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Effects of Need-Based Nitrogen Management and Varieties on Growth and Yield of Dry Direct Seeded Rice

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ABSTRACT

Proper application of nitrogen fertilizer is vital to improve crop growth and development. A field experiment was conducted to evaluate the need based nitrogen management using leaf color chart (LCC) on crop growth and yield of dry direct seeded rice (DDSR) with five nitrogen management practices {0 kg N ha^{-1}, 120 kg N ha^{-1} in three equal split applications, 30 kg N ha^{-1} as basal + 30 kg N ha^{-1} top dressing based on LCC critical value four, 30 kg N ha^{-1} top dressing (without basal N dose) at 15 days after sowing (DAS) + LCC based N application and pure LCC (without basal N dose) based N application} tested on three rice varieties (Radha-4, US-312 and Sukhkhadhan-5) in split plot design. The results revealed that the highest grain yield was observed in hybrid US-312 (4,695 kg ha^{-1}) with higher plant height, leaf area index (LAI) and dry matter production than the inbred varieties i.e. Radha-4 and Sukhkhadhan-5. All the nitrogen management treatments including LCC were similar to each other in respect of grain yield formation (4,695-4,891 kg ha^{-1}), but remained significantly superior over three split applications (4,408 kg ha^{-1}). Likewise, values of growth parameters were higher in LCC based treatments than the recommended practice and grain yield being the highest in pure LCC (4,891 kg ha^{-1}). Thus, pure LCC based nitrogen management found to be the best practice for both inbred and hybrid rice varieties.

Keywords: Crop growth, direct seeded rice, leaf color chart, yield

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most popular cereal crops in the world. It is the principal food for one third of the world's population. More than 90% of this rice is produced and consumed in Asia (Pathak et al., 2011). It provides some 700 calories per person, mostly residing in developing countries (Tari et al., 2009). Recently released statistics from the United States Department of Agriculture (USDA) (2018) reveal that total global rice production is 486.78 million mt from the area 160.82 million ha with average productivity of 4.52 mt ha^{-1} during 2016/17.

Puddled rice transplanting is the burdensome and time consuming crop establishment method with more labor and water requirement which are becoming scarce too. It destroys the soil physical properties by dismantling the soil aggregates and ultimately affects the growth and productivity of succeeding wheat crop (Bhurer et al., 2013). Due to climate change there may be the risks of early season drought and farmers are compelled for delayed transplanting by 1-3 weeks (Ladha et al., 2000; Pathak et al., 2011). Similarly, the methane emission is higher in flooded rice fields than in the non-flooded rice fields (Kakumanu et al., 2011). Therefore, DSR may be one of the best options to cope with the climate change.

Nitrogen is one of the most yield limiting nutrients in crop production in all agro-ecological regions of the world (Fageria & Baligar, 2005; Yoshida, 1981). Nitrogen management is considered as one of the most challenging parts of the direct seeded rice to achieve higher grain yield and nitrogen use efficiency (Ali et al., 2012). Shukla et al. (2004) stated that due to lack of synchronization between the nitrogen demand and nitrogen supply more than 60% of applied nitrogen was lost. Farmers generally apply nitrogen fertilizer in fixed time split doses without considering the plant's need for nitrogen at that time (Ladha et al., 2000). This does not consider the dynamic crop nitrogen requirement and soil nitrogen supply because recommendations are mainly derived from empirical testing of nitrogen response to few fixed doses (Cassman et al., 1998; Shukla et al., 2004). Therefore, it requires different amounts of nitrogen in different fields, depending on native nitrogen supply and crop demand.

The optimum use of nitrogen can be achieved by matching its supply with the crop demand. Synchronization of nitrogen fertilizer application with the crop demand following need-based nitrogen management is another approach for higher yields, reduced nitrogen losses and improved nitrogen use efficiency (Thind & Gupta, 2010). Need based nitrogen management include periodic assessment of nitrogen status in standing crop following its application according to the need of the crop (Witt et al., 2004). For this, chlorophyll meter or leaf color chart (LCC) can be used to assess the actual plant nitrogen status (Balasubramanian et al., 2003; Singh et al., 2002). Leaf color chart consists of panels (generally 4 or 6) that range from yellow-green to dark green sequentially starting from no 1 as yellow-green. It was jointly developed by the International Rice Research Institute (IRRI) and the Philippine

Rice Research Institute (PhilRice) from a Japanese prototype in late 1990s (Shukla et al., 2004). LCC provides the guideline for effective nitrogen management by giving the idea of when and how much nitrogen fertilizer to apply for maintaining and optimizing nitrogen status in rice plants (Sathiya & Ramesh, 2009).

