# Dry Season Rice Yield Responses to Nitrogen Fertilizer in Central Myanmar

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## Abstract

Rice crop yields in central Myanmar are considered to be relatively low due to inadequate applications of fertilizer, and particularly of nitrogen (N). In this study, replicated field experiments were conducted at two sites, Taungoo and Yezin, in Central Myanmar to determine the crop yield responses to N fertilizer for dry season irrigated rice in 2017. The two field experiments were identical in design and conducted at the same time. The experiments had a randomized complete block design with 3 replicates of 8 treatments. The 8 treatments included 6 rates of N fertilizer (0, 30, 77.6, 100, 130, and 160 kg N/ha), applied as two split surface-broadcast applications at 10 days after transplant (10DAT) and at crop panicle initiation (PI) in accordance with local farmer practice. In addition a urea deep placement (UDP) treatment with placement of 2.7 g urea briquettes at IFDC-recommended spacing and soil depth at a N rate of 77.6 kg N/ha was included, as well as a nil input control. All treatments except for the nil input control received basal applications of P, K, S, and Zn. Mean grain yields at Taungoo ranged from 3.54 t/ha (0 kg N/ha) to 5.24 t/ha (160 kg N/ha) whilst at Yezin they ranged from 6.78 t/ha (0 kg N/ha) to 8.15 t/ha (130 kg N/ha). The Taungoo site may represent a typical low-fertility farm site whereas the Yezin site had a more fertile soil. The 77.6 kg N/ha application rate was found to result in a 33% increase (i.e. +1.18 t/ha) in grain yield ($P<0.05$) at the Taungoo site and a 12 % increase (i.e. + 0.84 t/ha) at the Yezin site ($P<0.05$) indicating benefits from this N fertilizer rate, depending on economic analysis. At the Taungoo site the UDP treatment (77.6 kg N/ha) produced yields consistently higher than the comparable 77.6 kg N/ha surface broadcast treatment, with a UDP mean yield of 5.23 vs 4.72 t/ha for surface broadcast. However, analysis of variance (ANOVA) found this not to be significant at P=0.05, with a t-test estimating P=0.054 for this comparison. This is sufficient to encourage further research on UDP in this environment. Yield response curves were derived for N fertilizer applications from the experimental data from the two experiment sites. The Taungoo site yield response curve for N was thought to be more applicable to the general soil fertility levels of rice farms in central Myanmar. This paper presents the first results from these experiments which will be expanded on as the full dataset including soil and plant analysis is obtained.

**Key words: Rice yields, nitrogen fertilizer, urea deep placement**

## Introduction

Rice crop yields in central Myanmar have been found to be low relative to comparable countries and this is thought to be due to inadequate fertilizer applications (Denning et al. 2013, Hnin et al. 2013, Hla Myo Thwe et al. 2014). Min Thiha et al. (2010) reported yields of irrigated rice near Nay Pyi Taw in the range of 2.8 – 4.3 t/ha, with a mean of 3.3 t/ha when no fertilizer was applied, which increased to 3.7t/ha when a modest rate of basal NPK was applied. At a national level the use of N fertilizer is notably smaller than other comparable countries of Southeast Asia (IRRI 2014), and is thought to be a principal cause of the low yields of rice (Denning et al. 2013, Hnin et al. 2013, Hla Myo Thwe et al. 2014).

The most common farmers' practice for N fertilizer applications in the Yezin area of central Myanmar is to surface broadcast a total of just ~28 - 57 kg/ha of N as urea (i.e. ½ - 1 × 50 kg bag/acre) to the paddy as two equal split applications (i.e. 50/50); one at 10 days after transplanting (10DAT) and then another at the panicle initiation (PI) stage of the crop. IRRI recommends applying N as surface applications in 3 splits; 14 days after transplanting (14DAT), at mid-tillering (20-35 DAT), and at PI (40-50 DAT) (IRRI 2017). But research indicates that as much as half of the urea surface broadcast to paddy can be lost to the atmosphere by ammonia volatilization (Vlek and Craswell 1979, Humphreys et al. 1987, Dong et al. 2012, Rochette et al. 2013). Recent research has reported nitrogen fertilizer use efficiency and yield benefits in paddy rice crops from the deep placement of urea briquettes in Bangladesh (Miah et al. 2016, Huda et al. 2016, Datta et al. 2017) and granular urea in China (Liu et al. 2016, Liu et al. 2017).

