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Response of need based nitrogen application on growth and yield of rice (*Oryza sativa* L.) in irrigated transplanted condition in North India

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Abstract
Leaf colour chart (LCC) is an easy to use and inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the plant N status. We conducted an experiment at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (India), during 2010-11 and 2011-12 to compare plant growth and yield of three different rice cultivars (PA-6444, PHB-71 and NDR-359) by applying N based on leaf colour chart. Among these varieties, PA-6444 recorded tallest plant (115.32 cm), highest number of shoot (374 m^{-2}) and highest dry matter (1090 g m^{-2}) at the time of harvest. PA-6444 recorded significantly highest number of panicle (307.62 m^{-2}) over PHB-71 (291.17 m^{-2}) and NDR-359 (275.38 m^{-2}). Although, panicle length (28.80 cm) and number of grain per panicle (229.97) was recorded significantly higher in NDR-359, over both the remaining cultivars. Among rice cultivars significantly maximum grain yield (59.21 q ha^{-1}), and biological yield (140.10 q ha^{-1}) recorded by PA-6444. Among LCC scores, LCC<5+25%N as basal through urea, recorded highest grain and biological yield 62.80, and 148.59 q ha^{-1} respectively and was significantly higher over rest of the LCC scores except LCC<5+25%N as basal through FYM. From this experiment it has been concluded that LCC<5+25% N as basal through FYM with cultivars PA-6444 can be used as a low cost technology for maximum production per unit area.

Keywords: FYM, Leaf Colour Chart, Nitrogen, Rice

Introduction
Rice (*Oryza sativa* L.), is the principal cereal crop of Asia and is the second largest cereal and staple food of nearly one-half of the world's population. Our national food security system largely depends on the production and productivity of rice. India is the second largest producer of rice only after China and its production in India has increased from 20 million tonnes during 1950-51 to 106.4 million tonnes during 2013-2014 (Anonymous, 2014) [2]. Rice occupies a pivotal place in Indian agriculture and is the staple food for more than 70% of population and a source of livelihood for about 120-150 million rural households. Among the various strategies proposed to increase rice productivity, nitrogen management is of great importance. Nitrogen (N) is the nutrient that most often limits crop production (Shukla *et al*. 2004) [21] and the cost of mineral nitrogen fertilizer accounts for a major portion of the total cost of rice production (Padre *et al*. 1996) [14]. Even when nitrogen supply is satisfactory, importance of increasing use efficiency can't be underestimated. The N use efficiency varies with yield potential of the varieties and the growth environment (Ladha *et al*. 1998) [13] but is largely determined by the extent of N losses via NH_3 volatilization, denitrification and leaching. Fertilizer N losses are estimated to range from 10-65% of the applied N (Cassman *et al*. 1998; Singh and Singh 2003b) [6, 23]. In many field situations, more than 60% of applied N is lost because of the lack of synchrony of plant demand with N supply (Singh and Singh 2003) [25]. Therefore, its management strategies must be developed such that it should be responsive to temporal variations in crop N demand and soil N supply in order to achieve supply-demand synchrony for minimizing nitrogen losses. Different varieties may have varying responses to N depending on their agronomical characteristics. Peng and Cassman (1998) [15] demonstrated that RE (Recovery efficiency) of top dressed urea during panicle initiation stage could be as high as 78%. Hence, plant need-based N application is important for achieving high yield and high N use efficiency. Since, farmers have always used leaf colour as a visual and subjective indicator of the need for N fertilization (Wells and Turner 1984; Furuya, 1987) [24, 7] and generally prefer to keep leaves dark green, that leads to over application of N fertilizers, resulting low nitrogen use efficiency.

Hence, indirect measurement of N content through greenness by leaf color chart (LCC) provides a simple, quick, and non-destructive methods for estimating N content of rice leaves and, thus, for determining the right time of N top dressing (Yang *et al*. 2003) [25]. LCC is an easy to use and inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the plant N status, which is important in improving the balance between crop N demand and N supply from soil and applied fertilizer (Shiga *et al*. 1977; Cassman *et al*. 1994) [20, 5]. However, critical LCC values vary considerably among different rice genotypes having different genetic background, plant type and leaf colour Balasubramanian *et al*. (2003) [3], because leaf N status of rice is closely related to photosynthetic rate (Peng *et al*. 1995a) [16] and biomass production, (Kropff *et al*. 1993) [12]. The purpose of using LCC is to apply adequate amount of nitrogen and avoid application of fertilizer more than required. Keeping above in view, this study was undertaken to find out the response of LCC based N application on growth and yield of different rice cultivars.