Considering these facts, this experiment was conducted to evaluate growth and yield of dry direct seeded rice under LCC based nitrogen management.

MATERIALS AND METHODS

Study Site

A field experiment was conducted at Agronomy research block of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal (27^o 37’ North latitude and 84^o 25’ East longitudes) from June to October 2014. The experimental soil was sandy loam having following characteristics in the top 20 cm profile; clay 5.1%, silt 22.8%, sand 72.1% and pH 5.4. Similarly, the soil had 3.18% soil organic matter, 0.16 % total N, 41.45 kg ha^{-1} available P and 98.40 kg ha^{-1} available K which were under the medium category based on rating chart (Jaishy, 2000).

Experimental Design. The experiment was arranged in Split plot design with four replications. There were 15 treatments including three rice varieties (Radha-4, US-312 and Sukhkhadhan-5) as main plot factor and five nitrogen management practices as sub plot factor (Treatments detail in Table 1). Among the three rice varieties, Radha-4 and Sukhkhadhan-5 are the Nepalese high yielding inbred varieties whereas US-312 is Indian hybrid rice registered for cultivation in Nepal. Both Radha-4 and Sukkhadhan-5 (drought tolerant) varieties were originated from International Rice Research Institute (IRRI), Philippines with their designations IR8423-156-2-2-1 (Khush & Virk, 2005) and IR 83388-B-B-B-108-3 (Khanal et al., 2017) respectively. These varieties were purposively selected as they were commonly grown by the farmers in the region. Rice seeds were sown continuously in line at the seed rate of 40 kg ha^{-1} with row spacing of 20 cm under dry condition. Individual plot size was 10.5 m^2.

Observations

Biometrical observations on plant height, leaf area index (LAI), above ground dry matter production were measured and recorded starting from 15 DAS to 90 DAS at 15 days interval. The leaf area was measured by digital leaf area meter (LiCor-3100). Then, leaf area index was calculated by following formula (Lan et al., 2009):

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area (cm}^2)}{\text{Crop geometry (cm}^2)}$$

In LCC based treatments, nitrogen was applied through urea based on average LCC readings taken from 21 days after sowing (DAS) to heading at every 10 days interval. In each reading, the plots with average LCC reading (taken from 10 randomly selected upper healthy leaves) below the critical value i.e. 4, received nitrogen at the rate of 30 kg ha^{-1} through urea topdressing (Devkota et al., 2013). In pure LCC treatment, nitrogen was applied only based on the LCC readings without its basal application. The six-panel leaf color chart (Nitrogen Parameters, Chennai, India) was used for this experiment. For the above ground dry matter, destructive sampling was done following oven drying at temperature of 70^{o}C for 72 hours until the constant weight. Likewise, grain and straw yields were calculated in kg ha^{-1}. The grain yield adjusted at 14% moisture level and harvest index (HI) were calculated by the following formula as described by Shahiddullah et al. (2009) and Ismail (1993) respectively:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Plot yield (kg)* (100 – grain moisture content \%)* 10000 m}^2}{\text{(100-14)* net plot area (m}^2\text{)}}$$

$$\text{Harvest index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}}$$

Data Analysis

The data were statistically analyzed with GEN-STAT statistical software programs. Analysis of variance (ANOVA) was done on every measured parameter to determine the significance of differences between means of treatments. Means for each parameter were separated by the Duncan's multiple

Table 1
Details of treatment used in the experiment

Treatment combinations	Treatment details
T_1	Radha-4 + N_0 (control)
T_2	Radha-4 + N_{120} (in three equal splits at basal, AT and PI)
T_3	Radha-4 + N_{30} (basal) + LCC at cv. 4 @30 kg ha^{-1} N
T_4	Radha-4 + N_{30} (15 DAS) + LCC at cv. 4 @30 kg ha^{-1} N
T_5	Radha-4 + N_0 (basal) + LCC at cv. 4 @30 kg ha^{-1} N
T_6	US-312 + N_0 (control)
T_7	US-312 + N_{120} (in three equal splits at basal, AT and PI)
T_8	US-312 + N_{30} (basal) + LCC at cv. 4 @30 kg ha^{-1} N
T_9	US-312 + N_{30} (15 DAS) + LCC at cv. 4 @30 kg ha^{-1} N
T_{10}	US-312 + N_0 (basal) + LCC at cv. 4 @30 kg ha^{-1} N
T_{11}	Sukhkhadhan-5 + N_0 (control)
T_{12}	Sukhkhadhan-5 + N_{120} (in three equal splits at basal, AT and PI)
T_{13}	Sukhkhadhan-5 + N_{30} (basal) + LCC at cv. 4 @30 kg ha^{-1} N
T_{14}	Sukhkhadhan-5 + N_{30} (15 DAS) + LCC at cv. 4 @30 kg ha^{-1} N
T_{15}	Sukhkhadhan-5 + N_0 (basal) + LCC at cv. 4 @30 N kg ha^{-1} N

