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Effect of Organic Nitrogen Based Fertilizers on Leaf Photosynthesis, Yield and Yield Components of Rice (*Oryza sativa* L.)

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Abstract

Nitrogen based fertilizers play a prime role for increasing yield and biomass of rice plant. To investigate photosynthesis activity, yield and yield components as affected by different N levels and to increase farmers' awareness of improving rice yield potential with photosynthesis efficiency a study was conducted in randomized complete block design. Four different types of organic fertilizers (i.e., O1: Cattle pig dropping; O2: Poultry manure-II; O3: Sugarcane bagasse; O4: Cattle manure) were used in combination with one control (without any organic fertilizer or amendment) and three different N levels (50, 100, and 150 kg N per hectare). Field experiment has shown that there was high grain yield as level of N supply increased up to certain limit (100 kg N ha^{-1}) through enhanced sink size by increasing both panicle number and spikelet number per panicle. The increase in number of tillers per hill with N application resulted in higher dry matter production. Harvesting index (H.I.) was decreased with increasing N application rate in sequential order of C (0.49) > L (0.46) = M (0.46) > H (0.44). SPAD reading became more and more sensitive to nitrogen rates following growth stages. Grain weight was significantly correlated with panicle number ($r = 0.70$) and panicle weight ($r = 0.99$). The high percentage of filled grain was the reason associated with higher grain yield which benefited from the slow release of nutrients and extended photosynthesis activity during ripening. So, careful attention to nitrogen fertilization could be necessary for rice grower to obtain economic profit from optimum organic-N application.

Keywords: rice, photosynthesis, organic fertilizer, yield components, nitrogen

Introduction

Nitrogen (N) is the most essential nutrient for rice grain filling through the enhancement of photosynthetic capacity (Mae, 1997) and comparatively large amounts are required among the three macronutrients by rice crop (Wang *et al.,* 2004). However, at the same time, under-fertilization or over-fertilization of N causes several physiological changes in plant growth and development, which in turn, results low rice yield (Heenan, 1982). Rice is more sensitive to overdoses of nitrogen than to excess levels of potassium and adversely affect the quality of the grain. Increase in rice grain yield is accompanied to increase nitrogen rate and attains plateau at 180 kg N per hectare (ha) and becomes less at higher rates (Zhang *et al.*, 2009). The mechanism for differences in grain yield with different nitrogen rates are due to the difference in partitioning of dry matter between grain and straw. Nearly half of the total dry matter in modern varieties was partitioned to the grain (Bufogle *et al.*, 1997). Thus, productivity of rice varieties depends on their responsiveness of supplied N to soil.

Rice grain yield and dry matter production are closely related with the net photosynthesis assimilation of CO_2 throughout the entire season (Yoshida, 1981). About 80-90 percent of the biomass of green plants is derived from photosynthesis. Increasing level of nitrogen could produce adequate amount of chlorophyll in the leaves which ultimately effect on photosynthesis process (Marschner, 2008). For the production of photosynthates, spikelet and leaves play important role of sink and source respectively. Hasegawa et al. (1994) found that spikelet density which is major determinant for rice yield, increased with increased nitrogen concentrations. The leaf net photosynthetic rate was positively correlated with the leaf N content ($R^2 = 0.94$), and the stomatal conductance was positively correlated with leaf N content ($R^2 = 0.74$) (Lin *et al.*, 2005). Therefore, in order for higher yield, we must keep the photosynthetic rate of upper four leaves including flag leaf as active as possible to enable them for maximum CO_2 assimilation.