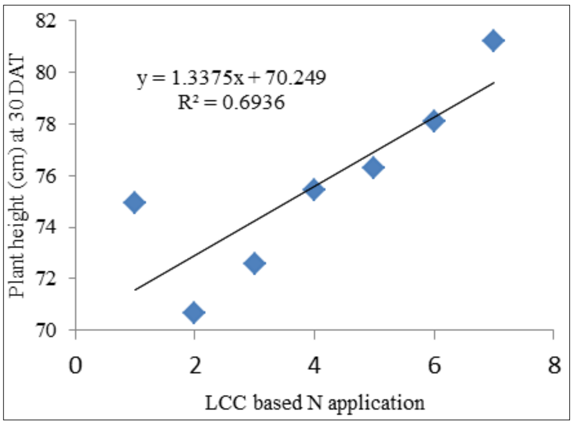
Materials and Methods

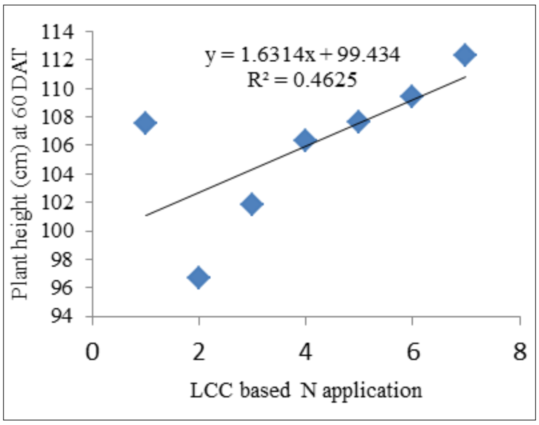
The field experiment was conducted during two consecutive *kharif* seasons of 2010-11 and 2011-12 at C.S. Azad University of Agriculture and Technology, Kanpur, situated (26°23'35''N latitude, 80°18′25''E longitude and at an altitude of 125.90 m above mean sea level) in the Central Plain Zone of Uttar Pradesh, India. The climate of Kanpur is semi-arid, sub-tropical with dry hot summer and cold winter. The average annual rainfall is 893 mm, major part of which is received during the later part of June to mid-September. The experimental soil was sandy clay loam in texture having medium organic carbon and low in available nitrogen (215 kg ha^{-1}), medium in available phosphorus (20.5 kg ha^{-1}), and medium in available potassium (201 kg ha^{-1}), and neutral in reaction (pH 7.1). The experiment was laid out in a split plot design with three replications. Three rice genotypes, PA-6444 (semi tall, medium duration variety, developed in 2001 by Bayer Bio-Science and released by Central Variety Release Committee (CVRC) with a yield potential of 6-8 t ha^{-1}), PHB-71 (tall, medium duration 130-135 days duration variety) NDR-359 (a medium duration high yielding variety released from NDUAT, Faizabad with a yield potential of 4-5 t ha^{-1}), were grown in the main plots while, the six N management treatments (with the help of LCC <3, <4 and <5 in combination with 25% N as basal through FYM and Urea with every LCC score) were allotted to sub-plots and were compared with fixed time recommended N rate of 150 kg ha^{-1}. In the recommended N dose treatment, nitrogen was applied in 1:2:1 ratio at the time of sowing, maximum tillering and panicle initiation stage respectively. Phosphorous and potassium @ 60 kg ha^{-1} 40 kg ha^{-1} and Zn @ 5 kg ha^{-1} were applied to all the plots as basal. The experimental field was prepared by one deep ploughing followed by two cross harrowing and levelling. After preparing the field 25 days old seedlings were transplanted at a spacing of 20×15 cm with 2 seedlings, per hill of PA-6444 and PHB-71 while, 3-4 seedling of NDR-359. After the establishment of seedlings a constant water level of 5±2 cm was maintained during the entire crop growth period till early dough stage. For the management of weeds two hand weeding were done at 25 and 45 days after transplanting (DAT). The crop was harvested manually at maturity. The data was statistically analysed with the help of analysis of variance (ANOVA) technique as suggested by Gomez and Gomez (1984) [8]. The results are presented at 5% level of significance (P=0.05) for making comparison between treatments.