The objective of this study was to determine the crop N requirement and optimal N fertilizer rate for dry season rice at two sites in central Myanmar. The study is a first step towards acquiring the necessary data to inform and validate the development of a fertilizer decision support tool for farmers in central Myanmar. A UDP treatment was included in this study to extend work currently being conducted by the IFDC in other rice growing regions of Myanmar.

## Materials and Methods

Replicated field experiments of identical design were established at two locations in central Myanmar to determine nitrogen fertilizer response curves for irrigated dry season rice. The two sites were at Yezin Agricultural University, near Nay Pyi Taw, and a farmer's field near Taungoo, Upper Bago. The topsoil of the Yezin site was a sandy medium textured soil (sandy clay loam to clay loam – sandy). The topsoil at the Taungoo site was a light silty clay. The experiments had a randomized complete block design with 8 treatments and 3 replications. The plots were 5 m × 5 m delineated by double bund walls 40 cm wide and 30 cm high. There was a 1 m spacing between plots in each block and a 3 m spacing between blocks. There were 8 treatments which included a nil input control (T1), 6 rates of N fertilizer applied as granulated urea by surface broadcasting [0 (T2), 30 (T3), 77.6 (T4), 100 (T5), 130 (T6) and 160 kg N/ha (T7)], and a deep placement (75 mm) treatment of 2.7 g urea briquettes according to the IFDC recommended spacing pattern at a rate of 77.6 kg N/ha (T8). The 6 surface broadcast granulated urea treatments (T2, T3, T4, T5, T6, T7) were applied to the plots in accordance with the dominant local farmer practice in the region, which is to apply the urea N fertilizer as two equal split applications (i.e. 50/50); one at 10 days after seedling transplanting (10DAT) and the second at the PI phase in the crop. The deep-placed urea briquettes were also applied to the plots 10 days after transplanting so a direct comparison could be made between surface broadcast (T4) and deep placement (T8) for the 77.6 kg N/ha N application rate.

The plots of all treatments, except for the nil control (T1), received basal applications of P as triple superphosphate at 40 kg of P/ha, S as gypsum at 25 kg S/ha, K as muriate of potash (KCl) at 25 kg K/ha (+ 2 later applications = total of 75 kg K/ha for each trial). The roots of the rice transplant seedlings, with the exception of T1, were dipped in a 2% Zn solution (as $ZnSO_4$) prior to transplanting in order to eliminate Zn deficiency. Rice seedlings were transplanted at a 20 cm plant hill spacing commencing 10 cm in from the edge of the plot with 3 to 4 individual seedlings planted on each hill on average. The '*Yadanar Toe'* rice variety was selected for these field experiments on the basis that it was a common dry season variety grown by local farmers. The plots were irrigated with bore water at the Yezin site and channel irrigation water at Taungoo. Initially the fields were flushed with irrigation water and the areas between the bunded plots filled with fresh irrigation water which was then bucketed by hand into the bunded plots until a water depth of about 15 cm was achieved. This water level within the bunded plots was then allowed to drop over time until it was only a few cm deep over any one plot, at which point the irrigation procedure would be repeated. The plots were irrigated on a regular basis to keep the water level within the plots between ~20 cm and 5 cm deep at all times.

The central 1.8 m × 1.8 m of each treatment plot was harvested by hand with sickles by cutting the plant just above the soil surface. The harvested rice was then threshed with a foot-pedal operated threshing machine and the threshed material was then sieved and winnowed to separate the grain from other plant matter. The total grain weight was weighed and the moisture content of the grain was measured at harvest using a grain moisture meter. The total fresh weight of the biomass of the rice crop plants from the harvested area was measured on a field balance following threshing, and a representative 1 kg subsample of the fresh biomass was then taken and placed in a paper sample bag and weighed on an accurate lab balance, dried to constant mass at 65°C in an oven, and reweighed to then calculate the dry matter biomass weight for the harvested crop plant (minus the grain). The harvested rice grain weight from the harvested area of each plot was then adjusted to the standard 14% moisture content used for rice research. These figures for dry matter crop biomass and grain yield (adjusted to 14% moisture content) were then converted to t/ha for data analysis. The full range of rice crop yield parameters (i.e. number of panicles; filled and unfilled spikelets, and tillers per area, and 1000 grain weight) were also determined from a subsample of 6 plant hills within the harvest area using the standard methodologies outlined in Dobermann and Fairhurst (2000).