Excess applications of chemical fertilizer result in degradation of soil fertility (accelerate the rate of soil acidification), loss of agro biodiversity, environment pollution, and ultimate economic losses. Low nitrogen fertilizer recovery remains a problem in rice production in Asia and has been reported to range from 30 to 40% of applied N (Chauhan and Mishra, 1989). For the production of 5 tons of brown rice per hectare, rice plants should absorb 110 kg N ha^{-1}, 23 kg P_2O_5 ha^{-1} and 132 kg K_2O ha^{-1} respectively (Ishizuka, 1980). This amount of nitrogen must be absorbed throughout the growing season in a fairly even manner, from the soil solution maintained at a low ammonium concentration. How to supply this large quantity of N at a low level of intensity, appear to be the key of successful paddy rice culture. In such a condition, organic fertilizer (OF) behaves like an ideal slow-releasing fertilizer (Onikura *et al.,* 1975) for promoting environment friendly agriculture ecosystem, high N recovery efficiency, and maintaining soil fertility and productivity for sustainable rice yield. The significant difference of this research from chemical farming, in which N quickly lifts and disappears, is that organic fertilizer has slow and continuous macro- and micro-nutrients releasing property which provides nutrients to the plants for long period after application. Also, organic rice farming have positive effect in attaining quality and higher grain yield as well as maintaining long-term productivity of soil (Tiessen *et al.,* 1994; Wander *et al.,* 1994; Drinkwater *et al.,* 1995). Therefore, farmers all over the world are now shifting toward organic farming for its long lasting benefits.

In context of Nepal, rice is the most important food crop for economics and social values which is grown from tropical plains up to high elevation of the world at 3050 meter above sea level (Chhumchure, Jumla). Rice covers about 46 percent of total cultivated area which provides more than 50 per cent of the total calories requirement of the Nepalese people. It contributes about 21 percent to the agriculture gross domestic production (Dahal, 2010). In the developing and land locked countries, cost and availability of chemical fertilizer is a serious problem. Increasing N use efficiency is a major challenge for rice researchers and farmers for low production cost of rice. For the sustainable agriculture system, maintaining of soil fertility has prime importance. Organic fertilizer can play an important role in this regards through slow and continuous release of ions, soil water retention during drought and increase drainage in wet weather. In Nepal, general recommended dose of organic manure for rice cultivation is 6 t ha^{-1}. When extension workers advise farmers on the amount of fertilizer for practical rice cultivation, both the quantity and quality is important because of varied amount of nutrients content of different organic fertilizers. Hsieh and Hsieh (1993) reported that organic matter is often used as an index of soil fertility because it generally influences soil physical, chemical and biological properties. In this study, we will discuss about the usage of different sources of organic fertilizer with special focus on N levels for improving leaf photosynthesis in connection with maximum yield and yield components of indica rice (*Oryza sativa* L. var. Taichung Sen No. 10). The main objectives of this study are: (1) to quantify leaf photosynthesis rate (i.e. photosynthetic oxygen evolution rate) as affected by different N levels under organic fertilizers growth condition; (2) to determine the environment-friendly optimum level of organic fertilizer application for improving rice growth and grain yield.

Materials and methods

Climatic Condition

During the field experiment, average light intensity in the field on May 19, 2010 at 9:00 am, 12:00 pm and 5:00 pm was 1350 and 1870 and 270 μmol m^{-2} s^{-1} respectively. Mean annual precipitation in the area was between 2000-2800 mm with the maximum falling between May and September. Precipitation during the growing season of rice in January, February, March, April and May was 4.5, 18.5, 3, 45.5 and 300.5 mm respectively. The site has a mean annual temperature of 25˚C. Average monthly variation in climatic characteristics during the experiment period is presented in Figure 1.

