Journal of Agricultural Science; Vol. 12, No. 8; 2020
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

# Effects of Improved Nursery Management, Seedling Transplanting Age and Split Nitrogen Fertilizer Application on Growth and Yield of Lowland Rice in Eastern Uganda

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Received: May 8, 2020 Accepted: June 10, 2020 Online Published: July 15, 2020

doi:10.5539/jas.v12n8p144 URL: https://doi.org/10.5539/jas.v12n8p144

**Abstract**

Rice yields in Uganda are still low due to poor rice production methods on smallholder farms in particular poor nursery and nitrogen fertilizer management practices. The study was set up to investigate the effect of nitrogen (N) fertilizer, nursery management and age of seedlings at transplanting on the yield of four rice cultivars (WITA 9, GSR 007, K 85 and K 5) in eastern Uganda. The nursery experiment was established with five treatments: 1) control (no chemical + transplanting 30-day old seedling), 2) di-ammonium phosphate (DAP) + fungicide + transplanting 14-day old seedlings, 3) DAP + transplanting 14-day old seedlings, 4) DAP + transplanting 30-day seedlings and 5) fungicide + transplanting 30-day old seedlings. Effect of split application of N on yield, was studied with urea (46% N) as the fertilizer source using a split-plot design with control (no fertilizer added) and 23 and 46 kg N $ha^{-1}$ applied either basally or in two splits. Applying fertilizer in the nursery and transplanting 14-day old seedlings increased yields by 23-30% relative to the control, while using 30-day old seedlings did not result in any yield gain irrespective of the treatment. Splitting N applications increased yields by 0.1-0.3 t $ha^{-1}$ and increased agronomic efficiency marginally. Applying 23 kg of N in two splits gave the highest return over fertilizer cost (US$ 855/ha). This demonstrates that lowland rice production in Uganda can be increased by a combination of nutrient management in the nursery, transplanting young seedlings and splitting applications of nitrogen fertilizer and represents a simple and economical option for farmers to increase rice yields. This is especially important considering that fertilizer use among smallholder farmers is restricted by high prices and limited availability. Improving N- and nursery management has great prospects for increasing rice yields on all cultivars in smallholder farms at minimal costs.

**Keywords:** lowland rice production, seedling vigor, small farms, East Africa

## 1. Introduction

Rice (*Oryza sativa* L.) is an important food and cash crop in Uganda. The major rice growing areas in Uganda include the districts of Pallisa, Butalejja, Iganga, Bugiri (eastern Uganda), Lira (northern Uganda) and Bundibujjo (southern Uganda) (Hainesh et al., 2013). Rice production has increased in the recent past from 72,000 ha producing 109,000 t in 2000 to 92,960 ha producing 260,786 t in 2018 (FAOSTAT, 2020). Despite the increase in rice production, rice yields are still low in the lowland rice ecosystem averaging 1.5 t $ha^{-1}$. One of the reasons for the low rice yields is that many farmers cultivate the crop without applying appropriate production and management practices (Balasubramanian et al., 2007). For instance, the majority of the farmers practice continuous rice cropping without fertilizer application leading to soil nutrient mining (Sanchez, 2002). The poor crop establishment methods practiced by farmers result in plant populations that are suboptimal and these do not support high yields. Furthermore, farmers who practice transplanting utilize old seedlings from poorly managed nurseries (Kijima et al., 2010) where they do not apply either manure or organic fertilizers thereby reducing the yield potential. Hainesh et al. (2013) found that only few farmers use inorganic fertilizers and other agrochemicals in Uganda which contributes to the low yields being observed on-farm. The few farmers who apply fertilizers use blanket application rates rather than matching the quantities to the plant nutrient requirements. Split applications of highly mobile nutrients such as N increase its use efficiency, reduce N losses and increase yields (Linquist & Sengxua, 2003).