This paper presents only the first results from Taungoo (established on 6 February, 2017 and harvested on 12 June 2017) and Yezin (established on 14 February, 2017 and harvested on 26 June 2017) field experiments.

The data were analyzed using a one-way ANOVA with blocking by Genstat® (18th ed.). Least significant difference (lsd) at 5% level was used to compare differences between treatment means when the F-test was significant (*P<0.05*). A student t-test was also carried out between harvest data of treatments T4 and T8 for the Taungoo site data to further evaluate if these treatment means were significantly different at P=0.05, and interpreted cautiously given Genstat® rated less than 5 replicates (3 in this case) as insufficiently robust. The Taungoo site harvest data were log transformed prior to the ANOVA and t-test analyses to meet normal distribution assumptions. The N response curves were fitted to the harvested grain yield data of the sites by fitting an exponential (or asymptotic regression) Mitscherlich curve function to the data using the FITCURVE function of Genstat®.

## Results and Discussion

### *Treatment effects at the Taungoo site*

The ANOVA results for the Taungoo site rice harvest data are shown in Table 1. The mean grain yield of the nil control (T1) treatment was found to be not significantly different to the 0 kg N/ha (T2) treatments, indicating basal nutrients (P, K, S, and Zn) were not limiting at the zero N rate at this site. The mean grain yield for T3 (30 kg N/ha) was found to be not significantly different (*P=0.05)* to the T1 (0 kg N / ha) mean grain yield. This finding is important as it indicates that the T3 treatment (30 kg N/ha), which represents the most common N application rate used by local poor farmers for summer rice (dry season rice) was not sufficient to significantly increase the grain yield at this location.

***Table 1 – Treatment mean grain yield (adjusted to 14% moisture), and dry biomass at harvest for the 2017 irrigated dry season rice crop at Taungoo.***

***Values in parenthesis are the means of the log $_{10}$ transformed data used in the ANOVA. Treatments with the same letter within each column indicate no significant difference between the treatment mean values at P=0.05. S.D is standard deviation***

| Treatment | Grain yield (14% M) (t/ha) | S.D | Dry biomass (t/ha) | S.D |
|---|---|---|---|---|
| T1 – nil Control | 3.74 (0.57) cd | 0.11 | 6.78 (0.82) cd | 1.54 |
| T2 – 0 kg N/ha | 3.54 (0.55) d | 0.31 | 5.86 (0.77) d | 0.28 |
| T3 – 30 kg N/ha | 4.15 (0.62) bc | 0.52 | 6.91 (0.83) cd | 1.62 |
| T4 – 77.6 kg N/ha | 4.72 (0.67) ab | 0.21 | 7.45 (0.87) bcd | 1.63 |
| T5 – 100 kg N/ha | 4.34 (0.64) b | 0.40 | 6.47 (0.81) cd | 0.57 |
| T6 – 130 kg N/ha | 4.37 (0.64) b | 0.25 | 8.68 (0.93) abc | 1.81 |
| T7 – 160 kg N/ha | 5.24 (0.72) a | 0.28 | 9.95 (1.00) a | 1.26 |

| | | | | |
|---|---|---|---|---|
| T8 – UDP – 77.6 kg N/ha | 5.23 (0.72) a | 0.25 | 9.38 (0.97) ab | 1.25 |
| *l.s.d (P=0.05)* | (0.06) | | (0.12) | |

However, the mean grain yield of T4 (77.6 kg N/ha) was found to be significantly higher than all of the other surface broadcast (farmer practice) rate treatments except for T7 (160 kg N/ha), the largest urea application rate, where no significant difference was found for mean grain yield. This suggests that the T4 treatment resulted in a significant increase in grain yield at the site, and that no significant increase in mean grain yield was achieved by increasing the urea application above this at this site, on this occasion.

