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Full Length Research Paper

Response of rice landraces and promising cultivars to nitrogen fertilizer application on sloping uplands

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This study aimed to determine appropriate nitrogen fertilizer levels for upland rice. The study was designed to detect genotype × fertilizer interactions. The trial included five fertilizer treatments: control, 30, 60, 90 and 120 kg/ha of nitrogen. Six cultivars were included in the trial: 1) Makhinsoung, 2) Nok, 3) Non, 4) IR55423-1, 5) B6144F-MR-6 and 6) IR60080-46[a]. The result showed that nitrogen fertilizer at 30 kg/ha increased rice grain yields in improved non-glutinous lines, and 50 kg/ha increased rice grain yields in the traditionally introduced cultivars. Highly significant difference was observed between fertilizer treatments (probability value was 0.000). The effect of the yield's increase was about 29 to 36% from the control to the improved lines, while the response range was from 25 to 29 kg/unit of nitrogen. The traditionally introduced cultivars' yield increased from about 25 to 34% for the control, whereas the response unit range was from 13 to 18 kg/unit of nitrogen. The fertilizer and cultivar interactions were also observed to be significant in the trial (probability value was 0.01). However, weed biomass decreased with fertilizer application, probably as a result of the inhibition of weed growth due to increased rice growth and earlier rice canopy closure in the plots which had been fertilized.

Key words: Upland rice field management, fertilizer applications, upland rice cultivars.

INTRODUCTION

Rice, the staple food crop, is grown in upland ecologies in the northern region in sloping land fields under slash-and-burn systems by resource-poor farmers for subsistence (Linquist et al., 2007). Traditional upland rice cropping accounts for about half of the total rice area in the north, yielding 1.7 t/ha on average versus more than 3 t/ha for lowland rice (Roder et al., 1995). Upland rice is typically grown without fertilizer under rainfall (Roder, 2001). The low productivity has been attributed to low soil fertility in this region which generally have low water-holding capacity as well as low nitrogen availability (Roder, 2001; Linquist et al., 2006; Saito et al., 2006).

The current policy of the government of Laos is to reduce the area under the 'slash-and-burn' agricultural system and to introd time for the natural fallows to regenerate soil fertility. It was reported that fallow decreased from 38 years during the 1950s and 5 years in 1992, thereby resulting in a rapid decline in soil fertility, increasing weed problems, and declining crop yields (Roder, 2001). Replacement of essential nutrients for crop growth and field management is a key factor towards improving crop yields through the judicious use of chemical fertilizers to involve the determination of appropriate rates of nitrogen fertilizer application for upland rice production.

Nitrogen (N) and Phosphate (P) deficiencies are the most important nutrient disorders in the upland condition of Northern Laos (George et al., 2001; Roder, 2001). Using traditional cultivars, various field fertilizer experiments have been conducted during 1991-2003, but these trials indicated that these were low response of traditional cultivars to N fertilizer application (Roder, 2001). However, little information is available about the differences in upland rice cultivars in response to

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Table 1. Description of the experiment in Luang Prabang Province, Lao PDR.

Variable	NAFReC	Houayhia	Packthor	B-moud	Somsanuck
Soil pH	5.9	5.5	5.6	6.3	5.8
Elevation (m)	330	605	325	315	320
Fallow (year)	2	3	5	Continuous	3
Land slope	10	30	10	5	10
Land preparation	Burning	Burning	Burning	Tillage	Burning

Nitrogen in Northern Laos for improved cultivars. Also the traditionally introduced cultivars were not responding to fertilizer (Saito et al., 2006).

The objectives of this study are to examine the effect of cultivars and Nitrogen fertilizer on grain yield in Northern Laos, and to determine the improved and traditionally introduced upland rice cultivars in response to N fertilizer.

MATERIALS AND METHODS

The locations used in this study are presented in Table 1. For the first year, the trial was conducted in a farmer's field in 2004 in Houayhia village, and the field was newly opened after three years of fallow. In 2005, the trial was conducted in Houayhia village and NAFReC, afterwards the field was newly opened after three years of fallow. In Banhmoud village, rice was grown in the field in 2006; as such the trial was conducted in NAFReC and Somsanuck village, Pack Ou District, after which the field was newly opened after two years (NAFReC) and three years of fallow. In 2008, the trial was conducted at NAFReC and in 2009 it was conducted in Pakthor village, Xiengngeun District, Luang Prabang Province. Almost all of the soil was clayey and was generally of low fertility.