Fertilizer usage among smallholder farmers is limited by the lack of access to initial capital, limited availability (Nakano & Kajisa, 2012), limited knowledge on their usage and often low returns of the fertilizer investment (Kyalo, 2014, unpublished report). Nhamo et al. (2014) indicated that the current mineral fertilizers application rates on rice used by smallholder farmers vary widely across locations and lack scientific basis. Moreover, most rates are extrapolations from other crops such as maize. One way of assisting farmers to maximize benefits from urea fertilizer is by applying it in splits at the active tillering and panicle initiation stages. Split applications of N have been shown to increase agronomic use efficiency (AE) by 4.1 kg $kg^{-1}$ N (Linquist & Sengxua, 2003). Similarly, vigorous seedlings can outcompete weeds and grow faster thereby producing better yields. Adequately managed seedbeds with adequate plant nutrition, optimal seedling density and use of seedlings at appropriate age are important factors leading to vigorous plant stands after transplanting (Lal & Roy, 1996). Together with the availability of water, labor, agrochemicals such as herbicides and other inputs, the age of seedlings is an important factor in determining performance of rice (Sarwar et al., 2011). Several researchers have reported increases in rice grain yields when rice seedlings are transplanted at less than 25 days old (Ashraf et al., 1999; Nandini & Singh, 2000; Thanunathan & Sivasubramanian, 2002). For example, Thanunathan and Sivasubramanian (2002) found that the use of 25-day old seedlings increases yield by 0.3 t $ha^{-1}$. Ros et al. (1997) found that rice grain yield in pots increased by 10% by applying N and P to the nursery and the effect could not be replaced by fertilizer application in the main field post transplanting. Smallholder farmers in Uganda who usually transplant seedlings that are more than 30 days old and do not use any form fertilization in the nursery would greatly benefit if they adopted improved nursery management practices like fertilizer application and planting seedlings of appropriate age. The additional small investment in raising healthy and vigorous seedlings in the nursery was projected to increase yields by up to 2 t $ha^{-1}$ (Panda et al., 1991). The aim of this study was to investigate the effect of split nitrogen applications, fertilizer and fungicide application in the nursery and use of young seedlings on the grain yield of four commonly cultivated lowland rice varieties in Uganda.

## 2. Materials and Methods

### *2.1 Site Description*

The experiments for this study were setup in Bugiri district (0°34′14.66″N, 33°44′56.04″E) in eastern Uganda in 2014. The soils covering most of the district are mainly loamy and sand loams with fine texture and rather loose structure. The soils are laterite and ferralitic, with deep reddish brown sandy loams mixed with clay loams and overlain by clayey subsurface horizons derived from gneiss and granites (Yost & Eswaran, 1990). The pH of the soil in the experimental area was 5.7, organic matter and nitrogen were 4.8 and 0.25% respectively, while P, K, Ca and Mg were 19.9, 40.7, 4081.3 and 573.70 mg $kg^{-1}$ respectively. Bugiri district has two distinct rainfall seasons per year—April to June and August to November—with a dry season lasting from December to March. The mean annual rainfall is 1,200 mm ranging from 1,000 mm and 1,500 mm in the southern parts of the district and 900 mm in the northwestern sections of the district. The northern and northwestern sections of the district are relatively drier with an average annual precipitation of 650 and 600 mm, respectively. Mean temperatures range from 16.7 to 28.1 °C with February being the hottest month. The average monthly rainfall totals for the period 2013 to 2014 is shown in Figure 1.