These results for the surface broadcast urea application treatments show that the application of urea at a rate of 77.6 kg N/ha increased the yield on average by 1.18 t/ha from 3.54 t/ha to 4.72 t/ha, at the Taungoo site (Table 1). In contrast an application of urea at a rate of 160 kg N/ha increased the yield on average by 1.70 t/ha. Thus increasing the N fertilizer from 0 kg N/ha to 77.6 kg N/ha resulted in a yield increase of 15.2 kg of rice for every kg of N applied per hectare, whilst the increase in yield for the additional urea to bring the application rate from 77.6 kg to 170 kg N/ha represented a yield increase of only 6.3 kg of rice for every additional kg of N applied as urea per hectare.

A comparison of the grain yield results for treatments T4 and T8 represents a comparison of the farmers' practice of surface broadcast application with the deep placement of urea briquettes (UDP) at a common urea application rate of 77.6 kg N/ha. At the Taungoo site, no significant difference at P=0.05 level was found between the mean grain yields of Treatment T4 (77.6 kg N/ha –surface broadcast farmer practice) and T8 (77.6 kg N/ha – deep placement of urea briquettes). Further comparison of the yield results for these treatments in Table 2 using a Student t test found that the probability that the difference between the means was due to chance was only P=0.054 (noting the replicate number was sub-optimal, n<5). Likewise the range of values for each treatment (i.e. the minimum to maximum values for the replicates), Table 3, did not overlap, providing a case supporting the need for further UDP research trials.

***Table 2 – Comparison of the grain yield results for treatments T4 and T8 (both 77.6 kg N/ha) for the irrigated dry season rice crop at the Taungoo site***

| **Treatment** | **Sample size (n)** | **Min. value** | **Max. value** | **S.D.** | **Mean grain yield (14% M) (t/ha)** |
|---|---|---|---|---|---|
| T4 | 3† | 4.50 | 4.93 | 0.21 | 4.72 (0.67)‡ |
| T8 – UDP | 3 | 5.01 | 5.50 | 0.25 | 5.23 (0.72) |
| ***Probability (P)**** (d.f = 4; t=-2.70) | | | | | 0.054 |

† Note Genstat 18th edition recommends n>5 to ensure t-test results are robust
*Probability that apparent difference in means is due to chance.
‡ $\log_{10}$ of mean in parenthesis (). Note t test was carried out on $\log_{10}$ transformed data

***Table 3 – Comparison of the dry biomass results for treatments T4 and T8 (both 77.6 kg N/ha) for the irrigated dry season rice crop at the Taungoo site***

| **Treatment** | **Sample size (n)** | **Min. value** | **Max. value** | **S.D.** | **Mean dry biomass (t/ha)** |
|---|---|---|---|---|---|
| T4 | 3† | 5.78 | 9.04 | 1.63 | 7.45 (0.86) ‡ |
| T8 – UDP | 3 | 8.28 | 10.73 | 1.25 | 9.38 (0.97) |
| ***Probability (P)**** (d.f = 4; t=1.60) | | | | | 0.184 |

† Note Genstat 18th edition recommends n>5 to ensure t-test results are robust
*Probability that apparent difference in means is due to chance.
‡ $\log_{10}$ of mean in parenthesis (). Note t test was carried out on $\log_{10}$ transformed data

Crop dry biomass (excluding grain) results presented in Table 1 show that only treatments T6 (130 kg N/ha), T7 (160 kg N/ha), and T8 (UDP – 77.6 kg N/ha) had mean dry biomass values significantly higher than T2 (0 kg N/ha) treatment. No significant difference was found between the mean dry biomass at harvest values for T4 (77.6 kg N/ha- farmer practice) and T8 (77.6 kg N/ha – UDP) (Table 1 and Table 3).

### *Treatment effects at the Yezin site*

The results of the ANOVA for the Yezin site rice harvest data are presented in Table 4. It is important to first note that the mean rice grain yield for the zero N treatment (T2) of 6.78 t/ha at the Yezin site is actually higher than the mean rice yield for highest N rate treatment (T7 – 160 kg N/ha) at the Taungoo site, which was 5.24 t/ha (Table 1). This suggests that there were significant amounts of plant available N being supplied to the rice crop at the Yezin site from the soil itself (soil mineral N reserves, mineralized N from organic N in the soil, N fixation from free living $N_2$ fixing microbes, applied water) before any N fertilizer was added. At present we can only speculate as to the reasons for the higher yield at the Yezin site, but when we have all of the analytical results from the soil, plant and water samples from the experiment, the reasons should be apparent.