Results & Discussion

Growth

Growth of rice plant is measured vertically in term of plant height and horizontally in terms of shoot numbers and dry matter production. Among rice cultivars, PA-6444 recorded significantly tallest plant (Table1) over NDR-359 at all the crop growth stages and over PHB-71 at 30 and 90 DAT and at harvest. It may be due to vigorous nature of PA-6444 which is highly responsive to the need based N application. Shoot numbers m^{-2} (Table 1) increased with the advancement of crop growth stages up 90 DAT and after that started to decline in all the rice cultivars during both the years of experimentation. Reduction in tiller numbers was basically due to mortality of shoots after 90 DAT. Among rice cultivars, PA-6444 recorded significantly higher shoot numbers m^{-2} (481.45, 683.49, 831.48 and 373.75 at 30, 60, 90 DAT and at harvest respectively, over NDR-359 and was statistically at par with PHB-71 at all the respective growth stages. It might be due to hybrid rice cultivars which have profuse tillering capacity. Angadi *et al*. (2002) [1] also reported different LCC threshold scores suitable for different direct dry-seeded rainfed lowland rice cultivars.





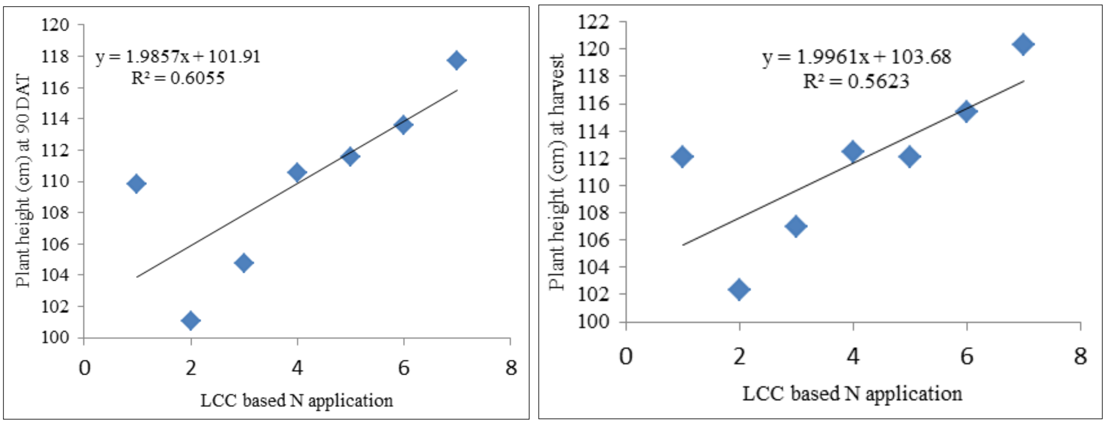


Fig 1: Showed relationship between leaf colour chart scores and plant height at different crop growth stages. There were highly significant and positive correlation existed as plant height increases with increasing LCC scores

Dry matter production also increased as crop growth progressed. PA-6444 recorded highest dry matter (Table 1) which was significantly higher over NDR-359 at all the crop growth stages. PA-6444 also showed significant difference over PHB-71 at 90 DAT and at harvest and was statistically at par at rest of the crop growth stages.