Note: DAS = days after sowing, LCC = leaf color chart, AT = active tillering, PI = panicle initiation, cv = critical value, N_0 = control i.e. no nitrogen applied, N_{30} (basal) = N application @30 kg ha^{-1} at the time of transplanting, N_{30} (15 DAS) = N topdressing @30 kg ha^{-1} at 15 DAS, N_{120} = N application @120 kg ha^{-1} in three equal splits range test (DMRT) at $P \leq 0.05$. Similarly, correlation-regression analysis was carried out to assess the relationship of grain yield with yield attributing characters and growth parameters.

RESULTS AND DISCUSSION

Growth Parameters

Effect of Varieties. The experimental results revealed that plant heights, leaf area index and dry matter production were found significantly influenced by the varieties. Significantly different plant heights were observed at 30 DAS and 75 DAS only (Table 2). The tallest variety was US-312 (77.95 cm) which was found statistically at par with Radha-4 (74.27 cm) whereas the lowest plant height was found in Sukhkhadhan-5 (70.19 cm) at 75 DAS. Regarding LAI, variety US-312 had significantly higher LAI as compared to Radha-4 and Sukhkhadhan-5 at 30, 60, 75 and 90 DAS (Table 3). The LAI of Radha-4 and Sukhkhadhan-5 did not differ significantly with each other. Similarly, significantly higher dry matter production of US-312 than other varieties was observed at 45 and 75 DAS only while it remained non-significantly higher than other varieties at 30, 60 and 90 DAS (Table 4). Varieties produced different plant heights based on their varietal characters and also different growth parameters. Sucharitha and Boopathi (2001) found notable superiority of hybrid over inbred varieties in terms of growth parameters and yield attributes. Similarly, variable plant heights among the rice varieties were observed (Hossain et al., 2008). Yamauchi (1994) reported that hybrid varieties had a vigorous growth rate during early vegetative stages due to rapid expansion of leaf area resulting higher dry matter production. Higher values of LAI in hybrid varieties than in inbred were also observed by Salem et al. (2011).

Effect of N Management Practices. Different N management practices had significant influence on plant height, LAI and dry matter production at all growth stages of the crop. In general, LCC based treatments showed greater plant heights as compared to the recommended practice of three split applications and control at 30, 60 and 75 DAS (Table 2). During the rapid growth at 75 DAS, LCC based treatments showed significantly higher plant heights as compared to recommended practice and control. Regarding the LAI, pure LCC resulted significantly higher LAI than recommended practice at all the dates of observation except at 30 DAS (Table 3). All the LCC based treatments were at par with each other all the dates of observations except in 30 DAS. In case of dry matter production, all the treatments receiving nitrogen fertilizer had significantly higher dry matter production than the control treatment (Table 4). More interestingly, LCC based N management produced higher dry matter than recommended practice at all the dates of observation. However, it was non- significant. The highest LAI (4.51) and dry matter production (596.1 g m^{-2}) were observed in pure LCC based treatment.

LCC based N management supplied the nitrogen according to the crop needs whereas in recommended practice N was applied at fixed time regardless the crop's need that promoted the higher N losses. Application of nitrogen in split according to the crop needs is the reason for better rice growth parameters (Sathiya & Ramesh, 2009). The reason behind higher LAI in LCC based treatments was the maintenance of nitrogen concentration at balance which enhanced the process of cell division and elongation and ultimately increased the leaf number and leaf area (Om et al., 1989). Brady (1999) reported that plant growth and development were influenced through several biochemical and physiological processes as affected by nitrogen application. Similarly, nitrogen fertilizer helps to increase the rate of leaf expansion leading to increased interception of solar radiation by the crop canopy (Squire et al., 1987). The decline in LAI after 75 DAS was mainly due to the senescence of lower leaves. Decrease of leaf area (due to senescence of early formed leaves) after initiation of panicle was associated with