No significant difference was found between the grain yield means for the nil control (T1) treatment and the zero N treatment (T2), indicating no grain yield response to the basal applications of P, K, S, and Zn at this site at 0 N/ha application rate. However, the T2 treatment did have a significantly higher mean dry biomass value compared to the nil control (T1), indicating that there was a crop biomass response to the basal fertilizers, but that this did not translate into an increase in grain yield.

***Table 4 – Treatment mean grain yield (adjusted to 14% moisture), and dry biomass (t/ha) at harvest for the irrigated dry season rice crop at Yezin.***
***Treatments with the same letter within each column indicates no significant difference between the treatment mean values at P=0.05. S.D is standard deviation.***

| Treatment | Grain yield (14% M) (t/ha) | S.D. | Dry biomass (t/ha) | S.D. |
|---|---|---|---|---|
| T1 – nil Control | 6.89 cd | 0.28 | 11.0c | 0.44 |
| T2 – 0 kg N/ha | 6.78 d | 0.06 | 13.3b | 0.37 |
| T3 – 30 kg N/ha | 7.10 bcd | 0.78 | 15.2ab | 1.48 |
| T4 – 77.6 kg N/ha | 7.62 abc | 0.29 | 15.0ab | 0.85 |
| T5 – 100 kg N/ha | 8.13a | 0.45 | 16.8a | 2.20 |
| T6 – 130 kg N/ha | 8.15a | 0.25 | 15.3ab | 1.15 |
| T7 – 160 kg N/ha | 7.49abcd | 0.18 | 15.4ab | 1.54 |
| T8 – UDP – 77.6 kg N/ha | 7.65ab | 0.88 | 17.0a | 1.14 |
| *l.s.d (P=0.05)* | 0.76 | | 2.2 | |

Even though the mean grain yield values for the treatments were greater than for the Taungoo site, the significant treatment responses are similar in some ways. The mean grain yield of the farmer practice N rate treatment, T3 (30 kg N/ha), was again not significantly different to T2 (0 kg N/ha). However, the results were highly variable with a very high S.D. The mean rice grain yield of 7.62 t/ha for T4 (77.6 kg N/ha) was significantly higher than the T2 (zero N) mean grain yield of 6.78 t/ha, but was not significantly different to the other N treatments (T3, T5, T6, T7, T8).

The grain yield results for the surface broadcast urea application treatments (T2-T7) show that the application of urea at a rate of 77.6 kg N/ha increased the yield on average by 0.84 t/ha from 6.78 t/ha to 7.62 t/ha, at the Yezin site. In contrast an application of urea at a rate of 130 kg N/ha increased the yield on average by 1.37 t/ha. Thus the yield increase associated with increasing the N fertilizer rate from 0 to 77.6 kg N/ha urea application represented a yield increase of 10.8 kg of rice for every kg of N applied per hectare, which was less than the Taungoo site result of an extra 15.2 kg of rice for every kg of N applied up to 77.6 kg N/ha. This suggests that there may be some potential yield response to applying this rate of N at the Yezin site, but the environmental impacts would need to be assessed in addition to the economics, before recommending this application rate.

The mean grain yields for T4 (77.6 kg N/ha-surface broadcast) and T8 (77.6 kg N/ha, as UDP briquettes) were not significantly different (P=0.05) at Yezin, being 7.62 and 7.65 t/ha, respectively. Likewise, no significant difference (P=0.05) was found between the mean dry biomass (t/ha) values for these treatments at harvest at the Yezin site.

In terms of crop dry biomass response it can be seen in Table 4 that only the 100 kg N/ha (T5) and the UDP treatment at a rate of 77.6 kg N/ha had mean dry biomass values that were significantly ($P<0.05$) higher than the zero N treatment (T2) mean value of 13.3 dry t/ha. The T5 and T8 treatments increased crop dry biomass relative to the zero N treatment (T2) by 26.3 and 27.8% respectively, at the Yezin site. The other treatment means for crop dry biomass at harvest were found to be not significantly different to the zero N treatment (T2) mean value.