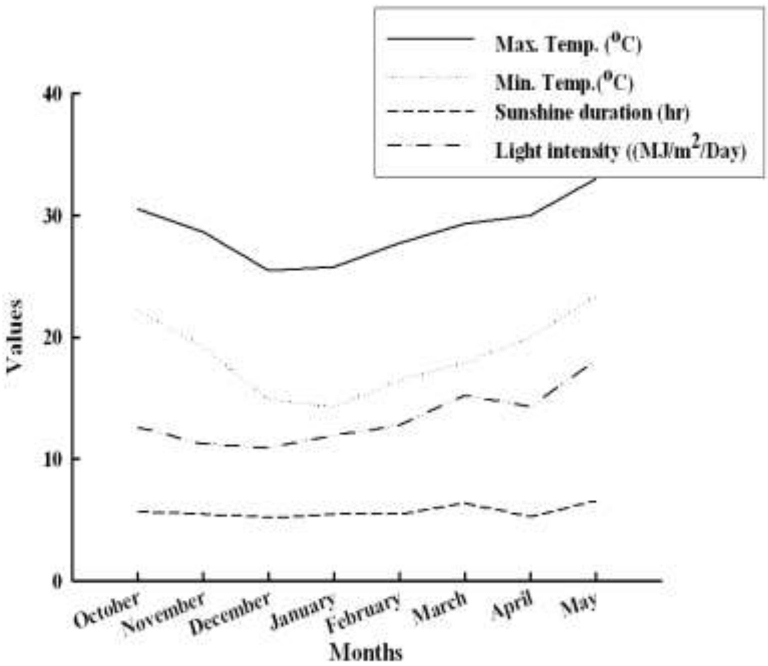

Figure 1. Average monthly variation in climatic characteristics of NPUST from October 2009 to May 2010.

Table 1. Bio-chemical characteristics of organic fertilizers used for field experiment

Name	pH^1	EC^1 (d S m^{-1})	OC %	Total N^2	Total P^3	C:P	Total Ca	Total Mg	Total K	Total Na	Fe	Mn	Cu	Zn	Ni
				-----%-----			-------------%------------				----------mg per kg^4----------				
Cattle pig dropping (O1)	6.61	22.0	41.9	4.6	1.37	31	9.4	0.9	0.6	0.3	3280	9	38	168	15
Poultry manure–II (O2)	7.0	5.91	34.7	1.4	0.71	49	6.3	0.7	0.1	0.2	1747	263	24	181	16
Sugarcane bagasse (O3)	7.14	16.8	34.7	2.5	0.59	59	0.6	0.9	0.5	0.4	3047	63	40	101	17
Cattle manure (O4)	6.73	3.15	18.1	1.3	0.71	25	8.7	0.7	0.5	0.2	14147	1050	49	327	23

[1]1:5 Compost: water

Source: Jobe and Tsai (2006) [2]Micro-Kjeldahl determination

[3]H_2O_2/H_2SO_4 digests

[4]Maximum Allowable level (mg per kg) of Ni = 25 and Cu = 100 (150)

Field Experiment Design

The field experiment was conducted at National Pingtung University of Science and Technology (NPUST) from December 20, 2009 to May 26, 2010 to evaluate the effects of different N levels using organic fertilizer on growth and yield performance of paddy rice (*O. sativa* var. Taichung Sen No. 10*)*.

The experiment was laid out as randomized complete block design (RCBD) with three replications for each of the four treatments. The treatments were: 1) control (C) without organic fertilizer or amendment; 2) low level (L) organic fertilizer with 50 kg N ha^{-1}; 3) medium level (M) organic fertilizer with 100 kg N ha^{-1}; and 4) high level (H) organic fertilizer with 150 kg N ha^{-1}.

Rice seeds were soaked for 48 hours to increase the seed water content and then were exposed to a temperature about 30˚C to promote germination. Seeds were sown in plastic seeding-box (60 cm x 30 cm x 3 cm) with 200 grams seed per box on December 20, 2009.

The amount of organic fertilizer was broadcasted by hand into three equals split doses; one-third at final land preparation as basal dose (January 7, 2010), one-third at active tillering (February 10, 2010) and rest one-third at panicle initiation stage (March 12, 2010) as shown in Table 2. Amount of organic fertilizers used in each treatment was doubled at the recommended dose due to availability of only about 40-50% nutrient during mineralization. One week before transplanting, the field was plowed, harrowed, and flooded.

The size of the experimental unit was 3.3 m × 3 m (9.9 m^2) and separated by 4.0 m × 30 cm plastic fence for minimizing movements of fertilizer out of plots through irrigated water. Rice seedlings were transplanted at spacing 30 cm × 15 cm with 3-5 seedlings per hill (222,222 hills ha^{-1}) on January 11, 2010. After transplanting, plots were flooded to a depth of about 5 cm for one week because of small size of seedlings and maintained about 5-10 cm during rice growth. The plots were only drained one week before panicle initiation and again one week before harvesting. Maintaining soil moisture at field capacity during panicle initiation stage helps to break through the cycle of pests, reduce active vegetative growth and promote the root extension and aeration (promote oxidation in soil due to reduction for long time water logging). In order to reduce the incidence of rice pest (leaf rollers, leaf hoppers, stem borers etc) and prevent the multiplication of pathogens, camphor oil at the rate of 200 ppm concentration was sprayed every week and maintained until heading. During the panicle initiation stage BT (*Bacillus thurengensis*) 1 g L^{-1} of water with Chinese berry extract was sprayed in place of camphor to control different pests. Vertebrate pest like mice were major problem specially during milking stage which was controlled by using poisonous bates, tobacco dust, and mouse trap simultaneously. Birds were controlled by covering the field plant with plastic net. During the early stage weed infestation was high. Therefore, hand weeding was done to control weed infestation frequently to maintain organic rice production system.