The materials used included five fertilizer treatments: 1) control, 30, 60, 90 and 120 kg/ha N. Six cultivars (three glutinous and three improved non-glutinous) were included in the trial: Makhinsoung, Nok, Non, IR55423-1, B6144F-MR-6 and IR60080-46a. The trial was laid out as a Split Plot in Randomized Complete Block Design with four replications. Each plot was 3 m^2. Rice was planted with a dibble stick as is the traditional practice, at a hill spacing of 0.25 m × 0.25 m with 5–6 seeds in each hill. During the middle to late May in each year (it was not at the same time), weeding was conducted normally three times per season at 25, 50 and 75 days after sowing. Nitrogen fertilizer was split into three equal applications as the first and second fertilizer applications were spread in between the hills and the third application was broadcasted over the crop after the third weeding.

Data collected from the trials due to dryness of weed from every weeding time were determined after oven drying at 65°C for at least 48 h, and rice plant height, tillering, yield component (panicle number, panicle length, spikelet fertility), grain yield and harvest index data were measured, observed and recorded, after which analysis of variance (ANOVA) was conducted on the combined data set across the eight sites for five years.

RESULTS AND DISCUSSION

From the eight sites and five years/seasons, the highest average yield (3.346 t/ha) was obtained when fifty kilogram of nitrogen fertilizer was applied on the cultivars, while the control treatment produced 2.585 t/ha. The value tended to decrease when the kilogram of nitrogen fertilizer applied on the cultivars was increased (Figure 1). There was highly significant difference between the thirty and fifty kilogram of nitrogen per hectare treatment when compared to the control and other values of nitrogen treatments. However, statistical analysis showed that the probability was 0.000 for the fertilizer rates, and the polynomial r-square was 94% (Table 2). The statistical analysis also showed that yield components (panicles per hill, panicle length, spikelet fertility and harvest index) and plant height were highly significant between nitrogen rates and cultivars, but no significant difference was found between interactions of fertilizer and cultivars (Tables 2 and 3).

Grain yield advantage in nitrogen application of the six rice cultivars was better in low levels, in that it can dramatically increase productivity of rice yield to 30 kg which is the best for improved lines and 50 kg which is the best for traditionally introduced cultivars. Moreover, B6144F-MR-6 cultivar was especially observed in upland conditions. Data are shown in Figure 2. And the grain yield was continuously decreased by way of continuous increase of nitrogen rates for all improved lines and traditional cultivars. Saito et al. (2006) reported that application of only N was non-effective to grain yield, while application of N and P together was increased to about 71% for improved lines and suitable areas only.

Data are not consistent with the usual fertilizer response profiles in which grain yield progressively increases with increasing application of fertilizer, but at a diminishing rate beyond an optimum fertilizer rate. The latter fertilizer yields' response pattern is reported in lowland or level land crop culture systems. The different patterns of response in upland systems may be due to the greater chances for higher levels of nitrogen application to be washed away with runoff than lower rates of application. The lower nitrogen application rates

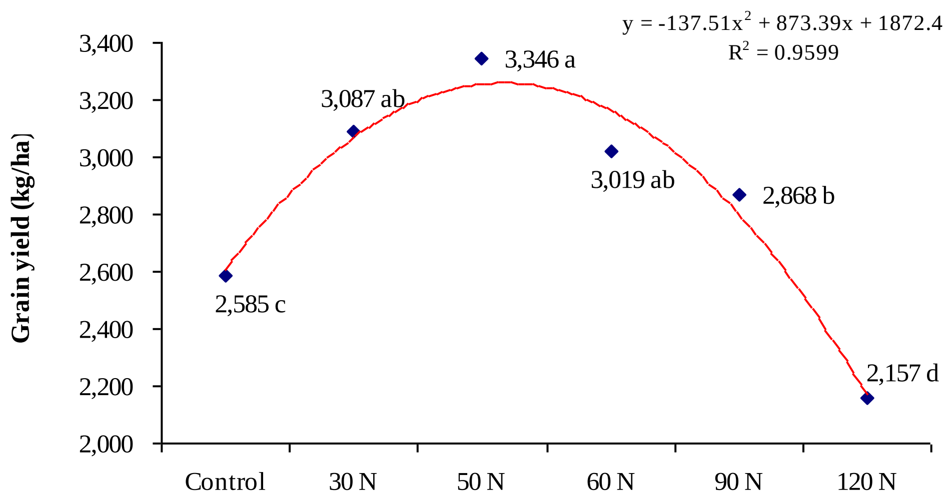

Figure 1. Grain yield of six rice cultivars at five rates of nitrogen application.

Table 2. Probability value of the statistical analysis for grain yield.