### *N response curves for grain yield at the two sites.*

Plots showing the development of the preliminary N response curves for grain yield in dry season irrigated rice at the Taungoo and Yezin experiment sites are presented in Figures 1 and 2 respectively. Of these two response curves, the one for the Taungoo site (Figure 1b) is thought to be more representative of the typical local farm situation (with a zero N rate grain yield of around 3 t/ha) and more reflective of the likely crop response to N on the farmers' fields. In contrast, the rice grain yield response curve for the Yezin site represents the response at a higher soil fertility site, with its zero N rate grain yield >6.5 t/ha, which is higher than the grain yield for the highest N rate (i.e. 160 kg N/ha) at Taungoo. The grain yield response curve for Taungoo is thought to be the most relevant to the most common farmer situation. An exponential functional form ($Yield = \alpha + \beta(\rho^N)$) was considered most appropriate since it assumes the crop yield increases with added N to a maximum, or plateau yield, which is represented in this function form as an asymptote.

For the Taungoo site, it can be seen in Fig. 1 (a) which includes all 5 N rates (0, 30, 77.6, 100, 130 and 160 kg N/ha), that two of these rates, 100 and 130 kg N/ha, for some reason appeared to have had a subdued response which did not fit well with the trend apparent from the other N rates. This contributed to a relatively poor fit ($R^2 = 0.498$) for response curve (I) which was fitted to the whole dataset (Fig 1b). When the grain yield data for these two rates was removed from the dataset, the response curve (i.e. curve II ) achieved an improved fit ($R^2$=0.792) for the remaining four N rates (see Fig. 1b). As such, the relationship for the fitted exponential curve for curve (II) in Fig. 1(b) which is $Y = 5.558 – 2.011(0.98859^{x})$, represents a relationship that better describes the yield response to N fertilizer at the Taungoo site. A simplistic substitution of the mean grain yield for the T8 - UDP treatment at Taungoo from Table 1 (i.e. 5.23 t/ha) into N response curve (II) in Figure 1b, would suggest that the UDP application of 77.6 kg N/ha would be equivalent to a surface broadcast application of 160 kg N/ha as urea.

For the Yezin site it is apparent that the yield response for the 30 kg N/ha rate was highly variable and that the highest N rate, 160 kg N/ha decreased to lower yields than the 100 and 130 kg N/ha rates, and this had a dominant influence on the initial fitted response curve (curve I), and impacted data variability ($R^2$ = 0.437) (Figure 2a). One option for improving the description of the response curve is to remove the grain yield data for the top rate which had an anomalous response and also the data for the 30 kg N/ha rate which Genstat identified as having high residuals in the curve (I) fitted in Figure 2b. When this was done, the exponential curve function fitted to the reduced data set slightly improved the proportion of data variability accounted for ($R^2$=0.621), but the curve (i.e. curve II) lost its classical asympto

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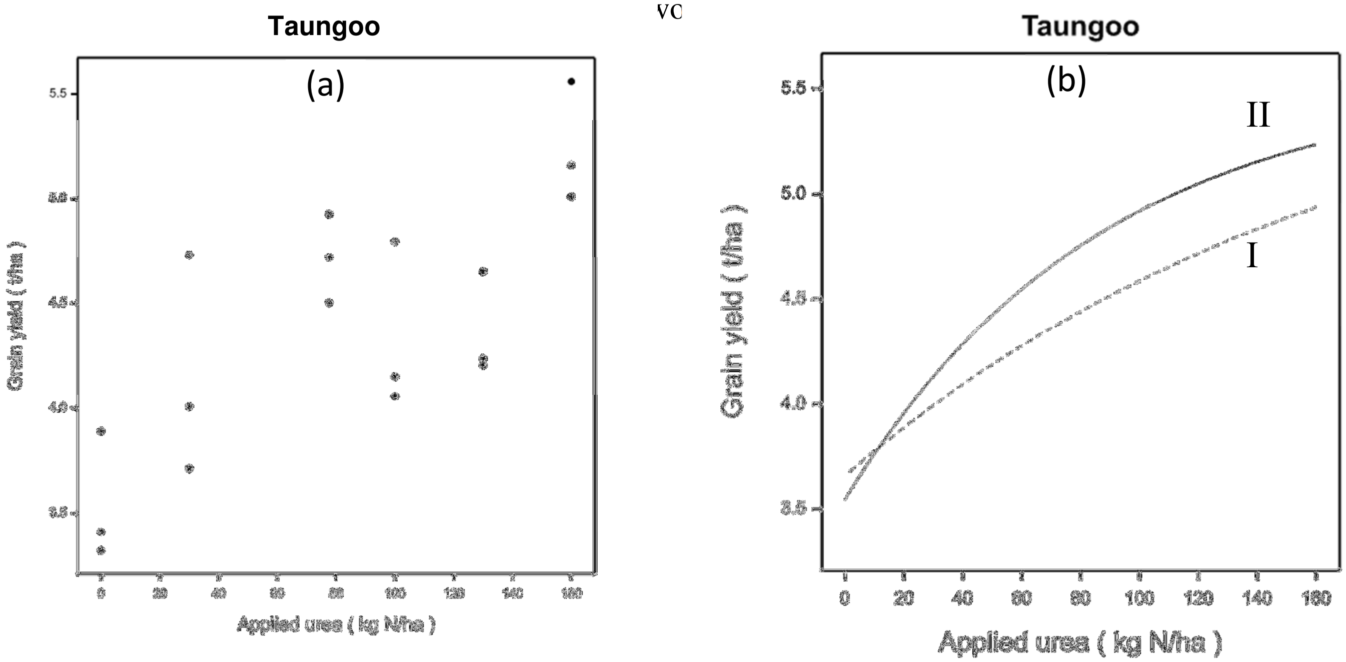