To explore chlorophyll content (SPAD meter reading), fully expanded leaf close to the flag leaf (young emerging leaf) was randomly selected from rice plants for data recording. A chlorophyll meter was used to collect chlorophyll readings in different treatments at active tillering stage (Feb. 26, 2010), panicle initiation stage (March 13, 2010), 90-95% heading stage (April 21, 2010) and grain filling stage (May 10, 2010). Data were recorded as average of three points of individual leaf blade: a) first 2/3 down from the leaf tip; b) second at mid-point; c) third at 1/3 of the away down from the leaf tip.

Lodging of some plants occurred about one week before harvesting and was recorded as lodging score which ranged from 0 (no lodging) to 5 (serious lodging). Rice was harvested when about 90-95 % rice panicle was ripened and turned yellowish color. Thirty hills per plot were randomly harvested to determine yield and yield components (panicle number, panicle weight, total kernel weight, and filled kernel weight). Plants were harvested from each row excluding guard rows. Plant height was measured from the base of the plant to the height point of top leaf. Number of panicles per hill was recorded from harvested plants. Rice panicle and straw was separated using scissors and dried in oven using 80˚C for 72 hours prior to investigation. Straw dry weight was recorded. Rice grain was cleaned using improved seed blower (Seed Buro, Chicago, ILL. 6067). The filled clean grain was collected in plastic bag and sealed. Bags were kept in air tight box with silica gel (high moisture absorption capacities to avoid spoilage or degradation). The dry rice grain samples were weighed. In this way, yield components viz. number of panicles per m^2, and percentage of filled panicle were recorded from the samples. Rice yield (t ha^{-1}) and harvesting index (H.I.) was computed as followed by Yoshida (1981).

Harvesting index (H.I.) = (economic yield ÷ biological yield)

= (grain yield ÷ combined yield of grain and straw)

Table 2. Amounts of organic fertilizer (kg $plot^{-1}$) used in different treatments for paddy rice field experiment[1]

Treatments	Rate of N (kg ha^{-1})	Rate of OF (t ha^{-1})	Rate of fertilizer at different stages		
			Basal	Active tillering	Panicle initiation
C	00	00	00	00	00
L	50	2.17	0.72	0.72	0.72
M	100	4.35	1.44	1.44	1.44
H	150	6.52	2.15	2.15	2.15

[1]Control (C): no any OF; low level (L): 50 kg N ha^{-1}; medium level (M): 100 kg N ha^{-1}; high level (H): 150 kg N ha^{-1}; OF: Organic fertilizer.

Results and discussion

Variation of SPAD Reading in Paddy Rice Experiment

SPAD reading at different growing stages (on 47, 62 and 101 DAT) was significantly increased with increasing N application rate. SPAD meter reading of Y-leaf with N application plant was significantly higher compared to control treatment as shown in Figure 2. The average SPAD reading among the treatments on 47 DAT was lower than average reading on 101 DAT. This showed that SPAD reading became more and more sensitive to nitrogen rates following growth stages. The important reason behind high SPAD reading on 101 DAT was due to accumulation of more chlorophyll with advanced growth. Treatments with high N application had comparatively higher SPAD reading due to high leaf nitrogen content. The SPAD reading was also reported to be increased with plant growth (Schepers *et al.*, 1992; Gholizadeh *et al*., 2009). Hussain et al. (2000) found that SPAD readings are closely related to leaf N content and can be used to monitor the N status of rice and thereby to adjust the rate of N fertilization in order to increase N use efficiency. Temporal SPAD readings of the same leaves under different N rates indicated that leaf age is an important factor deserving to be checked when SPAD measurements are used to plant N status diagnosis (Li *et al.,* 2009). Lin et al. (2010) noted that there was a close relationship between the average SPAD readings at the midpoint of each leaf blade, 30mm apart and one side of the midrib, and approximately one-third of the way down from the leaf tip and leaf N and chlorophyll concentration.

