Response of High-yielding Upland Rice to Fertilization for Intensive Nutrient Production System

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ABSTRACT

Selection of high-yielding and nutrient-responsive upland rice variety is indispensable in improving yield. The yield of five upland rice varieties was evaluated with the same levels of fertilization; the highest-yielding variety was then grown under different levels of nitrogen fertilization along with other recommended doses of phosphorus and potassium (no fertilization, recommended rate of 120-90-60, 180-90-60, 240-90-60, and 300-90-60 kg ha^{-1} NPK) at University of Science and Technology of Southern Philippines, Claveria campus in 2014 and 2015, respectively. The study followed a randomized complete block design with three replications. The traditional upland rice "Speaker" produced the highest yield among varieties when applied with the same levels of fertilization. However, when applied with varying levels of nitrogen fertilizer, the yield of "Speaker" plateaued at the application of twice the recommended rate. The yield increased by 172% relative to no fertilization and 60% relative to the recommended rate when the recommended nitrogen application was doubled. The total dry matter accumulation also plateaued when applied twice of the recommended nitrogen fertilizer. The relative chlorophyll content tended to remain higher with a higher level of nitrogen application. There was a positive correlation between the yield and the total dry matter weight at harvest, and the dry matter weight at harvest and relative chlorophyll content at one week after heading. The significant increase in the yield of traditional upland rice "Speaker" from 1.0 to 4.0 t ha^{-1} indicates its potential to respond positively under the intensive nutrient upland rice production system.

Keywords: dry matter accumulation, nitrogen fertilization, relative chlorophyll content, traditional upland rice, grain yield

INTRODUCTION

Traditional upland rice is usually grown organically with lesser cultural management practices worldwide. This practice resulted in its lower yield, thus, treated only as subsistence crop (Atlin et al., 2006; Fageria et al., 2010). Due to poor cultural practices and management intervention, the yield of upland rice is limited by nutrient deficiencies. Among the nutrients, nitrogen (N) is the most yield-limiting for upland rice production. Nitrogen deficiency in the upland agro-ecosystem is attributed to low organic matter, soil acidity, soil erosion and use of low level of N fertilizers. The nitrogen deficiency in the upland agro-ecosystem is also attributed to low N use

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efficiency due to losses by leaching, volatilization, and erosion (Fageria & Baligar, 2005; Fageria et al., 2010).

There was an increasing trend in the per capita rice consumption (PCRC) in the Philippines as opposed to the decreasing trend in other ASEAN countries (Francisco et al., 2013). This increasing trend in the PCRC triggers the Philippine government in promoting upland rice farming in every region of the country.

In the previous study, it was revealed that the traditional upland rice variety "Speaker" produced higher grain yield in comparison to the improved upland rice variety IR 55419, and outperforming the improved check variety UPL Ri-5 and two other local varieties, Dinorado and Cabuyok. In addition, the yield of traditional variety "Speaker" and improved upland rice variety IR 55419 was consistently higher even under drought induction (Taylaran et al., 2011, 2013; Taylaran, 2015).

The lower yield of upland rice can be augmented by using drought tolerant and nutrient-responsive upland rice varieties. These can be effectively achieved by using direct selection method (Venuprasad et al., 2007; Dixit et al., 2014). However, traditional upland rice varieties are generally less responsive to N fertilizer application and produce low but stable yields. Because of its low yield, upland rice is not considered to be suitable for intensive management practices aimed at high yields (Saito et al., 2006). In the present study, the yield of several traditional upland rice varieties as evaluated under the same fertilization levels; the highest-yielding variety was then selected and grown under different levels of nitrogen fertilization for intensive nutrient management.