Variant	Grand means	Standard deviation based on		C of V (%)	Replication	Fertilizer	Fertilizer × Replication	Variety	Fertilizer × Varieties
		Total SS	Residual SS						
Grain yield	2,841	869	829	29	0.65	0.000	0.000	0.047	0.01
Income	1,046	320	305	29	0.65	0.000	0.000	0.047	0.01

Table 3. The probability value of the statistical analysis for each weeding time, plant height and yield components.

Variant	Grand means	Standard deviation based on		CV%	Fertilizer	Cultivars	Fer*Cultivars
		Total SS	Residual SS				
First weed dryness (kg/ha)	461.43	305.39	298.25	6.5	0.70	0.40	0.95
2nd weed dryness (kg/ha)	356.61	356.96	301.50	8.5	0.08	0.17	0.14
3rd weed dryness (kg/ha)	67.38	74.21	72.92	10.8	0.01	0.47	0.66
Height at 25 days (cm)	44.47	9.65	5.90	13	0.01	0.00	0.10
Height at 50 days (cm)	61.79	13.11	8.22	13	0.00	0.00	0.51
Height at 75 days (cm)	97.25	18.48	6.51	7	0.00	0.00	0.36
Height at harvesting (cm)	120.33	19.76	7.07	6	0.00	0.00	0.33
Panicles per hill	6.93	2.23	1.15	17	0.00	0.00	0.72
Panicle length (cm)	25.20	2.55	1.39	6	0.00	0.00	0.50
Spikelet fertility (%)	89.85	6.73	5.07	6	0.01	0.00	0.47
Harvest index	0.33	0.10	0.06	18	0.01	0.00	0.88

may be more quickly taken up by the crop or adsorbed onto soil surfaces, whereas the higher rates of application may over-tax the absorptive capacity of the roots, leaving a larger concentration of nitrogen in the soil solution or lightly adsorbed to soil surfaces.

Differences in response of the traditional cultivars and the improved rice lines were consistent with reports in the literature. Improved rice lines have been shown to be more fertilizer responsive than traditional cultivars. The data in the trial were consistent with these reports, except for the traditional cultivar Nok which consistently had higher grain production compared to other cultivars and lines over all N fertilizer treatments (Table 4). Nok had a similar harvest index as the modern lines, thus the way it partitions biomass between straw and grain is similar to those of the modern lines. Grain yield among fertilizer ×

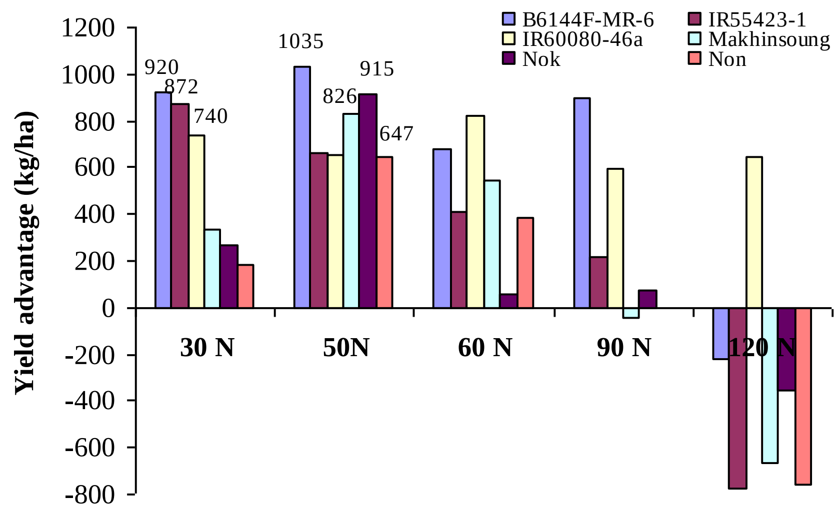

Figure 2. Yield advantage at difference rates of nitrogen application with six cultivars.

Table 4. Plant height of rice in plots fertilized with 0, 30, 50, 60, 90 and 120 kg N/ha.

Fertilizer	Plant height after sowing (days)				Panicle/hill	Panicle length (cm)	Grain yield (kg/ha)
	25	50	75	Flowering			
Control	42[bc]	55[d]	85[d]	107[c]	5[b]	23[b]	1661[c]
30 N	46[ab]	62[bc]	100[b]	123[ab]	7[a]	26[a]	2545[a]
60 N	40[c]	58[cd]	93[c]	119[b]	7[a]	26[a]	2134[abc]
90 N	46[ab]	65[ab]	103[ab]	127[a]	7[a]	26[a]	2371[ab]
120 N	50[a]	69[a]	106[a]	125[ab]	8[a]	25[a]	1800[b]
SE (N=24)	1.57	2.02	1.68	2.12	0.33	0.42	206.05
5%LSD	4.85	6.22	5.16	6.53	1.01	1.29	634.91
F-probability	0.01	0.00	0.00	0.00	0.00	0.00	0.00

cultivar interactions were not statistically different.