Table 2
Effect of varieties and nitrogen management practices on plant height of dry direct seeded rice

Treatments	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Varieties					
Radha-4	34.44[b]	45.99	57.05	74.27[ab]	96.05
US-312	37.33[a]	47.96	61.72	77.95[a]	94.13
Sukhkhadhan-5	32.61[b]	45.19	54.92	70.19[b]	92.56
Nitrogen management					
N_0	31.43[c]	40.89[d]	51.29[c]	67.18[c]	83.18[b]
N_{120}	31.94[c]	50.46[a]	57.43[b]	72.38[b]	96.69[a]
N_{30} (basal) + LCC	38.25[a]	46.66[bc]	61.13[a]	76.45[a]	98.44[a]
N_{30} (15DAS) + LCC	34.86[b]	48.73[ab]	59.02[ab]	77.96[a]	96.11[a]
Pure LCC	37.49[a]	45.15[c]	60.61[a]	76.71[a]	96.81[a]
CV, %	5.47	5.93	4.57	5.21	4.33
Grand mean	34.79	46.37	57.89	74.13	94.24

Note: Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan's multiple range test

Table 3
Effect of varieties and nitrogen management practices on leaf area index of dry direct seeded rice

Treatments	LAI				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Varieties					
Radha-4	0.55[b]	1.42	2.26[b]	3.62[b]	2.64[b]
US-312	0.71[a]	1.87	2.99[a]	4.51[a]	3.70[a]
Sukhkhadhan-5	0.49[b]	1.44	2.21[b]	3.32[b]	2.77[b]

Table 3 (*continue*)

Treatments	LAI				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Nitrogen management					
N_0	0.36^c	0.91^c	1.26^c	2.28^c	1.57^c
N_{120}	0.52^b	1.49^b	2.37^b	3.65^b	2.94^b
N_{30} (basal) + LCC	0.82^a	1.81^a	2.74^{ab}	4.36^a	3.43^{ab}
N_{30} (15DAS) + LCC	0.63^b	1.85^a	3.03^a	4.30^{ab}	3.52^{ab}
Pure LCC	0.59^b	1.83^a	3.04^a	4.51^a	3.72^a
CV, %	31.20	23.70	26.60	21.00	22.70
Grand mean	0.59	1.58	2.49	3.82	3.04

Note: Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan's multiple range test

Table 4
Effect of varieties and nitrogen management practices on dry matter production of dry direct seeded rice

Treatments	Dry matter production (g m^{-2})				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Varieties					
Radha-4	91.35	137.30^b	256.70	505.30^b	617.40
US-312	103.61	188.40^a	297.10	582.30^a	725.00
Sukhkhadhan-5	89.91	131.10^b	274.50	497.00^b	700.00
Nitrogen management					
N_0	65.88^c	96.90^c	158.60^c	332.30^b	387.90^b
N_{120}	88.32^b	149.70^b	278.20^b	562.70^a	710.00^a
N_{30} (basal) + LCC	108.03^a	175.70^a	297.80^{ab}	576.50^a	760.00^a
N_{30} (15DAS) + LCC	104.64^a	167.70^{ab}	314.70^{ab}	573.50^a	764.30^a
Pure LCC	107.91^a	171.30^a	331.30^a	596.10^a	781.80^a
CV, %	16.40	14.50	19.60	19.30	15.40
Grand mean	95.00	152.20	276.10	528.00	681.00

Note: Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan's multiple range test

the remobilization of stored metabolites from leaf sheath and stem to panicles (Chandrasekhar et al., 2001). Adhikari et al. (1999) stated the inefficient use of applied N in broad based blanket recommendation. This might be the reason for higher dry matter production in LCC based N application then in fixed time split application.

Grain Yield, Yield Attributes and Harvest Index

Effect of Varieties. Varieties as well as N management practices had significant effect on grain yield, yield attributes and HI (Tables 5 and 6). Among the varieties, hybrid US-312 gave significantly higher grain yield (4,695.23 kg ha^{-1}) than Radha-4 (4,089.39