METHODOLOGY

Plant materials used and establishment of rice plants

There were two (2) experiments conducted at the University of Science and Technology of Southern Philippines (USTP), Claveria campus Research Station, Claveria, Misamis Oriental from September 2014 to January 2015. USTP Claveria is located at 8^{0}36'36" North latitude, 124^{0}53'00" East longitude at an elevation of about 615 meters above sea level. The soil type is Jasaan clay with soil pH of 5.29. It has about 2% organic matter, about 69 ppm of Phosphorus, and has sufficient amount of Potassium. In the first experiment, the yield of five traditional upland rice varieties was evaluated under the same level of fertilization following the application rate of 120-90-60 kg ha^{-1} NPK. Four (4) of the varieties (Jasmin, Kalabugaw, Cahuben, Dinorado as check variety) were obtained from Dr. Agustin Mercado of World Agroforestry Center (WAC), Claveria and one (traditional variety "Speaker") was collected from DA-CES, Lanise, Claveria, Misamis Oriental. The study was laid out in a Randomized Complete Block Design (RCBD) with the five upland varieties as treatments and replicated three times. Seeds were sown directly at a 30cm distance between furrows and 20cm between hills in a 3m x 5m plot. Thinning of unhealthy seedlings was done at 10-14 days after seedling emergence. Only 2-3 seedlings were grown per hill.

Based on the performance in the first experiment, the traditional upland rice variety "Speaker" was selected and used in the second experiment. The "Speaker" variety was grown under five nitrogen fertilization levels (T1: no fertilization; T2: a recommended rate of 120-90-60 kg ha^{-1} NPK; T3: 180-90-60 kg ha^{-1} NPK; T4: 240-90-60 kg ha^{-1} NPK; T5: 300-90-60 kg ha^{-1} NPK). The study was laid out in a Randomized Complete

Block Design (RCBD) replicated three times. The seeds were sown directly on each experimental plot size of 3 m x 5 m at 30 cm distance between furrows and 20 cm between hills. Thinning of unhealthy seedlings was done at 10-14 days after seedling emergence. Only 2-3 seedlings were grown per hill. Fertilizers were applied following the respective treatments.

Measurement of relative chlorophyll content

The upper fully expanded flag leaf of three main stems per hill of ten (10) randomly selected plants per treatment was used for the measurement of relative chlorophyll value using SPAD chlorophyll meter (SPAD-502, Minolta, Japan). The measurement was done at heading stage, two weeks after heading and at three weeks after heading, and was recorded as a mean of six measurements for each selected individual leaf between 9:00 am and 2:00 pm.

Measurements of dry weight

Five hills per variety were randomly selected at heading and harvest. Plants were separated into leaves, leaf sheaths plus stems and panicles (after heading and harvest) (Taylaran et al., 2009). Each group of plant parts was dried in a ventilated oven (DY610C Yamato Scientific Chongquing Co., LTD) at 80oC for four days or to constant weight.

Measurement of yield

The plants in an inner row with an area of approximately 2.0 m2 for each plot were harvested for determination of yield per unit area. The yield was adjusted to 14% moisture content (MC) and expressed in ton per hectare.

Statistical analysis

The analysis of variance (ANOVA) was used to detect the difference among treatments while the Pearson correlation coefficient (r) measured the strength of a linear association between two variables. Tukey's test (0.05) was also used to analyze the significant difference between treatment means using the Assistat 7.7 beta software.

RESULTS

Grain Yield and Dry Matter Accumulation

The grain yield of selected upland rice is presented in Figure 1. Among the varieties evaluated, the traditional upland rice "Speaker" obtained the highest grain yield outperforming the check variety Dinorado. When applied with different levels of nitrogen fertilizer, the grain yield of the traditional upland rice "Speaker" increased as the levels of nitrogen fertilization increased up to twice of the recommended rate (Fig. 2). The grain yield decreases as the application of nitrogen further increased. The grain yield increased by 172% against no fertilization and 60% against the recommended rate when the recommended nitrogen application was doubled. The significant increase in grain yield of traditional upland rice "Speaker" from about 1 ton ha^{-1} to 4 ton ha^{-1} indicates its potential to be cultivated under intensive nutrient cultivation practices aimed at a higher yield.