Due to aging at senescence stage, the SPAD reading started to decline at 120 DAT. Dordas and Sioulas (2008) reported that chlorophyll content of safflower leaf decrease from anthesis to physiological maturity by an average of 23%. Nitrogen in old leaves could be re-translocated into young leaves when plants are of N deficiency. Lin et al. (2010) observed in rice plant that the average SPAD value of first fully expanded leaf was higher than that of third fully expanded leaf when the plants were N deficient, but the average SPAD value of first fully expanded leaf was lower than that of third fully expanded leaf when the plants were N adequate or excessive.

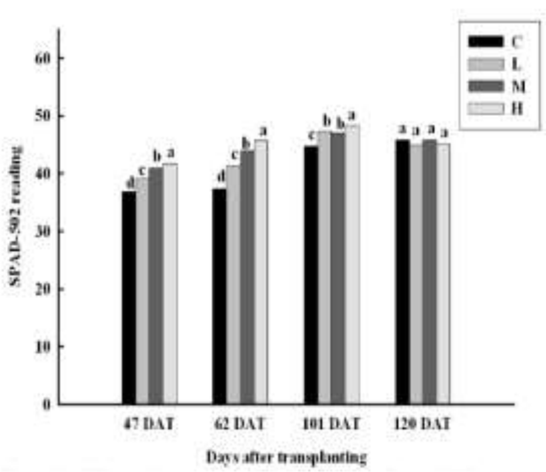

Figure 2. Effect of nitrogen level on SPAD reading at different growth stage of rice field experiment. Each vertical bar represents an average readings of 10 measured values in three replications with same N levels

Grain Yield and Yield Components of Paddy Rice

Rice grain yield and yield components were significantly different among the treatments (Table 3). The highest grain yield was observed in high level treatment (8.96 t ha^{-1}), followed by medium level treatment (8.69 t ha^{-1}), low level treatment (7.58 t ha^{-1}) and control treatment (6.36 tha^{-1}). The total grain yield is not significantly different between high level and medium level treatment which indicates the use of organic fertilizer with 100 kg N ha^{-1} could be the maximum limit for economic yield and no profitable beyond this level. This might be due to maximum uptake of ions required for plant as well as maximum genetic yield potentiality of rice variety. Zhang et al. (2009) found that chemical-N application rates above 180 kg ha^{-1} gave no significant effect on rice grain yield. For the environment and economic benefits of fertilization, it is advisable to set the optimal N application rate at 225-270 kg hm^{-2} for rice with a target yield of 7000-8100 kg hm^{-2} (Wang *et al.*, 2004). Shiga et al. (1971) and Mikoshiba et al. (1975) reported that a continuous N supply is beneficial to rice yields because of the pattern of nitrogen uptake of the high-yielding rice plant. Suzuki et al. (1990) reported the results of a 60-year experiment in Japan in which the effects of continuous application of inorganic or organic (rice straw compost) fertilizers on rice field soil fertility and rice yield were investigated. During the first 10 years the compost-treated plots had lower rice yield than the plots fertilized with inorganic. However, the grain yield in the compost-treated plots gradually recovered and after 13 years these plots generally produced higher rice yields than those treated with chemical fertilizers.

Panicle number, panicle dry weight, total grain weight and total filled grain weight was increased as the supply of N increased. The highest values were observed in high level followed by medium level, low level and the control. Panicle number in high treatment and medium treatment was significantly different but the yield was not. This was attributed by grain

Table 3. Grain yield and yield components of paddy rice as influenced by organic-N levels in field experiment[1]

