally broadcast prilled or granular urea fertilizer into paddy field by hand. Broadcast application of urea results in losses of N mainly through volatilization (Zhao et al., 2012). Broadcast application stimulates weed growth, and crops are deprived of full benefits of fertilizers (Mohanty et al., 1999). Weed competition reduces both yield and quality of the crop produce (Singh, 1996). IFDC and others have proven UDP technology can increase the yield of transplanted lowland rice by 15-20% with less use of urea (up to 40%) compared to broadcast application (Gaihre et al., 2016). UDP technology is a one-time application that allows plants to access nitrogen whenever it is needed. It also reduces weed infestation, reduces the cost of weeding, and increases yield. Also, hidden hunger due to the absence of N is minimized. The plant gets a continuous supply of N during the growing period. With sufficient nitrogen, the plant is able to make better use of other essential elements, and a healthier plant is more resistant to pests and diseases. Even straw has a higher nitrogen content and becomes a higher quality animal food. As an environmental benefit, deep placement reduces greenhouse gases entering the atmosphere (Gaihre et al., 2017), and there is less leaching of nitrogen compounds into the groundwater and less runoff of nitrogen compounds into waterways (Kapoor et al., 2008).

A five-year Fertilizer Sector Improvement (FSI) project funded by the United States Agency for International Development (USAID) was launched in March 2014 to improve food security and increase income for smallholder farmers in Myanmar by sustainably increasing agricultural productivity through using UDP technology. The extension activity of the FSI project started in Myanmar in the 2015 dry season with local non-governmental organizations (NGOs) and an international NGO (INGO) as collaborating partners. The aim was to promote the application of UDP to increase rice production with less urea. To extend its reach, the FSI project provided grants to local partner organizations to implement extension activities, such as farmer training, field demonstrations, field days, and motivational field trips. FSI generally implements 60 farmer trainings and 30 field demonstrations per season in its three target regions. On average, 1,800 farmers per year have a chance to learn about the UDP technology and to test UDP on about 0.15-0.2 acre of their land. In every season, crop cuts are harvested in fields of farmers who apply the UDP technology to measure the benefits of UDP over non-UDP.

Materials and Methods

1. Field Demonstrations

FSI collaborated with eight local NGOs and one INGO to implement field demonstrations, farmer trainings, field days, motivational field trips, and crop cuts for every season since the dry season of 2015 (Table 1). The objective of field demonstrations was: (1) to demonstrate UDP technology on transplanted rice and broadcast-seeded rice to farmers, (2) to demonstrate a balanced fertilizer application on broadcast-seeded rice to farmers, and (3) to show the benefits of UDP in terms of reduced urea use and more yield per hectare.

Table 1. FSI Collaborating Partners.

Names	Acronyms	Status
Welthungerhilfe	WHH	INGO
Golden Plain	GP	NGO
Myanmar Heart and Development Organization	MHDO	NGO
Nine Network	NN	NGO
Village Integrated and Development Association	VIDA	NGO
Group of Development Research and Index	GDRI	NGO
Green Land	GL	NGO
Technical Alliance for Farmers	TAF	NGO
Karuna Myanmar Social Service	KMSS	NGO

In the dry season of 2015 and the wet season of 2016, demonstration plots were established with three treatments as: (a) UDP on transplanted rice, (b) UDP on broadcast-seeded rice, and (c) farmers' practice (usually broadcast-seeded rice with broadcast urea). They were established to show the benefits of UDP technology as an agronomic benefit, socio-economic benefit, and environmental benefit. A basal fertilizer dose of 80 kg triple superphosphate (TSP)/ha, 40 kg muriate of potash (MOP)/ha, and 25 kg gypsum/ha was applied at the last leveling to the two UDP treatments.

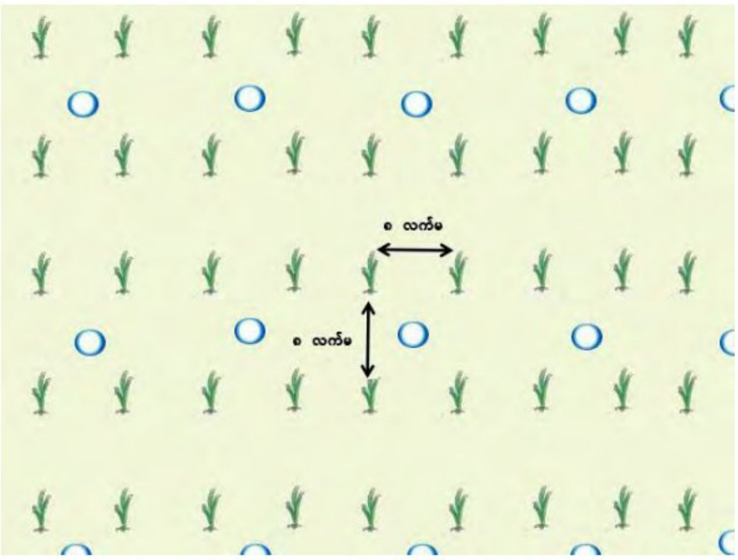

Figure 1. Schematic diagram for placement of urea briquette.

Treatment 1 comprised of: 25-day-old seedlings as two to three seedlings per hill for transplanting with a plant spacing of 20 cm x 20 cm. Deep placement of urea briquettes was done by hand at seven days after transplanting. One briquette was deep-placed at the middle of every alternate four rice hills at 7-10 cm depth (Figure 1). Briquette size of 1.8 g for the wet season gave a rate of 109 kg urea/ha, and briquette size for the dry season of 2.7 g gave a urea rate of 164 kg/ha. Treatment 2 with broadcast-seeded rice used the same basal fertilizers (UDP, TSP, MOP, and gypsum) as Treatment 1. The broadcast seed rate was 80 kg/ha for the wet season and 100 kg/ha for the dry season. Deep placement was done by hand at 20-25 days after sowing. One briquette was placed at a depth of 7-10 cm using a marked rope for the same spacing as in Treatment 1 (Figure 1). Briquette size and rate were also the same as Treatment 1 for each season. Treatment 3 (farmers' practice) followed the local farmers' practice for broadcast or transplanted rice. The fertilizer dose and time of application also followed farmers' practice. Information on the number of demonstration plots, implementing partners, and locations are given in Table 2.