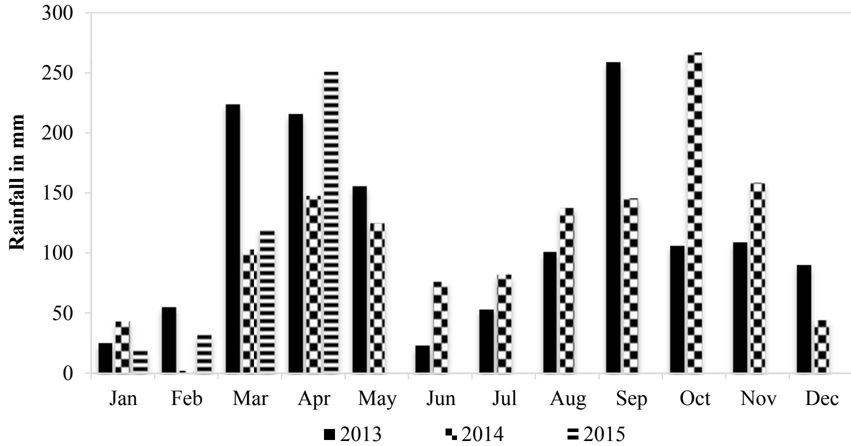


Figure 1. Average monthly rainfall (mm) totals for Kibimba and surrounding villages 2013-2015. Courtesy: TILDA rice scheme (Kibimba) weather station

*2.2 Field Layout, Experimental Design and Treatments*

2.2.1 Effect of Seedling Age at Transplanting and Application of Fertilizer and Fungicide in the Nursery on Rice Grain Yield

The experiment was initially set up in the nursery using four treatments: 1) control (no chemical), 2) di-ammonium phosphate (DAP) + fungicide, 3) DAP and 4) fungicide. Four varieties namely WITA 9, GSR 007, K 85 and K 5 were used for the experiment. Each treatment was imposed on all four varieties on a plot measuring 4 $m^2$ (1 $m^2$ per variety). Di-ammonium phosphate (DAP) was applied to the nursery at a rate of 50 g $m^{-2}$ and incorporated in the soil before sowing. In the fungicide treatment, seeds were soaked in carbendazim (methyl benzimidazol-2-yl carbamate) over night before being pre-germinated. Carbendazim is indicated for the treatment of fungal pathogens on cereals, fruits, cotton, tobacco, ornamental crops and vegetables. The fungicide solution was constituted by mixing 25 ml in 20 liters of water, as per the manufacturer's recommendations. In order to be able to transplant both 14 and 30 day old seedlings at the same time, another nursery with the same treatments was set up 16 days after the first nursery. The nurseries were well prepared, levelled and watered whenever necessary. Seedlings were transplanted to the main experimental field at 14 and 30 days after sowing using the following treatments: 1) control (no chemical + transplanting 30-day old seedling, 2) di-ammonium phosphate (DAP) + fungicide + transplanting 14 day old seedlings, 3) DAP + transplanting 14 day old seedlings, 4) DAP + transplanting 30 day old seedlings and 5) fungicide + transplanting 30 day old seedlings. The treatments were arranged using a split plot design with treatments as main plots and varieties as sub plots and replicated four times. Main plots were measuring 8 × 6 m while subplots were measuring 3 × 4 m. Three rice plants were transplanted per hill at a spacing of 25 × 25 cm. Weeds were managed manually by hand weeding twice each season at 25-30 days after transplanting (DAT) and 40-50 DAT and by spraying with satunil 60EC (40% Theobencarb and 20% propanil at a rate of 200-500 l/ha) 2-3 weeks after transplanting. The experiment relied on rainfall and no fertilizers were added during the field phase. Birds scaring was used to prevent damage of crops on the experimental plots.

2.2.2 Effect of Splitting N Applications on Rice Yield

In order to investigate the effect of split application of N on yield, an experiment was setup in first season 2013 and repeated in first season 2014 using urea (46% N) as the fertilizer source. The experiment was set up with four N fertilizer treatments: 1) 23 kg N/ha applied at once basally, 2) 23 kg N/ha applied in 2 splits at tillering and panicle initiation, 3) 46 kg N/ha applied at once basally and 4) 46 kg N/ha applied in two splits at active tillering and panicle initiation and 5) Control (no fertilizer added). The experiment was laid out in a split-plot design with fertilization treatments as main effects and varieties as sub plots. Main plots were 60 $m^2$ while subplots were 15 $m^2$. The experiment was replicated four times and 2-3 rice plants were transplanted per hill at a spacing of 25 × 25 cm. The fertilizer N rate used for treatment 1 and 2 is adopted from the average rate of 53-60 kg urea/ha used by farmers in lowland rice production in Uganda (Hainesh et al., 2013). To explore the potential of increasing productivity through N fertilizer, the rate was doubled in treatments 3 and 4. The experiment was set up for two cropping seasons in 2013. A nursery was established with four varieties at a rate of 50 kg/500 $m^2$. Seedlings were transplanted at 21 days after sowing. Weeds were managed manually by hand weeding twice at