kg ha^{-1}) and Sukhkhadhan-5 (4,315.43 kg ha^{-1}). The grain yields of Sukhkhadhan-5 and Radha-4 remained statistically similar with each other. Higher grain yield in US-312 was attributed to vigorous crop growth with significantly higher LAI (Table 3) and more dry matter production (Table 4) than Radha-4 and Sukhkhadhan-5. The variety Radha-4 was found significantly superior over hybrid US-312 and Sukhkhadhan-5 for panicle weight, thousand grains weight and sterility percentage (Table 6). However, panicle length and grains per panicle were significantly higher in hybrid US-312 (24.24 cm and 95.51 respectively) as compared to Radha-4 and Sukhkhadhan-5 that ultimately contributed for higher grain yield. Hybrid rice varieties have higher heterosis for grains per panicle than the improved rice varieties resulting higher grain yields (Salgotra et al., 2002). Hosain et al. (2014) reported higher yield of hybrid was ascribed due to more panicle length (3.4 %) and more spikelets per panicle (9.8 %) as compared to inbred variety. Regarding the harvest index, Sukhkhadhan-5 had significantly higher HI (0.48) as compared to Radha-4 (0.43) and US-312 (0.45). Similarly, HI of US-312 (hybrid) was statistically greater than Radha-4. The highest HI in Sukhkhadhan-5 might be attributed to its lowest straw yield (4987.12 kg ha^{-1}) in relation to its grain yield (4315.43 kg ha^{-1}). Higher grain yield and HI of hybrids than that of inbreed varieties were also reported by Yang et al. (2007).

Effect of N Management Practices. The highest grain yield (4891.23 kg ha^{-1}) was obtained in pure-LCC treatment (Table 5). In case of yield attributes, all LCC based treatments were found insignificantly different from recommended practice in effective tillers per m^2, thousand grain weight and sterility percentage (Table 7). But grains per panicle remained significantly higher in LCC based treatments as compared to the recommended practice. All the LCC based treatments had statistically similar grain yields with each other but statistically higher than recommended practice and control. The lowest grain yield (3,094.15 kg ha^{-1}) was observed in control. Grain yield in LCC based treatments ranged from 4,695.21 to 4,891.23 kg ha^{-1} whereas it was only 4408.06 kg ha^{-1} ha in recommended practice. Higher recovery efficiency of nitrogen in LCC based treatments contributed to increase in chlorophyll concentration in leaves which led to higher photosynthetic rate and ultimately plenty of photosynthates available during grain development (Manzoor et al., 2006). Straw production followed the trend as that of grain yield being the highest in pure LCC and the lowest in control treatment. Regarding the harvest index, all the nitrogen management practices including control had non-significant influence on HI. Non-significant influence on HI when applying nitrogen from 0 to 400 kg ha^{-1} in upland rice was also observed by Fageria et al. (2011).

Significantly higher grain yield in LCC based treatments was attributed to optimization of N supply and more efficient utilization by the crop which ultimately maintained higher LAI (Table

3) and higher dry matter production (Table 4). In recommended practice, fixed rate of nitrogen was applied in the fixed time irrespective to the crop demand which leads to loss of applied nitrogen through various processes occurring in the soil. Therefore, less efficient N utilization caused lower grain yield in recommended practice of fixed time three equal splits.

In an experiment, comparable or even higher grain yield was observed in LCC based nitrogen application with basal application of 30 kg ha^{-1} N and critical value 4 receiving 30 kg ha^{-1} N than in recommended practice (Singh et al., 2010). Similar results were also reported by Jayanthi et al. (2007). Similarly, grain yield increment of 400 kg ha^{-1} in Aman and 600

Table 5
Effect of varieties and nitrogen management practices on grain yield, straw yield and harvest index of dry direct seeded rice

Treatments	Parameters		
	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (HI)
Varieties			
Radha-4	4089.39^{b}	6619.35^{a}	0.43^{c}
US-312	4695.23^{a}	6631.03^{a}	0.45^{b}
Sukhkhadhan-5	4315.43^{b}	4987.12^{b}	0.48^{a}
Nitrogen management			
N_0	3094.15^{c}	3982.23^{c}	0.45
N_{120}	4408.06^{b}	6216.11^{b}	0.45
N_{30} (basal) + LCC	4695.21^{a}	6352.04^{b}	0.45
N_{30} (15DAS) + LCC	4746.08^{a}	6923.50^{a}	0.45
Pure LCC	4891.23^{a}	6924.21^{a}	0.46
CV, %	7.80	9.52	2.40
Grand mean	4367.35	6079.14	0.4533

Note: Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan's multiple range test

Table 6
Effect of varieties and nitrogen management practices on yield attributing characters of dry direct seeded rice