Treatments	Panicle Number	Straw dry wt. g $hill^{-1}$	Panicle dry wt.	Total grain wt.	Filled grain wt.	Total biomass production	Grain Yield	Harvesting Index (H.I.)
	no. $hill^{-1}$		g $hill^{-1}$			g $hill^{-1}$	t ha^{-1}	
C	12.88d	27.47d	31.58c	30.04c	28.64c	59.05d	6.36c	0.49a
L	14.72c	35.40c	37.83b	36.46b	34.12b	73.23c	7.58b	0.46b
M	16.36b	41.70b	43.60a	41.32a	39.09a	85.29b	8.69a	0.46b
H	17.60a	46.36a	45.11a	42.93a	40.30a	91.47a	8.96a	0.44c

[1]In a column, means followed by different letters are significantly different at $p < 0.05$ probability level according to Duncan's Multiple Range Test (DMRT). Control (C): no any OF; low level (L): 2.17 t ha^{-1}; medium level (M): 4.35 t ha^{-1}; high level (H): 6.52 t ha^{-1} organic fertilizer.

Filling percentage of spikelet which was 95% and 94% in medium level and high level treatments respectively as reported previously (Chen *et al.*, 2007). Nakano and Morita (2008) noted that rice plants that received 300 kg N ha^{-1} produced 10% higher dry matter yield than those that received 150 kg N ha^{-1} due to increased number of tillers per meter square. Similarly, panicle numbers was attributed to the availability of nitrogen which is required for dry matter production through photosynthesis process. Leaf N plays an important role to activate Rubisco in chloroplast because its basic structural unit is amino acid sequences that determine the carboxylation activity of CO_2 assimilation in green plants. Strong positive correlation has been observed between leaf nitrogen and Rubisco content during senescence, contributed to increase dry weight & higher grain yield (San-oh *et al.*, 2006). Super-rice hybrids (Liangyoupeijiu and Hua-an 3) showed 20-30% higher grain yield than traditional rice hybrid (Shanyou 63) due to larger amount of active Rubisco content and higher RuBPase activity, even all had same light saturated assimilation rates (Wang *et al.,* 2006).

Fageria and Baligar (2001) reported that 1,000-grain weight was of minor importance in increasing rice yield and that panicle per unit area was the most important component accounting for 87% of the variation in grain yield. It is also reported that spikelet sterility accounted for a 7% variation in yield, and 1,000-grain weight a 3% variation in yield. Khunthasuvon et al. (1998) showed that single grain weight and proportion of unfilled grain was not affected by different N levels but number of panicles per meter square increased with N rate and had positive effect on grain yield variation. Yoshida (1981) also reported that, in general, increased panicles per unit area was the single most important component of yield associated with rice yield, with percent filled grains per panicle and total grain per panicle of secondary and tertiary importance. In this study also we have used single variety with three N levels and one control, therefore, 1,000-grain weight was not significantly different.

Harvesting index (H.I.) is associated with total dry matter production of the plant and ranged from 0.44 to 0.49 among different treatments (Table 3). The value of H.I. decreased slightly with increased rate of N application. This is because partition of photosynthates to the sink was low for high N treatment (0.44) compared to control (0.49). The result indicated that sink size was not enough for photosynthates in high level treatment. Khunthasuvon et al. (1998) found the differences in grain yield was associated with total dry matter production at maturity with harvesting index of 0.39, 0.37 and 0.34 for control, farm yard manure and chemical treatments. George et al. (2001) reported that increasing upland rice yield in Asia would require genotypes with higher H.I. (i.e., larger proportion of biomass partition to grain) in addition to phosphorus fertilization. Grain weight was significantly correlated with panicle number (r = 0.70***), dry matter production (r = 0.96***), panicle weight (r = 0.99***) as shown in Table 4. Thus, application of 4.35 t ha^{-1} organic fertilizers (based on 100 kg N ha^{-1}) would be appropriate for an economical for environment-friendly rice grain production.

Table 4. Pearson Correlation Coefficients (r) among yield and yield components of paddy rice in field experiment[1]

Variables	Plant height	Panicle number	Dry matter production	Panicle weight	Grain weight
Plant height	1.00	0.47***	0.62***	0.55***	0.52***
Panicle number		1.00	0.81***	0.76***	0.70***
Dry matter production			1.00	0.98***	0.96***
Panicle weight				1.00	0.99***
Grain weight					1.00

[1]*** Significant at $p < 0.001$ level of probability.