A positive high correlation was observed between the grain yield and dry matter weight at harvest (Fig. 3). There was also a positive correlation between the grain yield and the increased in dry matter weight after heading to harvest (Fig. 4). These imply that grain yield of traditional upland rice "Speaker" is not only associated with the higher dry matter production at harvest but also to the increased in dry matter production after heading to harvest.

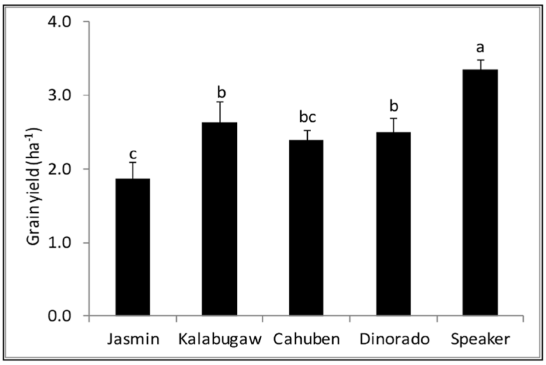

Figure 1. Grain yield of selected upland rice varieies nbapplied with 120-90-60 kg ha^{-1} NPK under Claveria condition.

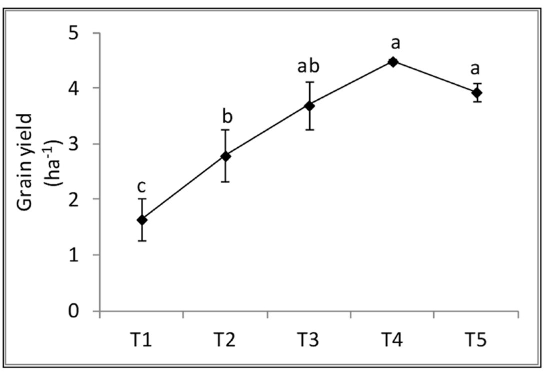

Figure 2. Grain yield (ton ha^{-1}) of traditional upland rice "Speaker" as affected by different levels of Nitrogen fertilization under Claveria condition. T1 = no fertilization; T2 = recommended rate of 120-90-60 kg ha^{-1} NPK; T3 = 180-90-60 kg ha^{-1} NPK; T4 = 240-90-60 kg ha^{-1} NPK; T5 = 300-90-60 kg ha^{-1} NPK, respectively.

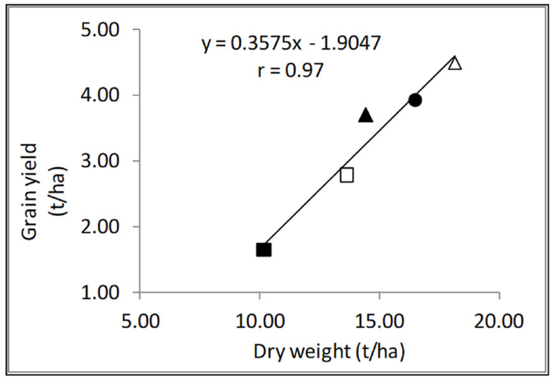

Figure 3. A relationship between grain yield and dry matter weight at harvest of traditional upland rice "Speaker" as affected by different levels of Nitrogen fertilization under Claveria condition. Symbols represent the treatment means such as filled square = no fertilization; unfilled square = the recommended rate of 120-90-60 kg ha^{-1} NPK; filled triangle = 180-90-60 kg ha^{-1} NPK; unfilled triangle = 240-90-60 kg ha^{-1} NPK; filled circle = 300-90-60 kg ha^{-1} NPK, respectively.