Table 2. Demonstration plot distribution over seasons and locations.

Season	Number of Demo Plots	Implementing Partners	Number of Townships	Regions
2014-15 dry	23	5	8	3
2015 wet	30	4+ FSI	14	3
2015-16 dry	31	7	18	3
2016 wet	30	7	24	3
2016-17 dry	35	7	16	3
2017 wet	40	8	24	3

Sample plot harvesting was done in every season with a sample plot size of 10 m^2 (2 m x 5 m). Yield and moisture content were measured at harvest, and plot yields were reported with 14% moisture content correction.

2. Farmer Trainings

In the dry season of 2015 and the wet season of 2016, all farmer training was provided to new recruits. Two batches of trainings were conducted in each village tract that contained one demo plot. Each batch holds 30 farmers, and priority was given to lead farmers, interested farmers, and smallholder farmers. The trainees were asked to transfer their knowledge to friends and neighbors and become advocates of UDP technology and all other technologies learned from training. In the 2017 dry season, revision training was started and run in parallel with the training of new recruits. In these revision batches, there were 40 past trainees invited to return to keep in touch with the technology and re-energize their interest. Additional details on the number of trainings, farmers, and villages are given in Table 3.

The training message was supported by brochures, videos, field days, television presentations, and FSI extension activities. Within the training, farmers learned about balanced nutrient management, urea deep placement, best management cultivation practices, seed production technology and seed treatment, pest and disease management, and Syngenta's five "golden rules" when using plant protection products. During training, FSI provided pamphlets on UDP, balanced nutrient management, and seed treatment and a booklet on seed production, best management practices, pest and disease control, and the five golden rules. All new trainees also received 10 kg of urea briquettes together with guide bags to allow every trainee to test UDP technology in their fields.

Table 3. Farmer trainings per year.

Season	Number of Training	Attended Farmers			Village	Observer	DOA Staff
		Male	Female	Total			
2014-15 dry	48	952	513	1,465	99	0	8
2015 wet	60	1,268	527	1,795	202	0	11
2015-16 dry	58	1,241	554	1,795	165	0	32
2016 wet	65	1,386	547	1,933	243	10	32
2016-17 dry (new training)	30	732	182	914	94	21	24
2016-17 dry (re-training)	53	1,096	525	1,621	141	19	45

3. Motivational Field Trips

The motivational field trips or farmer cross visits were aimed to allow farmers (both hosts and visitors) to exchange and share experiences, views, and perceptions among themselves. This can occur at any time but is best during maximum tilling stage or ripening stage. The hosts are experienced farmers from the village where the demonstration plot is established, and visitors are from different villages within the same township (Table 4). The host farmers are selected as advocates to share their experience and discuss the benefits of the new technology. Project staff and partners' staff are facilitators on the field trips. The visitors walk through the field to observe the differences in tillers, plant height, and crop color between plots that are using UDP technology and plots of non-UDP.

Table 4. Distribution of field trips over years and location.

Season	Locations	Host			Visitors			Village	DOA
		M	F	Total	M	F	Total		
2014-15 dry	6 Townships	55	20	65	75	24	99	20	0
2015 wet	6 Townships	20	10	30	103	10	113	20	0
2015-16 dry	6 Townships	32	7	39	106	18	124	30	14
2016 wet	6 Townships	35	10	45	98	23	121	20	5
2016-17 dry	6 Townships	42	10	52	108	18	126	29	8

4. Field Days

Field days are conducted around the demonstration plots at harvest time to share a positive message about the benefits of the technology being demonstrated (Table 5). Fifty farmers, farm laborers, teachers, fertilizer dealers, and community leaders are invited from surrounding villages. All the attendees can see the benefits of balanced nutrient management and UDP technology by harvesting, threshing, and weighing the demonstration plots on that day. This reinforces the message given at training and is a big motivator for farmers to apply the new technologies after they see the response of each treatment.

Table 5. Summary of field days – years, locations, and attendance.

Season	Locations	Times	Attendance			Village	DOA
			Male	Female	Total		
2014-15 dry	7 Townships	11	365	265	630	58	10
2015 wet	9 Townships	9	360	188	548	43	0
2015-16 dry	11 Townships	11	403	188	591	68	18
2016 wet	7 Townships	7	251	102	353	25	35
2016-17 dry	7 Townships	7	234	82	316	30	24

5. Crop Cuts

Crop cuts are taken from a random selection of farmers who have applied UDP in the season. The sample plot size is 10 m^2 (2 m x 5 m) and a crop cut is taken from each of the UDP fields and an adjacent non-UDP field to allow comparison. UDP fields used an N rate of 109 kg/ha and non-UDP fields used an N rate between 124 kg/ha and 185 kg/ha in the wet season. UDP fields used an N rate of 164 kg/ha, and non-UDP fields used an N rate between 185 kg/ha and 370 kg/ha in the dry season. The N rate in UDP fields is a standard rate, but the N rate in non-UDP fields can change depending on farmers' desires. A short gross margin questionnaire is filled out with the farmer at the time of the cut. Paddy crop cuts have been taken since the 2015 dry season. From 2016 and 2017 dry seasons, crop cuts from the following gram crop have also been taken to check the residual effect of UDP into the gram crop after rice (Table 6). The crop cut size was 10 m^2.