25-30 and 40-50 days after transplanting (DAT) and by spraying with Satunil 60EC™ (40% theobencarb and 20% propanil at a rate of 200-500 l/ha 2-3 weeks after transplanting. Rice blast was managed by spraying with Orius (250g $l^{-1}$ tebuconazole) at 750 l $ha^{-1}$ once a season. Each treatment plot was bunded to maintain a uniform water depth and also to ensure that fertilizer treatments did not mix. Bird scaring was done to prevent damage of the crop.

*2.3 Data Collection and Analysis*

Data from experimental plots were collected according to the standard evaluation system of rice. Data was collected on plant height at 89 and 105 days after sowing (DAS), number of tillers at 89 and 105 DAT, number of panicles, grain yield and rice biomass dry weight at harvest. Panicles were counted prior to harvest. Plant height was taken on two hills per plot whereas numbers of tillers and panicles were taken on an area of 0.0625 $m^2$. Plants were harvested from 12 hills in each plot at physiological maturity and used to determine percentage of filled grains, harvest indices and nutrient concentrations in plant tissue. Grain yields were obtained from a central 5 $m^2$ harvest area in each plot at harvest. Grain yields and total biomass (grain + straw yields) were adjusted to 14% moisture content.

For all the variables, Shapiro-Wilks test ($P < 0.05$) (Shapiro & Wilk, 1965) and visual inspection of their respective histograms and box plots showed that they were approximately normally distributed across seasons and treatments with their standard errors in normal range (Cramer, 1998). Data was analyzed using Genstat 12$^{th}$ edition using a generalized model for analysis of variance (ANOVA). Means were separated using fishers LSD at $P < 0.05$.

Agronomic N use efficiency (AE), the increase in yield per unit of applied fertilizer N was used as a measure of N use efficiency (Linquist & Sengxua, 2003). AE was calculated as:

$$AE = \frac{\text{Yield (kg) in+N plots} - \text{Yield (kg) in-N plots}}{\text{Amount of Fertilizer applied (kg)}} \quad (1)$$

Internal Use efficiency (IEN) (kg grain per kg N taken up) was also calculated:

$$IEN = GYN/UNN \quad (2)$$

Where, GYN is the grain yield in a treatment with N application (kg $ha^{-1}$), UNN is the total plant nutrient accumulation measured in above ground biomass at physiological maturity (kg $ha^{-1}$).

Gross return over fertilizer cost (GRF), which is the farm gate revenue from produced rice minus cost for fertilizer N applied and provides a relative measure for the benefit derived by farmers from the use of fertilizer N was calculated as follows:

$$GRF = PRYR - TFC_N \quad (3)$$

Where, $TFC_N$ = total fertilizer cost of N fertilizer (US$/ha), PR = price of rice (US$0.36/kg paddy), and YR = rice yield (kg/ha). $TFC_N$ = PNFN; where PN = price of N fertilizer (US$1.94/kg N), FN=amount of N applied (kg N/ha)

## 3. Results

*3.1 Effect of Fertilizer and Fungicide Application and Age of Seedlings on Yield*

Application of DAP, fungicide and transplanting young seedlings (14-days old) resulted in significantly higher yield than in the control treatment (Table 1). Applying DAP and transplanting young seedlings resulted in the most yield gain of 800 kg $ha^{-1}$ compared to the control.