There were more weeds in plots where no N fertilizer was applied at all sampling times. As such, there was no significant difference in the first and second weeding time, but in the third weeding time, a significant difference was observed by statistical analysis as the probability was 0.01 (Figure 3). In the linear case of dryness weed in which no fertilizer was applied, the r-square of each weeding time was only 66%, but in cases when nitrogen 120 kg/ha was applied, the r-square increased to 99%. Weed biomass decreased at each sampling time, however the rate of decline in weed biomass between the first and second sampling was greater in places where N fertilizer had been applied; this may be attributed to inhibition of weed growth because of more rapid growth and earlier rice canopy closure in the plots which had been fertilized.

Nitrogen fertilizer was effective and highly significant to both the introduced and improved cultivars as 30 and 50 kg/ha of nitrogen was used for the statistical analysis, with a probability of 0.0001. It was observed that the yield increased from about 29 to 36% for improved lines with a higher response at 30 kg/ha of N ranging from 25 to 29 kg/unit of nitrogen. The introduced traditional cultivars also responded to N fertilizer, but at a different application rate. When 50 kg/ha of N was applied, the yield increased from about 25 to 34%, or 13 to 18 kg/unit of nitrogen (Figure 4). This result was different from that of Saito et al. (2006) which showed that grain yield of the introduced traditional cultivars from nitrogen was about 71% of the yield which increased for the improved line in some suitable areas. Other results showed that any introduced lines, and selected/purified landraces performed better, under the same environmental conditions, as local varieties (Asai et al., 2009). And only the improved rice germplasm produced higher yields in both low and high fertility conditions (Saito et al., 2007).

This result also shows that there is benefit per hectare between different rates of nitrogen fertilizer applications. It was observed that if 30 kg/ha is applied to the cultivars

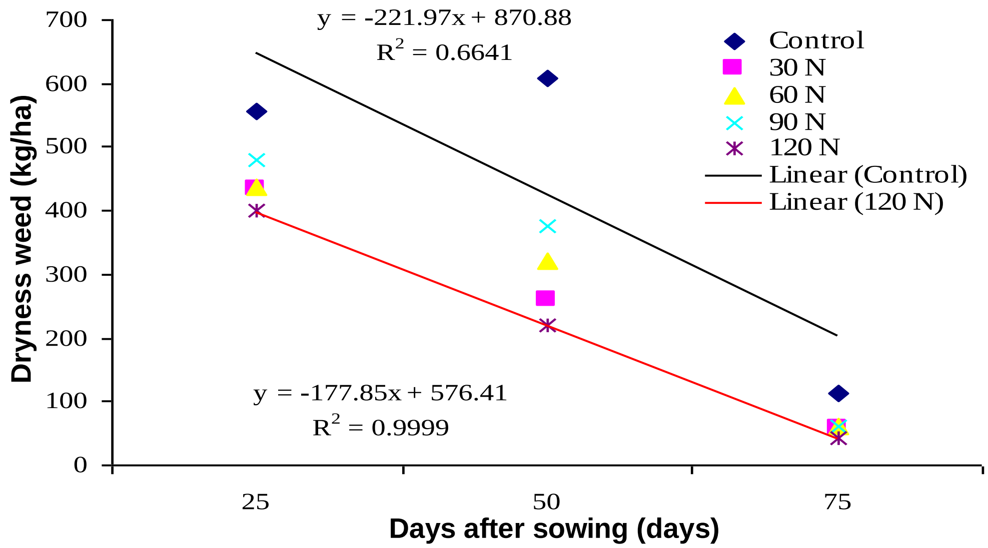

Figure 3. Weed biomass at three sampling times over the growing season in plots fertilized with five rates of N.