Table 6. Number of paddy and gram crop cuts.

Season	Crop	Quantity of Crop Cuts
2014-15 dry	Paddy	97
2015 wet	Paddy	113
2015-16 dry	Paddy	137
2015-16 dry	Gram	40
2016 wet	Paddy	121
2016-17 dry	Paddy	86
2016-17 dry	Gram	71

6. Cooperation with Department of Agriculture

The Department of Agriculture (DOA) is particularly helpful in identification of progressive farmers and site selection for demonstration plots. DOA township managers or village tract staff members attend farmer trainings and encourage farmers to apply UDP technology during their field visits. DOA staff members also attend field days and help in showing results to farmers. In cooperation with DOA in the 2016-17 dry season, UDP technology was evaluated with (1) System of Rice Intensification (SRI), (2) good agricultural practices (GAPs), (3) use of a seeder, and (4) local transplanted rice in Taikkyi, Kungyangon, Maubin, Kangyidaunt, and Zalun townships.

7. Analysis of Variance for the Demonstrations

The analysis of variance to test the effects of treatment, variety, and the interaction of treatment*variety was performed using a Generalized Linear Mixed

Model (Gbur et al., 2012). The mixed model had two types of terms: the fixed effect terms (treatment, variety, and treatment*variety) and the random effect terms (latitude and longitude of the farmers' fields). The residual was used as the random error for testing hypotheses about treatments, varieties, and the interaction of treatments with varieties.

The set of methodologies developed by Gbur et al. allows for making the analysis of variance in situations away from the conventional randomized complete block design (RCBD), such as in this situation in which the demonstration plots have no replications. The farmers' fields are assumed to be the replications, and the spatial variability between the fields is used to estimate the error term needed in the analysis of variance.

The data generated by the demonstration plots are unbalanced because the different rice varieties were not tested in every farmer's field; this condition makes necessary an adjustment of the means by least square regression. The least square adjusted means (LSMEANS) are used for comparison of treatments, varieties, or treatments within varieties depending on whether treatment, variety, or the interaction are significant in the analysis of variance. Comparisons between means were done using the Least Significant Difference (LSD). Results from the analysis of variance or from the comparison of a pair of means were considered significant at P-values (Pr>F in the analysis of variance or Pr>t in the LSD) of 0.1 or lower. The 0.1 boundary for the significance, instead of the conventional 0.05, is due to the need for allowing higher tolerance under the condition of high uncontrolled variability that occurs in trials and demonstration plots run in farmers' fields.

Analyses were done using the Statistical Analysis System (SAS) software.

Results

1. Demonstration Plots of All Seasons

Seasonal demonstrations are located in different regions, different townships, and different soil conditions. Different partner organizations implemented the demonstrations with the same protocol. Regardless of these variations, the yields from UDP on transplanted rice usually produced the highest yield, followed by UDP on broadcast-seeded rice.

2015 Dry Season

In the 2015 dry season, five partner organizations (CDDCET, PRC, Shan Maw Myay, KMSS, and WHH) implemented 23 demonstration plots in eight townships. Sample plots were harvested from 19 of 23 demonstration plots. The detailed data from the 19 harvests for all three treatments are given in Appendix 1.

The analysis of variance (ANOVA) table showed that only the effect of fertilizer treatments was significant; there were no effects of variety or fertilizer treatment x variety interaction on paddy yield (Table 7). Yield from the transplanted UDP treatment was significantly higher than the other two treatments (Table 8). There was no significant yield difference between UDP and farmers' practice treatments on broadcast-seeded rice. On average, the UDP transplanted yield was 1.1 t/ha and 1.4 t/ha higher than broadcast-seeded rice with UDP and farmers' practice, respectively.

Table 7. Analysis of Variance for 2015 dry season.

Effect	Num DF	Den DF	F Value	Pr>F
Fertilizer Treatment	2	15.43	4.65	0.0263 (significant)
Variety	2	5.783	0.25	0.7902
Fertilizer*Variety	4	15.43	1.95	0.1530

Table 8. Treatment comparison of rice grain yield for 2015 dry season.

Treatment	Mean (t/ha)	
Transplanted with UDP	5.42	a
Broadcast-seeded with UDP	4.34	b
Broadcast-seeded with FP	4.04	b

** Least square means with the same letters are not significant at p < 0.05.*

2015 Wet Season

In the 2015 wet season, four partner organizations (VIDA, PRC, KMSS, and WHH) and the FSI project implemented 30 demonstration plots in 14 townships; 29 of the 30 demonstration plots were harvested. Depending on the location, 15 demonstration plots used broadcast-seeded rice (FP-BR) and 14 demonstration plots used local transplanted rice (FP-TPR) in farmers' practice plots (Appendix 2). The ANOVA for the 2015 wet season (Table 9) showed significant fertilizer treatment by variety interaction. Hence, the fertilizer application effect on rice yield varied between varieties (Table 10).

UDP application on transplanted rice (UDP-TPR) gave significantly higher yield than on broadcast-seeded rice (UDP-BR) for all varieties except Ayar Min and Thee Htat Yin, for which there was no significant difference (Table 10). Overall, on transplanted rice, UDP gave higher yield by 0.82 t/ha, 1.18 t/ha, and 0.85 t/ha than farmers' practice on high-yielding varieties (HYV), hybrid varieties, and local varieties, respectively. Rice yields were significantly higher for Sin Thu Kha, Sin Thwe Latt, and Thee Htat Yin with UDP than farmers' practice on transplanted rice (Table 10).

UDP application on broadcast-seeded rice gave higher yield than farmers' practice. The yields were significantly higher for Sin Thu Kha, Sin Thwe Latt, Hmwabi-2, and Yadanar Toe (Table 10).