Treatments	Yield attributing characters					
	ET m^{-2}	Sterility (%)	TGW (g)	Panicle length (cm)	Panicle weight (g)	Grains per panicle
Varieties						
Radha-4	322.40	13.42^{a}	23.38^{a}	20.89^{b}	2.03^{a}	77.94^{b}
US-312	321.10	10.36^{b}	18.12^{c}	24.24^{a}	1.83^{b}	95.51^{a}
Sukhkhadhan-5	319.70	9.72^{c}	22.35^{b}	20.60^{b}	1.77^{b}	76.01^{b}
Nitrogen management						
N_0	248.3^{b}	14.42^{a}	20.00^{b}	19.72^{c}	1.38^{c}	62.33^{c}

Table 6 *(continue)*

Treatments	Yield attributing characters					
	ET m^{-2}	Sterility (%)	TGW (g)	Panicle length (cm)	Panicle weight (g)	Grains per panicle
Nitrogen management						
N_{120}	337.6^{a}	10.67^{b}	21.46^{a}	21.98^{b}	1.85^{b}	81.81^{b}
N_{30} (basal) + LCC	335.6^{a}	9.84^{b}	21.69^{a}	22.74^{a}	2.13^{a}	89.43^{a}
N_{30} (15DAS) +LCC	337.3^{a}	10.52^{b}	21.29^{a}	22.43^{ab}	1.99^{ab}	90.26^{a}
Pure LCC	346.4^{a}	10.38^{b}	21.97^{a}	22.68^{ab}	2.04^{a}	91.96^{a}
CV, %	10.27	9.40	3.70	3.70	9.50	9.30
Grand mean	321.03	11.17	21.28	21.91	1.88	83.20

Note: Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan's multiple range test, ET = effective tillers, TGW = thousand grain weight

kg ha^{-1} in Boro rice were observed with LCC based nitrogen management over the recommended practice (Alam et al., 2005). Fixed time LCC based N application (120 kg ha^{-1}) produced significantly higher grain yield (4,940 kg ha^{-1}) than 120 kg ha^{-1} (4,170 kg ha^{-1}) applied in three equal splits in direct seeded Boro rice (Islam & Rahman, 2003).

Interaction between Varieties and Nitrogen Management

There was non-significant effect of interaction between rice varieties and nitrogen management practices on plant height, leaf area index, dry matter production), yield attributes, grain yield and harvest index. In case of grain yield, there was a quantitative difference among treatments. In all nitrogen management practice, the highest grain yield was observed in US-312. But among the varieties, US-312 and Radha-4 produced the maximum grain yield in Pure LCC treatment and Sukhkhadhan-5 produced the maximum in N_{30} (basal) + LCC treatment (Table 7).

Table 7
Interaction effect of varieties and nitrogen management on grain yield (kg ha^{-1}) of dry direct seeded rice

Treatments	Varieties		
	Radha-4	US-312	Sukkhadhan-5
N_0	3054.18	3358.71	2869.55
N_{120}	4032.69	4710.48	4480.51
N_{30} (basal) + LCC	4208.75	5058.67	4816.22
N_{30} (15DAS) + LCC	4433.79	5061.84	4741.51
Pure LCC	4717.52	5286.83	4668.70
LSD (0.05)		ns	
SEm (±)		179.70	
Grand mean		4367.35	

Note: 'ns' means non-significant

Regarding the correlation, yield attributing characters like panicle length, grains per panicle and effective tillers per meter square were found highly correlated with grain yield (i.e. highly significant). Similarly, same trend was observed in case of leaf area index at 75 DAS and dry matter production at 90 DAS. But, harvest index remained non-significantly correlated with grain yield (Table 8).

Table 8
Regression equation and correlation coefficient between different parameters and yield of dry direct seeded rice

Linear regressions	Equations (Y = a + bx)	'r' value
Yield (kg ha^{-1}) against LAI at 75 DAS	Y = 483.53x + 2520.306	0.739**
Yield (kg ha^{-1}) against dry matter (gm^{-2}) at 90 DAS	Y = 3.209x + 2182.115	0.755**
Yield (kg ha^{-1}) against grains per panicle	Y = 34.402x + 1505.9	0.708**
Yield (kg ha^{-1}) against panicle length	Y = 240.2x - 895.93	0.666**
Yield (kg ha^{-1}) against effective tillers per m^2	Y = 11.244x + 757.08	0.705**
Yield (kg ha^{-1}) against HI	Y = 4143.57x + 2488.524	0.129^{ns}

**means significant at 0.01 level of significance, 'ns' means non-significant

CONCLUSION

Better performance was observed in LCC based practices in terms of growth and yield parameters than in the recommended practice on nitrogen management in rice. Pure LCC based nitrogen management was the most efficient practice for both inbred and hybrid varieties of rice.

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