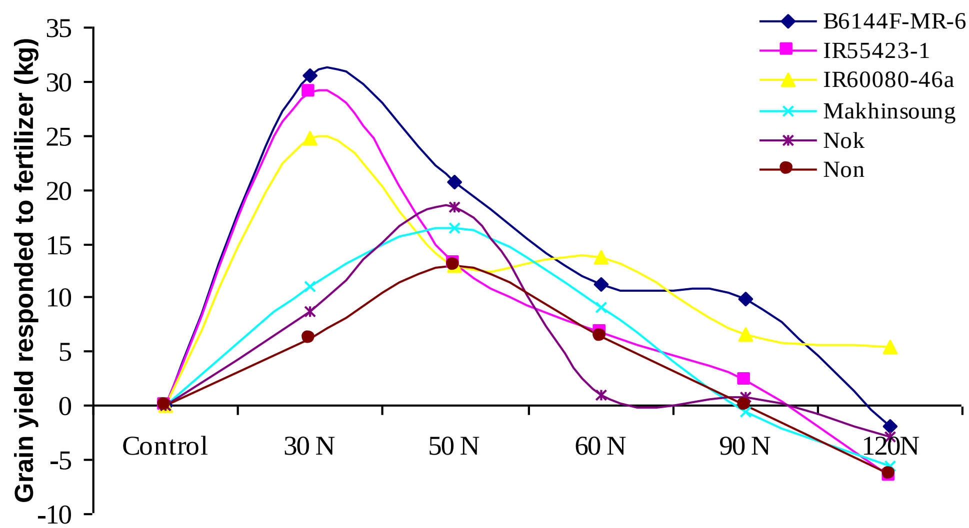

Figure 4. Grain yield response of six rice cultivars to nitrogen application.

of the improved non-glutinous lines, it would yield more of benefit per hectare of about 224 to 273 US$, than if the rates of 50 kg/ha is applied to the traditionally introduced cultivars. Both of these rates will provide the better benefit than the local rates which can provide about 158 to 257 US$. As such, no other result was recommended except the above result. However, the grain yield of some improved lines did not decrease very much as the r-square of IR60080-46a line was only 19%, but when nitrogen fertilizer was continuously added, the grain yield of almost all the traditionally introduced cultivars decreased vastly as the r-square of Makhinsoung cultivars was 61% (Figure 5).

Conclusion

It was observed that the suitable nitrogen fertilizer application rate in upland rice productivity which increased rice grain yields and produced better income for modern non-glutinous rice was 30 kg/ha, while that for traditional cultivars was 50 kg/ha. The observed result was highly and significantly different for fertilizer × cultivar interactions at 95% (p=0.01) in the trial. However, weed biomass decreased with fertilizer application, probably as

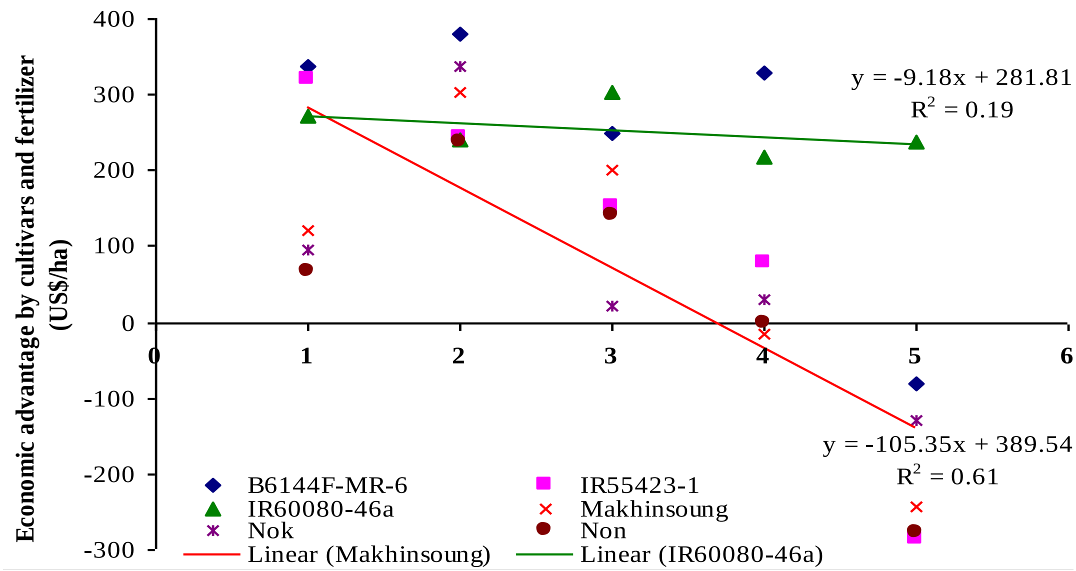

Figure 5. Impact of upland rice cultivars and different fertilizer application rates on upland condition.

a result of the inhibition of weed growth due to increased rice growth and earlier rice canopy closure in the plots which had been fertilized.

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