In this season, yield of UDP-TPR with HYV variety was 0.77 t/ha more than FP-BR, 0.82 t/ha more than FP-TPR, and 0.68 t/ha more than UDP-BR. In general, rice grain yield with farmers' practice for both transplanted and broadcast-seeded rice was similar.

Table 9. Analysis of variance for 2015 wet season.

Effect	Num DF	Den DF	F Value	Pr>F
Fertilizer Treatment	3	31.16	13.44	<.0001
Variety	5	17.8	1.32	0.2987
Fertilizer*Variety	14	30.75	2.00	0.0529

Table 10. LS means comparison of rice grain yield with different fertilizer treatments and varieties.

Treatment Comparison	Mean Treatment Differences in Yield for a Given Variety (Pr >t)					
	Hmawbi - 2	Manaw Thu Kha	Sin Thu Kha	Sin Thwe Latt	Thee Htat Yin	Yadanar Toe
Broadcast UDP vs Farmer Practice (Broadcast)	0.087	ns	0.049	0.028	-	0.02
Broadcast UDP vs Farmer Practice (Transplant)	ns	ns	ns	ns	0.016	ns
Broadcast UDP vs Transplant UDP	0.01 (-)	0.02 (-)	0.0003 (-)	0.017 (-)	ns	0.02 (-)
Transplant UDP vs Farmer Practice (Broadcast)	0.0003	ns	<0.0001	0.0002	-	ns
Transplant UDP vs Farmer Practice (Transplant)	ns	ns	0.007	0.007	0.017	ns
Farmer Practice Broadcast vs Farmer Practice Transplant	ns	ns	0.086 (-)	ns	-	ns

Comparisons that are not significant ($p \geq 0.1$) are designated ns.

2016 Dry Season

In the 2016 dry season, seven partner organizations (VIDA, PRC, KMSS, WHH, Ayar Aung Tagon, Yadanar Ayar, and Golden Plain) implemented 31 demonstration plots in 18 townships. All farmer practice plots during the dry season were broadcast-seeded with one plot in Mawlamyinegyun Township sown with a drum-seeder. All demonstration plots used HYV rice. A demonstration plot at Twantay Township was damaged by animal feeding and was not harvested (Appendix 3).

The main treatment effect on grain yield as shown in the ANOVA table was due to fertilizer treatments (Table 11). Since all demonstration plots had used HYV, it was not surprising that there was no effect of variety or fertilizer by variety interaction. Rice grain yield of both transplanted and broadcast-seeded rice with UDP was significantly higher by 1.2 t/ha and 0.9 t/ha, respectively, than farmer practice (Table 12). There was no significant difference between transplanted and broadcast-seeded rice with UDP application; on average, transplanted yield was higher by only 0.3 t/ha.

Table 11. Analysis of variance table for 2016 dry season.

Effect	Num DF	Den DF	F Value	Pr>F
Fertilizer Treatment	2	42.85	9.36	0.0004
Variety	3	19.96	1.67	0.2065
Fertilizer*Variety	6	42.85	1.71	0.1422

Table 12. Comparison of rice grain yield for 2016 dry season.

Treatment	Mean	
Transplanted with UDP	5.5088	a
Broadcast-seeded with UDP	5.2162	a
Broadcast-seeded with FP	4.3453	b

Least square means with the same letters are not significant at $p < 0.05$.

2016 Wet Season

In the 2016 wet season, seven partner organizations (VIDA, Nine Network, KMSS, MHDO, GDRI, Golden Plain, and WHH) implemented 30 demonstration plots in 24 townships. HYV rice was planted in 29 demonstration plots and only one plot used quality rice, Paw San Yin in Bogale Township. Of the 30 demonstration plots, one (in Mawlamyinegyun Township) could not be harvested due to rodent and bird damage as a result of an earlier growing time than neighbors' plots (Appendix 4).

Since all but one plot had quality rice, the effect of variety was not considered in the ANOVA. The fertilizer treatments were significantly different from each other (Table 13). The UDP application with transplanted rice gave significantly higher grain yield than UDP application and farmers' practice with broadcast-seeded rice (Table 13). The UDP transplanted yield was 0.69 t/ha higher than broadcast-seeded UDP and 1.21 t/ha higher than farmers' practice. On broadcast-seeded rice, UDP also gave significantly higher grain yield by 0.52 t/ha than farmers' practice.

Table 13. Effect of fertilizer treatment on rice grain yield for 2016 wet season.

Treatment	Estimate	
Transplanted with UDP	5.004	a
Broadcast-seeded with UDP	4.310	b
Broadcast-seeded with FP	3.792	c

Least square means with the same letters are not significant at $p < 0.05$.

2. Paddy Crop Cuts

Crop cut data from four seasons, as presented in Table 14 and Figure 2, show that rice grain yields from UDP fields were consistently and significantly higher ($p<0.01$) than non-UDP fields. On average, the rice grain yield with UDP was from 14.33 baskets/acre to 18.20 baskets/acre higher than the non-UDP fields.

Table 14. Comparison of rice crop cut yield from four seasons for UDP versus non-UDP fields.