Table 1. Average grain yield number of panicles and tillers, harvest index and percentage of filled grains for four varieties under different treatments of fertilizer and fungicide in the nursery in 2014

| Trt | Yield (t ha$^{-1}$) | | | Number of tillers | | | Number of panicles | | | % filled grains | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014A | 2014B | Mean | 2014A | 2014B | Mean | 2014A | 2014B | Mean | 2014A | 2014B | Mean |
| Control | 1.2 | 3.1 | 2.6 | 434.0 | 712.5 | 573.4 | 282.5 | 507.5 | 395.0 | 84.1 | 81.1 | 82.6 |
| F+DAP+14D | 3.1 | 3.3 | 3.2 | 602.5 | 610.5 | 606.5 | 507.0 | 513.0 | 510.0 | 81.8 | 82.8 | 82.3 |
| DAP+14D | 3.2 | 3.5 | 3.4 | 650.0 | 668.0 | 659.0 | 525.0 | 540.5 | 532.7 | 76.1 | 77.1 | 76.6 |
| F+30D | 1.6 | 3.1 | 2.4 | 511.5 | 626.5 | 569.0 | 384.5 | 501.0 | 442.8 | 87.5 | 81.0 | 84.3 |
| DAP+30D | 1.9 | 2.9 | 2.4 | 602.0 | 635.0 | 618.5 | 443.0 | 516.6 | 485.0 | 83.9 | 84.9 | 84.5 |
| Mean | 2.2 | 3.2 | | 560.0 | 650.5 | | 428.4 | 551.7 | | 82.0 | 81.4 | |
| $LSD_{0.05}$ Trt | 0.8 | | | 145.7 | | | 112.5 | | | 8.5 | | |
| $LSD_{0.05}$ S | 0.2 | | | 33.4 | | | 24.7 | | | 8.2 | | |
| $LSD_{0.05}$ Trt × S | 0.9 | | | 152.4 | | | 117.3 | | | 1.6 | | |
| CV (%) | 19.1 | | | 4.5 | | | 15.4 | | | 15.6 | | |

*Note*. Trt: Treatment; Control: No fertilizer + no chemical + transplanting 30-day seedlings; F: fungicide; DAP: Diammonium phosphate; 14D: transplanting 14-day-old seedlings; 30D: transplanting 30-day old seedlings; S: season.

The second best treatment was application of DAP, fungicide and young seedlings which yielded 600kg more than the control. No major yield gains were recorded when DAP was not applied or when it was applied and seedlings transplanted 30 days after seeding. Both treatments yielded only 200kg more than the control. It is important to note that seedlings transplanted at 14 days were harvested 7 days after harvesting the seedlings transplanted at 30 days after seeding. No significant differences were recorded between treatments for number of panicles and tillers and harvest index. However, the interaction between treatment and season was significant for number of tillers, number of panicles and filled grains. Overall, more tillers and panicles were produced in 2014B than 2014A (Table 1). The highest numbers of tillers and panicles were produced when DAP was applied and seedlings transplanted at 14 days after sowing (average number of tillers and panicles = 659 m$^{-1}$ and 532.7 m$^{-1}$ respectively). Despite recording a low yield of 3.1 t ha$^{-1}$, the control treatment produced the highest number of tillers in 2014B. Similarly, the percentage filled grains were lower when DAP was applied in the nursery and seedlings transplanted at 14 days after sowing than in the rest of the treatments. Mean yields were not significantly different across varieties. Harvest index was similar across treatments ranging from 0.32 to 0.37.

*3.2 Effect of Split Application of N Fertilizer on Yield and Yield Components*

There were no significant differences in number of tillers, number of panicles and plant height across treatments (Table 2). Harvest index and percentage of filled grains were significantly different across treatments. However, harvest index was generally low ranging from 0.31 to 0.39. Application of 46 and 23 kg of N ha$^{-1}$ at once had significantly lower harvest indices (HI = 0.31 and 0.32 respectively) than the control and split applications of 23 and 46 kg of N ha$^{-1}$.