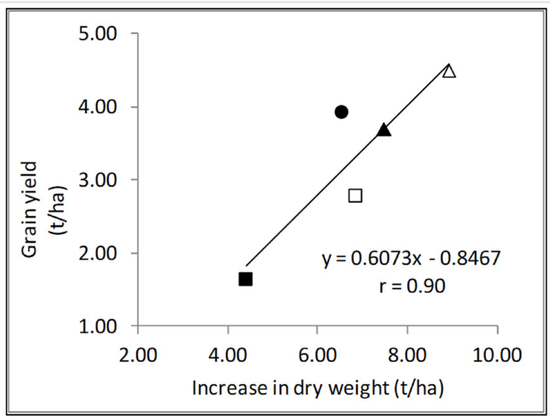

Figure 4. A relationship between grain yield and increase in dry matter weight after heading to harvest of traditional upland rice "Speaker" as affected by different levels of Nitrogen fertilization under Claveria condition. Symbols represent the treatment means such as filled square = no fertilization; unfilled square = the recommended rate of 120-90-60 kg ha-1 NPK; filled triangle = 180-90-60 kg ha-1 NPK; unfilled triangle = 240-90-60 kg ha-1 NPK; filled circle = 300-90-60 kg ha-1 NPK, respectively.

Relative chlorophyll content of upland rice "Speaker"

The relative chlorophyll content in the leaves of traditional upland rice "Speaker" was relatively higher from approximately 40 days after planting to 1 week after heading with higher nitrogen application (Fig. 5). Generally, the relative chlorophyll value increases as the rate of nitrogen application increases up to twice of the recommended rate. There was also a strong positive correlation between the dry weight at harvest and the relative chlorophyll content at one week after heading (Fig. 6). The maintenance of higher relative chlorophyll content after heading to ripening could be a potential characteristic of upland rice "Speaker" variety in improving grain yield.

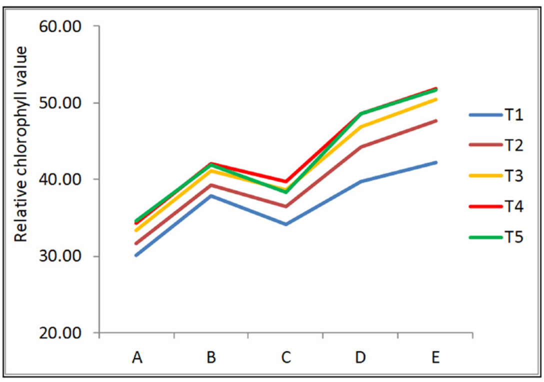

Figure 5. Relative chlorophyll content of leaves at different growth stages of traditional upland rice "Speaker" as affected by different nitrogen fertilization under Claveria condition. The letters represent growth stages, A = 40 days after planting (DAP); B = 60 DAP; C = panicle initiation stage; D = heading; E = approximately 1 week after heading, respectively. T1 = no fertilization; T2 = recommended rate of 120-90-60 kg ha^{-1} NPK; T3 = 180-90-60 kg ha^{-1} NPK; T4 = 240-90-60 kg ha^{-1} NPK; T5 = 300-90-60 kg ha^{-1} NPK, respectively.

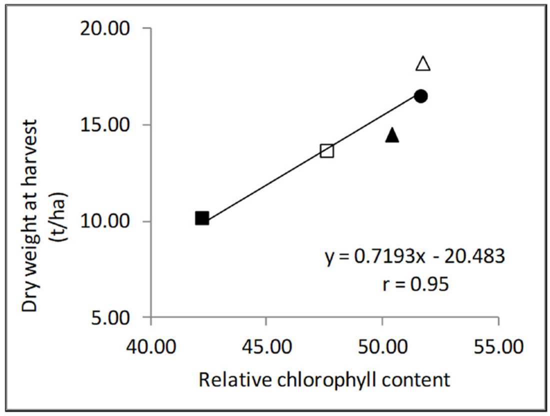

Figure 6. A relationship between dry weight at harvest and the relative chlorophyll content of leaves at one week after heading of traditional upland rice "Speaker" as affected by different levels of nitrogen fertilization under Claveria condition. Symbols represent the treatment means such as filled square = no fertilization; unfilled square = the recommended rate of 120-90-60 kg ha^{-1} NPK; filled triangle = 180-90-60 kg ha^{-1} NPK; unfilled triangle = 240-90-60 kg ha^{-1} NPK; filled circle = 300-90-60 kg ha^{-1} NPK, respectively.