Season	Quantity of Crop Cuts	Average Yield of UDP (t/ha)	Average Yield of Non-UDP (t/ha)	Yield Difference (UDP> non-UDP) (t/ha)	Yield Difference (UDP> non-UDP) (baskets/acre)	Significant ($p < 0.01$)
2014-15 dry	94	4.82	4.01	0.81	15.68	**
2015 wet	113	4.49	3.75	0.74	14.33	**
2015-16 dry	137	5.40	4.63	0.77	14.91	**
2016 wet	121	4.44	3.67	0.77	14.91	**

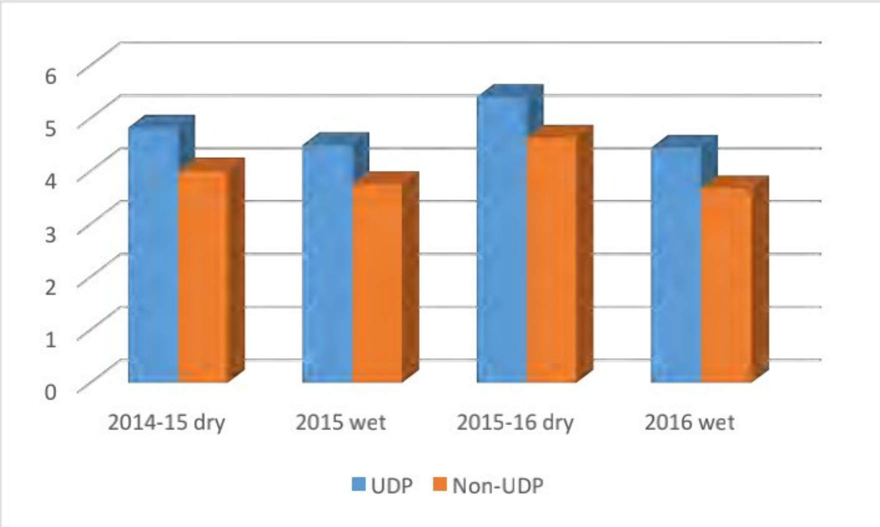

Figure 2. Rice grain yield (t/ha) based on crop cuts for UDP vs. non-UDP fields.

3. Gram Crop Cut

Gram crop cuts are taken from gram fields where UDP was applied in the previous rice crop and compared with cuts from fields without UDP application. Overall, due to the residual effect of UDP, gram yield was higher by 0.27 t/ha, or 25%, compared to non-UDP fields (Table 15). In general, UDP from paddy crops had a positive effect on the yield of the following gram crop.

Table 15. Comparison of gram crop-cut yield from two seasons with residual effect of UDP versus non-UDP.

Season	Quantity of Crop Cut	Average Yield of UDP (ton/ha)	Average Yield of Non-UDP (ton/ha)	Different Yield (UDP>Non-UDP) ton/ha
2016 dry season	40	1.38	1.10	0.28
2017 dry season	40	1.26	0.99	0.27

4. DOA Results

The DOA's technology demonstration plots for SRI, GAPs, and drum seeders compared to local transplanted rice all used UDP. The average results from five townships are shown in Table 16. The highest yield gains were obtained with the combination of UDP and SRI. On average, the yields were 1.14 t/ha (22 baskets per acre) more than local transplanted rice. UDP in combination with GAPs produced 1.03 t/ha (19.86 baskets per acre) more than local transplanted rice with UDP.

Table 16. Yield on four cultivation types with UDP application.

Sr	Township	Village Tract	Village	Variety	SRI	GAPs	Farmer Transplant	Seeder
					Yield ton /ha (14% M)			
1	Zalun	Pet Tan	Tin Koke Su	Hmawbi-3	5.83	6.09		5.94
2	Kangyidaunt	War Du	War Du	90 days		4.83	5.17	3.98
3	Maubin (a)	Tar Pat (west)	Tar Pat (west)	Thee Htat Yin	6.18	6.83		
	Maubin (b)	Let Pan Kone	Let Pan Kone	Yae Nel Lo-7	6.99			5.21
4	Kyungyangon	In Ga Lone	Yan Gyi Aung	Thee Htat Yin	4.63	5.14	3.86	
5	Taikkyi	Oke Pon	Yae Twin Gyi	Yadanar Toe	5.28	5.47	4.91	
					28.91	28.36	13.94	15.13
			Average yield		5.782	5.672	4.6467	5.0433

Discussion

According to the results of crop cuts from demonstrations over four seasons, yields in transplanted rice with urea deep placement technology (UDP-TPR) were higher than the farmers' practice every year. UDP-TPR was higher than FP-BR by 1.4 t/ha in the 2015 dry season and by 0.82 t/ha over FP-TPR and 0.68 t/ha over FP-BR in the 2015 wet season. It was higher than FP-BR by 1.2 t/ha in the 2016 dry season and by 1.21 t/ha over FP-BR in the 2016 wet season.

Yield with urea deep placement technology in broadcast-seeded rice (UDP-BR) was 0.3 t/ha higher than FP-BR in the 2015 dry season, 0.87 t/ha higher than FP-BR in the 2016 dry season, and 0.52 t/ha higher than FP-BR in the 2016 wet season. Even when there was no significant difference between UDP-BR and FP in the 2015 wet season, UDP-BR was still 0.1 t/ha higher than FP-BR and 0.14 t/ha higher than FP-TPR in this season.

UDP plot yields were also 0.74-0.81 t/ha higher than non-UDP plots in crop cuts in farmers' fields over the four seasons and crop cuts in the gram crops after UDP in rice indicated a residual effect of UDP.

All results were well-noted by farmers as day-to-day observations of growth and color and during field days, field trips, and crop cuts. The contact farmers and related farmers became strong advocates of the technology and shared the information among the farmers in their community. Despite this, the adoption has been slow. Most farmers have not adopted the new technology even though they acknowledge the benefits. Despite the positive results from the demonstrations, crop cuts, and famers' own experience with UDP technology, farmers are not adopting it due to the labor intensity involved, the increasing trend of labor outmigration, and the resulting lack of available labor.

It is well-known among extension workers that despite the benefits and the understanding of any technology by farmers, not all farmers accept the new technology at the same time. According to Rogers (1962), there are five different categories of farmers in terms of their ability to adopt new ideas: innovators (2%), early adopters (14%), early majority (34%), late majority (34%), and laggards (16%). FSI has found that innovators and early adopters have been following up with the new technology since the beginning of their training. They have used the 10 kg of briquettes provided during the training as a test, and in the following seasons, they bought briquettes and applied to them more areas. They also shared the information on the benefits with their relatives and neighbors.