Table 2. Effect of splitting N application on agronomic efficiency (AE), gross return over fertilizer N (GRF), yield and yield components

| Treatment | AE (kg kg$^{-1}$) | IEN kgkg$^{-1}$ | GRF ($/ha) | No. Tillers (m$^{-2}$) | No. Panicles (m$^{-2}$) | HI | % filled grains |
|---|---|---|---|---|---|---|---|
| Control | 22.6 | 57.8 | 720 | 480 | 398.5 | 0.38 | 89.5 |
| 23 (2 splits) | 25.7 | 60.4 | 855.4 | 513 | 406.7 | 0.39 | 81.8 |
| 23 (once) | 27.1 | 79.0 | 819.4 | 502 | 408.8 | 0.31 | 81.3 |
| 46 (2 splits) | 19.6 | 65.8 | 846.8 | 555 | 457.8 | 0.34 | 81.3 |
| 46 (once) | 18.1 | 54.8 | 738.8 | 560 | 448.5 | 0.32 | 84.4 |
| Mean | 22.6 | 63.6 | | 522.0 | 424.0 | 0.35 | 83.6 |
| LSD | - | 16.1 | - | NS | NS | 0.04 | 4.6 |
| CV | - | 16.4 | - | 9.2 | 10.0 | 8.6 | 3.6 |

*Note*. NS: Not significant at 5% level of probability; S: Significant at 5% level of probability.

There were no significant differences in mean yield between treatments but the interaction between split N applications and variety was significant for yield. Average yield across treatments was 2.4 t ha$^{-1}$. When 23 kg of N was applied at once to all varieties, GSR 0057 yielded better than WITA 9 but its yield was statistically similar to K 5 and K 85 (Table 3). The agronomic efficiency (AE) of fertilizer N usage was variable registering an average of 22.6 kg $kg^{-1}$. Split application of 46 kg of N increased AE slightly from 18.1 to 19.6. The internal use efficiency was highest when 23 kg of N was applied once (79.0 kg $kg^{-1}$) followed by split application of 46 kg of N (65.8 kg $kg^{-1}$). Applying 46 kg at once had lower internal use efficiency than the control. The gross return over fertilizer increased as the amount of N increased but it was highest (\$855.4 $ha^{-1}$) when 23 kg of N was applied in splits compared to \$846.8 $ha^{-1}$ when 46 kg of N was applied in splits (Table III). Compared to the control, applying 23 and 46 kg of N in splits had net benefits of \$135 and 126 \$ respectively.

Table 3. Average yield of four varieties under different N split treatments

| Treatment | Varieties | | | | Mean |
|---|---|---|---|---|---|
| | GSR 0057 | K5 | K85 | WITA 9 | |
| Control | 2.1 | 2.5 | 1.1 | 2.3 | 2.0 |
| 23 (2 splits) | 2.4 | 2.6 | 2.3 | 2.5 | 2.5 |
| 23 (once) | 2.9 | 2.1 | 2.8 | 1.9 | 2.4 |
| 46 (2 splits) | 2.8 | 2.7 | 2.6 | 2.2 | 2.6 |
| 46 (once) | 2.3 | 2.1 | 2.7 | 1.9 | 2.2 |
| Mean | 2.5 | 2.1 | 2.3 | 2.1 | 2.4 |
| $LSD_{0.05}$ (Trt) | | | NS | | |
| $LSD_{0.05}$ (Trt × Variety) | 0.9 | | | | |
| CV (%) | 15.6 | | | | |

*Note*. NS: Not significant.

## 4. Discussion

### *4.1 Effect of Fertilizer, Fungicide Application and Age of Seedlings on Yield*

These results are consistent with findings by Rajagopahan and Krishnarajan (1987) and Ros et al. (1997, 2015) who found application of fertilizers in the nursery to increase yield by 21 and 12% respectively compared to the control. It is not clear why the treatment without fungicide performed better than the one where seeds were soaked in fungicide before planting. Using healthy and vigorous seedlings with sufficient nitrogen fertilizers in the nursery has been shown to result in more productive tillers hence better yields (Panda et al., 1991). The yield increase in this case was 30%, slightly more than that reported by Rajagopahan and Krishnarajan (1987). The higher yields could have been caused by the high rate of DAP used (50 g/$m^2$) compared to that used by Rajagopahan and Krishnarajan 1987 and others (50 kg/ha). Ros et al. (2015) achieved high yields due to application of N in the nursery and attributed it to the early vigour of seedlings in the nursery as indicated by taller plants and increased number of tillers. The current findings show that the problem of poor nursery management which has been cited by Balasubramanian et al. (2007), and Kijima et al. (2010) as one of the factors contributing to low yields at smallholder farms can be managed.