DISCUSSION

Effects of Nitrogen on Grain Yield and Dry Matter Accumulation

Nitrogen is one of the most important components of fertilizers in rice production (Ntamatungiro, Norman, McNew, & Wells, 1999). Nitrogen is primarily involved in all metabolic processes in plants, and 75% of leaf nitrogen is associated with chloroplasts, which are essential for dry matter production through photosynthesis (Arima, 1995; Mae, 1995). In rice, nitrogen increases leaf area and the rate of photosynthesis; it also increases dry matter production and grain yield if no lodging occurs (Taylaran et al., 2009; Taylaran et al., 2011b). Previously, it was demonstrated that the traditional upland rice variety Speaker produced significantly higher dry matter yield at harvest among the selected upland rice varieties even grown organically (Taylaran et al., 2011 & 2013; Taylaran, 2015). The traditional upland rice "Speaker" produced significantly higher dry matter after heading to harvest. In the present study, the grain yield of traditional upland rice "Speaker" increased as the levels of nitrogen application increased (Fig. 2). However, the grain yield decreased with further application of nitrogen at 2.5 times than the recommended rate. The increase in grain yield in "Speaker" from about 1 ton ha-1 to 4 ton ha^{-1} indicates its potential response to intensive nutrient cultivation. There was a positive correlation between the grain yield and dry weight at harvest (Fig. 3) and the increase in dry weight after heading to harvest (Fig. 4). The higher grain yield could be attributed to the higher dry matter production in traditional upland rice "Speaker" (Taylaran, 2015). However, harvest index in "Speaker" was significantly lower than in improved upland rice variety IR 55419 when grown organically (Taylaran et al., 2011, 2013).

Effects of Nitrogen on Relative chlorophyll content of upland rice "Speaker"

The relative chlorophyll content in the leaves is directly proportional to leaf nitrogen content (Evans, 1983; Mae, 1995); thus nitrogen application level affects the relative chlorophyll content in the leaves. Moreover, Makino et al. (1985) reported a close correlation between the level of Rubisco and leaf nitrogen. A linear relationship existed between the relative chlorophyll content SPAD values and leaf nitrogen concentration (Gholizadeh et al., 2009) and between leaf nitrogen and the rate of leaf photosynthesis (Hirasawa et al., 2010) has been reported leading to higher dry matter production. The present study revealed higher relative chlorophyll content SPAD value in "Speaker" from approximately 40 days after planting to 1 week after heading, respectively. There was also a positive correlation between the dry weight at harvest and the relative chlorophyll content at about one week after heading. The maintenance of higher relative chlorophyll content after heading could be attributed to higher leaf nitrogen content, thus resulting in higher photosynthetic capacity (Makino et al., 1985; Hirasawa et al., 2010; Taylaran et al., 2011; Taylaran, 2015).

CONCLUSION

The traditional upland rice "Speaker" produced higher grain yield among the five varieties under the same levels of fertilization. When grown under different levels of nitrogen application, the grain yield has increased by approximately 172% against no fertilization and 60% against the recommended rate when the recommended rate of nitrogen application was doubled. These might suggest that "Speaker" variety has a nutrient-responsive characteristic needed in improving the yield of upland rice. The significant increase in grain yield in traditional upland rice "Speaker" from approximately 1.0 t ha^{-1} to 4.0 t ha^{-1} suggests its potential to be used under intensive nutrient management in the upland rice production system. The higher dry matter production through the maintenance of higher chlorophyll content might be one of the avenues in improving the yield of traditional upland rice.

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