Normally, it takes a long time to change traditional practices, cultural practices, and mindsets of risk-averse smallholder farmers. The FSI project introduced UDP in the 2014-15 dry season. In the past two years, the UDP technology, as shown from the results of the demonstration plots and crop cuts, has increased rice yield and, in most cases, also reduced the cost of urea. In the demonstration plots, in every year, transplanted rice with UDP gave the highest yield, followed by UDP on broadcast or direct-seeded rice. According to the crop cut results of four seasons, farmers who applied UDP technology increased yield by 15-20%. Results can vary depending on soil conditions, management practices, including water management, and seed quality and variety, but UDP yield was significantly higher than non-UDP yield. The positive residual effect of UDP on gram yield – up to 25% increase – also improves farmers' income and food security.

Given the diverse cultural and planting practices (transplanting, drum-seeding, broadcast-seeding), land preparation, land topology, soil types, and water management, more methods, types, and timing of UDP need to be evaluated. Every UDP-adopting farmer is convinced of the benefits of the technology. They can see the superior yield over their own practice. However, even though they are convinced of the benefits, their adoption is constrained by lack of labor for manual application. A mechanized applicator is likely to have a big impact on adoption.

Conclusion

Through the extension activities of the FSI project, farmers are given the opportunity to learn about balanced nutrient management and UDP technology in farmer training together with field practical application. They also see the actual results of the classroom teachings in field days and motivational field trips and have the opportunity to test the technology in their field using the sample provided during training. Farmers have observed taller, greener, and more tillers and higher yield on UDP plots than broadcast prilled urea plots. Another advantage was the reduction in weeding, especially in the dry season.

In the 2017 dry season, the FSI project has added two more treatments to its demonstrations to promote not only urea deep placement technology but also balanced fertilization. The five demonstration plot treatments are: (1) UDP on transplanted rice (with basal P and K); (2) UDP on broadcast seeded rice (with basal P and K); (3) farmers' practice; (4) basal compound fertilizer application with urea topdressing on broadcast-seeded rice (dry season)/transplanted rice (wet season), and (5) urea-only application dressing on broadcast-seeded rice (dry season) and on transplanted rice (wet season).

FSI is trying to build a strong network between the farmer community, briquette machine operators (BMOs), and retailers to improve the availability of inputs. IFDC has been working on applicators for several years and has introduced a number of different types to Myanmar on a trial basis. The manual injector type and the push type still required labor and were difficult to manage. Now, in collaboration with John Deere and Khedut Engineering, a mechanical applicator has been developed and is undergoing field tests during the wet season of 2017.

Going forward, FSI has to encourage partner organizations for strong participation in multiplying the diffusion rate, to strengthen cooperation with DOA extension activities, and finally to maintain intensity on the message of balanced fertilizer with UDP.

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Appendix 1. 2015 Dry Season Paddy Yield for 19 Demonstration Plots

Sr	Township	Village Tract	Village	Variety	Yield (ton/ha) TPR (UDP)	BR (UDP)	FP (BR)
1	Htantabin	Sat Ka Lay	Ein Lay Lone	Shwe Pyi Htay	4.32	2.54	3.98
2	Htantabin	Tha Pyay Khone	Tha Pyay Khone	Hmaw Bi San	4.73	3.67	3.57
3	Htantabin	Hnget Thaik	Hnget Thaik	Thee Htet Yin	7	7.92	6.34
4	Htantabin	San Da Yaw	Boe Wea Gyi Su	Shwe Pyi Htay	4.53	4.04	3.87
5	Htantabin	Htein Hnit Pin	Pet Inn Gyi	Shwe Pyi Htay	5.8	4.2	4.57
6	Bago	Ma Yin	Ma Yin Kan Gyi	Thai Manaw	5.78	5.26	4.66
7	Bago	Wan Be Inn	Wan Be Inn	Thai Manaw	6.29	5.19	3.94
8	Letpadan	Kyoet Pin Sa Khan	Shwe Nyaung Pin	Yatanar Toe	5.87	5.42	4.2
9	Letpadan	Chan Thar Kone	Chan Thar Kone	Yatanar Toe	6.27	5	5.72
10	Letpadan	Gon Min Kwin	Shar See Hpo	Yatanar Toe	4.68	4.91	4.59
11	Letpadan	Na Be Kwin	Ywar Thar Yar	Yatanar Toe	6.59	5.33	5.49
12	Taikkyi	Oke Pon	Oke Pon	Yatanar Toe	5.9	4.46	5.14
13	Taikkyi	Hpa Lon Ywar Ma	Hpa Lon Ywar Ma	Yatanar Toe	6.04	5.94	5.69
14	Hlegu	Thu Ngeit Chaung	Min Lwin Kone	IR 90	4.1	3.1	2.33
15	Hlegu	Kyun Kone	Kyun Kone	Vietnum	6.03	1.85	0.89
16	Hlegu	Sar Ta Lin	Sar Ta Lin	Manaw Thu kha	5.27	4.64	3.29
17	Thanlyin	Hpa Yar Kone	Hpa Yar Kone	Palae Thwe	6.76	4.1	4.4
18	Thanlyin	Thama College		Vietnum	5.48	3.83	3.02
19	Thanlyin	Ba Yet	Ba Yet	Palae Thwe	6.09	4.76	4.59