Transplanting young seedlings resulted in better yields than transplanting 30 day old seedlings as is the practice for most smallholder farmers in Uganda. This finding is in agreement with Thanunathan and Sivasubramanian (2002) and Sarwa et al. (2011) who found that use of 10 and 25 day old seedlings had a positive impact on yield. The current findings however contradict those of Adhikari et al. (2013) and Bhagat et al. (1991). Adhikari et al. (2013) did not find statistically significant effect of fertilizer management in the nursery on yield. Besides, they also found that older seedlings (40 days old) had a highly significant and positive impact on yield. Similarly, Bhagat et al. (1991) found that 40 day old seedlings produced higher grain yields compared to 30, 50 and 60 day old seedlings. Experiments by Adhikari et al. (2013), and Bhagat et al. (1991) were however conducted in Nepal and Bangladesh respectively where there are varying seasons and climates, and different recommendations for age of seedlings. For example, it is recommended that farmers use 20-30 day old seedlings for the March/April to August, 20-35 day old seedlings for the T. Aman season (harvested during November/December) and 40-45 day old seedlings for the Boro season (October to March) (BRRI) in Bangladesh. The current findings have shown that applying DAP in the nursery and transplanting young seedlings can increase yields by up to 800 kg $ha^{-1}$.

### *4.2 Effect of Split Application of N Fertilizer on Yield and Yield Components*

The effect of split application of N on yield and number of tillers and panicles contradicts that reported by Hirzel et al. (2011) and Kamruzzaman et al. (2013) who showed that the number of tillers, panicles and yield of rice increased with increasing levels of N. The low yields, panicles and tillers could be the result of the low rates of N applied. Many authors (Hirzel et al., 2011; Kamruzzaman et al., 2013; Islam et al., 2009; Kaushal et al., 2010; Liu et al., 2016) obtained best results while applying more than 100 kg of N per ha. The fertilizer N rate used in this study was adopted from the average rate of 53-60 kg urea/ha used by farmers in lowland rice production in Uganda (Hainesh et al. 2013). Results have however showed that this rate is too low for farmers to realize significant yield gains. The poor performance of K85 in the control implies that variety K 85 requires fertilization to produce sufficient yields. The low harvest indices could have been caused by increased vegetative growth at the expense of reproductive growth. De Datta et al. (1988) attributed the increased yield in split experiments to reduced N losses and more effective crop utilization of N while Mikkelsen (1987) attributed it to N application at the tillering stage when crop N demand is highest. Currently, farmers will have to increase amounts of fertilizer they apply to get maximum benefits. Still, as Nhamo et al. (2014) has argued, balancing both micro and macro nutrients is necessary for sustainable management of soil fertility.

## 5. Conclusions

Application of DAP and fungicide combined with transplanting young seedlings has been shown to increase yield by up to 30% depending on variety. Given that poor nursery management practices have been cited as one of the factors contributing to low yields at smallholder farms, these results show potential for smallholder farmers to increase yield at minimal costs. Further research is however needed to ascertain the limit at which yield begins to decline with age of seedlings, and what other nutrients need to be added to the nursery for best results. It also not clear whether the available organic fertilizers would achieve the same results as the inorganic fertilizers. This is important considering that organic fertilizers may be more readily available than inorganic fertilizers. This study did not indicate gains in yield when nitrogen was applied in splits due to the low doses used. Further experiments should be set up with 100-125 kg of N per ha applied in two or three splits.

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