Lodging of Paddy Rice Plants in Field Experiment

Rice plants with high N application rate had a higher lodging score, followed by medium and low level treatments at harvest and there was no lodging in control treatment (Table 5). Nakano and Morita (2008) observed that plants that received 300 kg N ha^{-1} had a higher lodging score (2.8) than that received 150 kg N ha^{-1} (1.8) at booting stage. Thus, fertilizer application is the major factor that not only determines grain yield but also tiller number and plant height, consequently, excess N fertilizer could cause lodging and yield loss. Therefore, balance between benefit of fertilizer application and lodging loss is very important for increasing grain yield. Kashiwagi et al. (2010) found that combination of lodging resistance locus (*prl5*) and fertilizer application is a useful way to improve grain yield, biomass and forage quality without higher risks of lodging in rice. Fertilizer application reduces lodging resistance by highly elevating the center of gravity, but that *prl5* can counteract this effect by enhancing the physical strength of the lower parts through delaying leaf senescence and increasing non-structural carbohydrate re-accumulation in culms without any effect of fertilizer rates. Setter et al. (1997) reported that lodging reduced canopy photosynthesis by 60–80%, and every 2% of lodging caused a decrease of 1% in grain yield. Yoshida (1981) reported that heavy application of N lead to greater losses of rice due to lodging.

Table 5. Effect of organic-N levels on lodging scores of paddy rice in field experiment[1]

Treatments	Lodging scores (0-5)[a]
C	0.00c
L	0.40c
M	1.87b
H	2.57a

[1]In a column, means followed by different letters are significantly different at $p < 0.05$ probability level according to Duncan's Multiple Range Test (DMRT). Control (C): no any OF; low level (L): 2.17 t ha^{-1}; medium level (M): 4.35 t ha^{-1}; high level (H): 6.52 t ha^{-1} organic fertilizer; (0-5)[a]: lodging scores ranges from 0 (no lodging) to 5 (serious lodging).

Conclusion

Nitrogen is one of the most important essential nutrients for growth and development of rice plants. In this study, we studied whether the organic-N levels can affect photosynthetic oxygen rate, SPAD reading, total N content, productive tillers and yield components of rice in field level experiments. The cumulative evidences from this study have shown potential for effective use of organic fertilizer to improve photosynthesis and eventually yield components, and sustain environmentally healthy soil and crop system as well. Under field experiment, SPAD reading was significantly different among the treatments at different growth stages. The average SPAD reading among the treatments on 47 DAT was lower than that of 101 DAT. The result showed that SPAD reading became more and more sensitive to nitrogen rates due to accumulation of chlorophyll with advancing growth of plants. Therefore, it can be used to monitor the N status of paddy rice and thereby to adjust the rate of N fertilization in order to increase N use efficiency. Similarly, panicle number and total biomass production per hill were found to differ significantly among the treatments. Filled grain weight was not significantly different between medium and high level treatment that eventually affected on total yield of crop. Plants of medium level produced greater grain yield than control and lower level tratments, but was similar to high level treatment. Partition rate of dry matter to the sink was low for high N treatment (H.I. = 0.44) compares to control (H.I. = 0.49) which indicated that sink (panicle) size is not so enough capacity for storage of photosynthates in high level treatment.

In Nepal, where chemical fertilizer is expensive and shortage during growing season of rice crops, the use of organic fertilizer would be recommended as an appropriate practice that restores sustainable soil fertility and productivity while protecting the environment over the long term and reducing the cost of production. Organic fertilizer could be as effective as chemical fertilizer, provided the manure contained high nutrient content. While applying organic fertilizer, it should be based on nutrient content (100 kg N ha^{-1}) rather than volume basis in order to optimize the sink-source relationship for maximum partitioning of dry matter during ripening stage. Besides, in the degraded upland areas, organic application could protect the soil against erosion and increase its water holding capacity and plants nutrients source to increase rice yield. In the irrigated area, the use of organic fertilizer could reduce soil acidity, increase soil fertility potential, and probably reduce the cost of fertilizers while increasing paddy rice yield. More investigation on split applications of chemical nitrogen is necessary to understand its long lasting effect on photosynthesis activity and yield components because rice yield is better correlated with leaf nitrogen concentration at ripening stage than at flowering stage.

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