Appendix 2. 2015 Wet Season Paddy Yield for 29 Demonstration Plots

Sr	Township	Village Tract	Village	Variety	Yield (ton/ha)			
					TPR-UDP	BR-UDP	FP-BR	FP-TPR
1	Htantabin	Hnget Thaik	Htoo Lay Su	Sin Thwe Latt	4.17	3.23	2.228	
2	Htantabin	San Da Yaw	San Da Yaw	Sin Thu Kha	4.538	3.88	3.602	
3	Htantabin	Daunt Gyi	Set Su	Sin Thu Kha	3.9	3.92	2.59	
4	Htantabin	Kyar Hone	Kyein Paik	Sin Thu Kha	4.03	3.11	2.49	
5	Bogale	Nyi Naung	Min Hla Su	Sin Thwe Latt	4.16	3.66	3.33	
6	Bogale	Sa Bai Kone	Dar Chaung	Sin Thwe Latt	4.82	4.02		3.52
7	Bago	Tat Ka Lay	Ka Li	Manaw Thu Kha	6.53	5.41	6.08	
8	Bago	Ka Twin Chan	Ka Twin Chan	Sin Thu Kha	5.948	5.34	5.1	
9	Letpadan	Kun Chan	Kun Chan	Sin Thu Kha	4.36	3.8		4.5
10	Letpadan	Thaik War Chaung	Thaik War Chaung	Yadanar Toe	4.125	3.06		3.62
11	Daik-U	Ka Toke Hpa Yar Gyi	Ka Toke Hpa Yar Gyi	Hmawbi-2	5.45	4.88	3.52	
12	Daik-U	Kyaik Sa Kaw (East)	Kyaik Sa Kaw (East)	Sin Thu Kha	4.01	3.65		3.32
13	Thayarwady	Ma Gyi Kwin	Leik Inn (Ah Lel Su)	Yadanar Toe	4.05	3.27		3.69
14	Thayarwady	Kywe That	Kywe That Gyi	Sin Thu Kha	4.77	4.03		4.37
15	Taikkyi	Tar Gwa	Inn Yet Gyi	Hmawbi-2	2.625	2.437		2.29
16	Taikkyi	Oke Kan Kan Kone	Oke Kan Kan Kone	Hmawbi-2	4.86	3.268	3.64	
17	Hlegu	Sar Bu Taung	Sar Bu Taung	Manaw Thu Kha	4.656	4.053		4.46
18	Hlegu	War Net Kone	War Net Kone	Ayar Min	2.958	3.359	3.482	
19	Thanlyin	Kayin Seik	Kayin Seik	Taung Pyan Yin	6.42	4.61	4.19	
20	Kyauktan	Tadar	Tadar	Yadanar Toe	3.12	3.6	3.78	
21	Kangyidaunt	Ah Htet Ta Khun Taing	Ma Gyi Kone	Thee Htat Yin	4.86	4.97		3.9
22	Kangyidaunt	Myin Ka Seik	Sar Hpyu su	Pa Khan	4.74	4.8	4.31	
23	Kangyidaunt	Kyon Gyi	Kyu Chaung	Thee Htat Yin	3.68	3.6		2.88
24	Pantanaw	Ba Waing	Ba Waing	Palae Thwe	5.05	4.27		3.87
25	Pantanaw	Kyon Tone Gyi	Zee Hpyu Su	Sin Thu Kha	6.55			6.02
26	Nyaungdon	Tu Chaung	Tu Chaung	Sin Thu Kha	5.73	5.14	5.2	
27	VaNyaungdon	Nat Pay	Nat Pay	Swawanar	7.22	5.62	6.13	
28	Maubin	Nga Gyi Ga Yet	Nga Gyi Ga Yet	Sin Thwe latt	5.31	5.05		4.73
29	Maubin	Thu Htay Kone	War Yon Ga Yet	Sin Thu Kha	5.78	4.36		4

Appendix 3. 2016 Dry Season Paddy Yield for 30 Demonstration Plots

Sr	Township	Village Tract	Village	Variety	Yield (ton/ha)		
					TPR (UDP)	BR (UDP)	FP (BR)
1	Hmawbi	Myaung Tagar	Yoe Wa	Yadanar Toe	7.93	6.16	5.05
2	Hlegu	Moke Soe Nyaung Pin	Shan	Thee Htet Yin	5.22	4.96	7.6
3	Taik Kyi	Yin Taik Kwin	Yin Taik Kwin	Yadanar Toe	5.8	5.99	5.23
4	Taik Kyi	Taung Boet Hla	Taung Boet Hla	Yadanar Toe	6.508	5.63	4.78
5	Twan Tay	Htaw Tho	KyaukSayit Kone	Shwebo	6.39	5.32	5.11
6	Kungyangon	In Ga Lone	In Ga Lone	Thee Htet Yin	5.602	4.618	3.547
7	Kungyangon	Taw Kha Yan (West)	Taw Kha Yan (West)	Thee Htet Yin	3.62	4.34	3.61
8	Htantabin	Yoe Gwa	Yoe Gwa Myauk Su	Yay Nae Lo-4	6.13	5.18	4.076
9	Htantabin	Yoe Gwa	Yoe Gwa KayinSu	YN 3153 (IRRI)	5.885	5.455	4.865
10	Pantanaw	Dawwar	Daw War A Htet Su	Sinthukha	5.19	5.35	4.38
11	Myaungmya	Kyon War	Kyon War	Thee Htet Yin	5.73	3.65	4.98
12	Myaungmya	Kyar Hpu Ngon	Kyar Hpu Ngon	Thee Htet Yin	6.58	6.16	5.77
13	Kangyidaunt	Kyaik Lat	Kyaik Lat	Thee Htet Yin	3.15	3.49	2.62
14	Kangyidaunt	War Du	Ahnauk Su Gyi	Thee Htet Yin	4.943	5.96	4.206
15	Maubin	Tar Pat (west)	Tar Pat (west)	Thee Htet Yin	5.95	6	5.53
16	Nyaung-don	Sarmalauk	Sarmalauk	Sin Ayar	5.44	4.08	2.89
17	Bogale	Tha Kan Wa	Kyon Hpar	Thee Htat Yin	5.31	5.9	5.13
18	Bogale	Boe Di Kwe	Kun Thee Chaung	Thee Htat Yin	4.683	4.463	4.425
19	Kyaiklat	Bon Lon Chaung	KhayawPin Seik	Thee Htat Yin	7.36	6.205	6.148
20	Kyaiklat	Hle Seik	Hle Seik	Thee Htat Yin	6.75	5.45	5.31
21	Mawlamyinegyum	Myinkakone Ka Lay	Daung Yae Kyaw	Thee Htet Yin	7.02	6.778	5.155
22	Mawlamyinegyum	Kyar Chaung	Kyar Chaung	Pakhan Shwe War	7.19	6.702	6.52
23	Mawlamyinegyum	Htiparlel Thaung tan	Thaung Tan	Thee Htat Yin	5.957	7.086	5.973
24	Mawlamyinegyum	Kyaik Pi	Shwe Ta Chaung	Thee Htat Yin	6.28	6	5.43
25	Bago	Kawt Che	Pauk Taw	Thai Manaw	4.09	5.133	3.897
26	Daik-U	Pyin Ma Lwin	Pyin Ma Lwin	Thai Manaw	3.83	5.39	4.1
27	Daik-U	Ka Toke Ywar Ma	U Daung Su	Thai Manaw	5.34	4.21	3.68
28	Letpadan	Pyin Htaung Twin	Pyin Htaung Twin	Thai Manaw	8.156	8.045	5.84
29	Thayarwady	Thityar Kone	Ohntaw Su	Shwe Thwe Yin	5.6	5.57	4.257
30	Thayarwady	Kyun Kone	Late Oo Kone	Yadanar Toe	7.92	6.26	3.81