***Figure 1. Crop grain yield (adjusted to 14% moisture) response to N application rate (surface broadcast) at the Taungoo site with; (a) individual data; (b)response curves; I - fitted to whole dataset [Y = 5.79 – 2.13 (0.9943 $^{x}$) ; P = 0.002, $R^2$ = 0.498] ; II - fitted to treatments 0,30, 77.6, and 160 kg N/ha [Y = 5.558 – 2.011(0.98859 $^{x}$) ; P<0.001, $R^2$ = 0.792]***

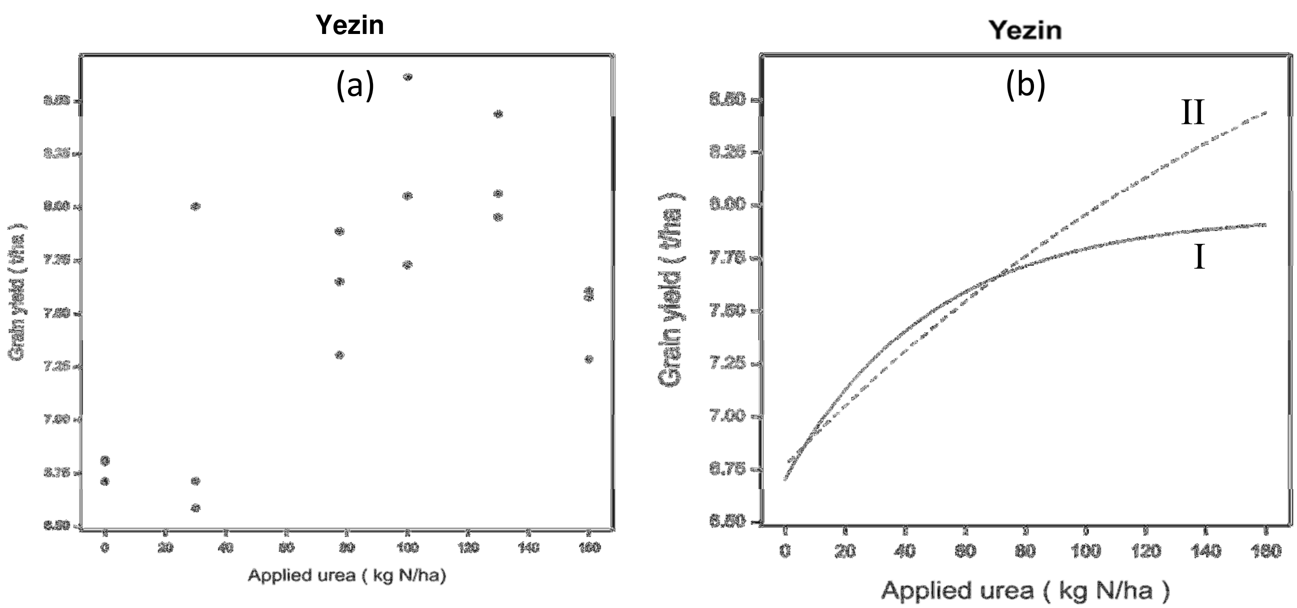

***Figure 2. Crop grain yield (adjusted to 14% moisture) response to N application rate (surface broadcast) at the Yezin site with; (a) individual data; (b )response curves I - fitted to whole dataset [Y = 7.955 – 1.247 (0.9796 $^{X}$) ; P = 0.005, $R^2$ = 0.437] ; II - fitted to treatments O, 77.6, 100 and 130 kg N/ha [Y = 9.93 – 3.16 (0.9953 $^{X}$) ; P<0.001, $R^2$ = 0.765]***

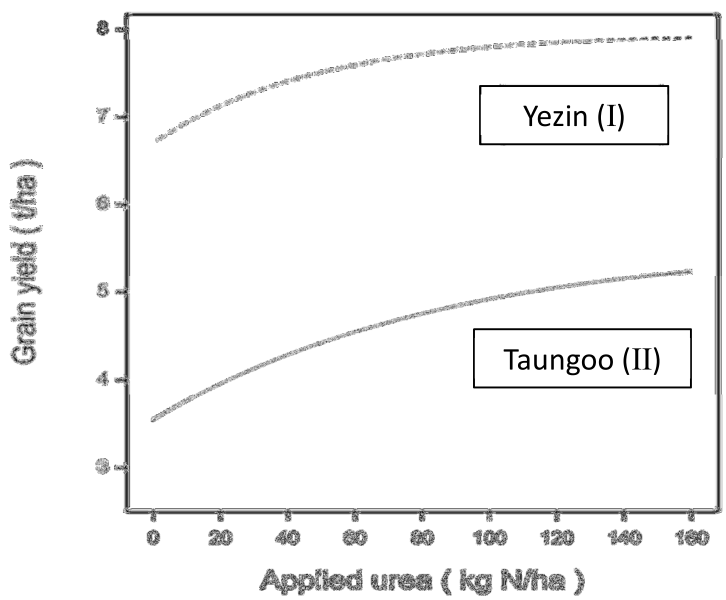


***Figure 3. A comparison of the dry season rice grain yield (adjusted to 14% moisture) response curve (II) at the Taungoo site (Fig 1(b)) with grain yield response curve (I) for the Yezin site (Fig 2(b))***

The preliminary N response curve for dry season rice grain yields for the Yezin site is compared with that of the Taungoo site in Figure 3. The grain yield response curve for the Taungoo site is a fairly standard response curve form and is thought to be more representative of the typical farm situation in central Myanmar. In contrast, the Yezin site response curve is perhaps one reflecting a more fertile site with naturally higher background soil N levels, or higher fertility levels resulting from its previous use as a research station. Although response curve (II) probably accounts for the trends and variability in the data for the Yezin site better than curve (I), curve (I) provides a more standard response curve form (Figure 3). Yezin curve (Yezin I) appeared slightly flatter overall than the Taungoo response curve (Taungoo II), with the Taungoo curve being noticeably steeper at the lower rates < 80 kg N/ha (Figure 3). The Taungoo N yield response curve function may prove to be of value for crop modeling applications and the development of tools for predicting yield response to N in irrigated rice in the dry season for central Myanmar. The results in this paper reflect the preliminary results from the first field experiments for this project, interpreted without the benefit of soil and plant data. As such, these results are preliminary and will be refined with further analyses.

## Conclusion

The two field experiments at Taungoo and Yezin provided results on the response of irrigated dry season rice to N fertilizer at two central Myanmar sites with contrasting soil fertility. The results from the Taungoo site provided an adequate N response curve for what is believed to be the more common soil fertility conditions which will allow further analysis incorporating economics. The 77.6 kg N/ha urea rate achieved a significant increase in yield at the Taungoo site and also at the Yezin site. The UDP treatment achieved a higher mean grain yield than the comparable surface broadcast treatment at Taungoo, just falling short of 5% significance, but providing enough encouragement for future investigations. It is hoped that further soil and plant analyses, and data for 15N labeled urea microplots, when they become available, will allow a detailed assessment of the N use efficiency at these experiment sites to complete the study.

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