Appendix 4. 2016 Wet Season Paddy Yield for 29 Demonstration Plots

Sr	Township	Village Tract	Village	Variety	Yield (ton/ha)		
					TPR (UDP)	BR (UDP)	FP (BR)
1	Thanlyin	Sit Pin Kwin	Sit Pin Kwin	Thai Manaw	4.97	4.86	3.08
2	Daik-U	Ein Chay Lay Se	Ein Chay Lay Se	Sin Thu Kha	5.34	4.96	3.91
3	Pantanaw	Pa Thwei	Ta Loke Su	Sin Thu Kha	6.39	5.6	4.69
4	Kyauktan	Nyaung Waing	Myaing Thar Yar	Thee Htat Yin	5.52	4.52	3.85
5	Kyauktaga	Than Pu Yar Khon	Than Pu Yar Khon	Sin Thu Kha	6.37	4.42	5.48
6	Zigon	Wet Sa Poe	Wet Sa Poe	Yadanar Toe	4.67	4.09	4.01
7	Twantay	Hpa Yar Gyi	Za Yat Kone	Sin Thu Kha	4.16	4.56	3.37
8	Maubin	Thone Gwa	Thone Gwa	Thee Htat Yin	4.9	4.74	4.29
9	Mawlamyinegyun	Sa Khan Gyi	Nauk Pyan Toe	Sin Thwe Latt	6.54	4.86	4.35
10	Kyaunggon	Ka Nyin Thone Sint	Ka Nyin Thone Sint	Sin Thu Kha	5.22	4.496	3.865
11	Kungyangon	Ka Mar Par	Ka Mar Par	Thee Htat Yin	6.424	5.629	2.644
12	Kyauktaga	Myo Chaung	Myo Chaung	Sin Thu Kha	5.294	2.68	4.39
13	Letpadan	Ma Gyi Kwin	Shwe Bo Su	Sin Thu Kha	4.76	4.47	3.96
14	Pyay	Ah Shey Let Khoke Pin	Min Kone	Yadanar Toe	4.73	3.98	5.41
15	Einme	Htein Ngu	Kywe Lan	Sin Thu Kha	5.13	4.73	2.96
16	Hmawbi	Nyaung Kone	Nyaung Kone	Sin Thu Kha	4.95	3.59	3.45
17	Kangyidaunt	Khon Zin Kone	Kyun Chaung	Mashuri	3.64	2.92	2.49
18	Pyapon	Koe Ein Tan	Naung Taw Gyi	90 days	4.72	3.66	3.04
19	Myaungmya	Tha Pyay Chaung	Tha Pyay Chaung	Sin Thu Kha	3.71	1.92	2.63
20	Hlegu	Hpaung Gyi (East)	Hpaung Gyi (East)	Sin Thu Kha	4.6	4.37	4.23
21	Kungyangon	War Kauk Taw	War Kauk Taw	Sin Thu Kha	6.988	6.622	5.46
22	Bago	Hpa Yar Ngoke To	Ah Shey Kone	Manaw Thu Kha	4.92	4.197	3.82
23	Bogale	Tha Kan Wa	Da None Chaung	Paw San Yin	3.49	3.37	3.11
24	Taikkyi	U To	U To	Sin Thu Kha	5.29	4.08	3.8
25	Hlegu	Dar Pein (South)	Dar Pein (South)	Sin Thu Kha	4.68	3.89	3.32
26	Kawhmu	Ma Gyi Kan	Za Loke Gyi	Sin Thu Kha	4.735	5.719	4.135
27	Pyay	Twin Bye	Kyoet Yat Thar	Sin Thu Kha	3.76	3.55	3.45
28	Thayarwady	Nga Hpyu Ka Lay	Nga Hpyu Ka Lay Ywar	Yadanar Toe	4.59	4.46	3.87
29	Kyaiklat	Pan Be Su	Pan Be Su	Thee Htat Yin	4.63	4.04	2.89