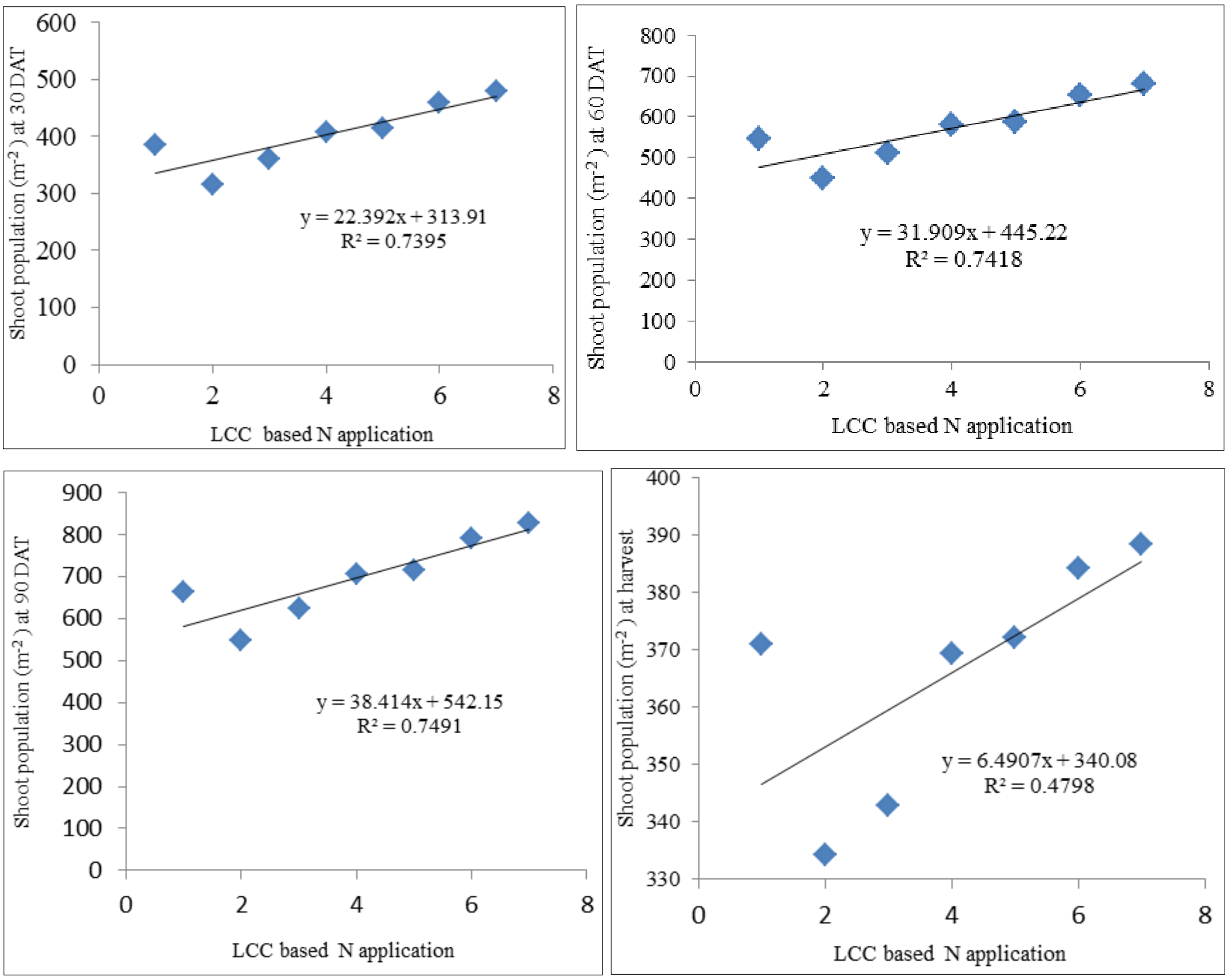


Fig 2: Showed relationship between leaf colour chart scores and shoot populations (m^{-2}) at different plant growth stages. There were highly significant and positive correlation existed as shoot numbers increases with increasing LCC scores.

PHB-71 also accumulated significantly higher dry matter over NDR-359 at all the crop growth stages. The LCC scores had significant effect on the plant growth at different growth stages. Plant height reveals the overall vegetative growth of the crop in response to various treatments. LCC<5+25 % N as basal through Urea recorded tallest plant (81.22, 112.31, 117.69 and 120.21 cm at 30, 60, 90, DAT and at harvest). But, LCC<5+25 % N as basal through FYM was found at par with LCC<5+25 % N as basal through Urea at all the growth stages except 30 DAT. These results are in close conformity with Pillai and De (1980) [17]. LCC<5+25% N as basal through urea recorded highest (Table 1) shoot numbers (480.1, 681.9, 827.6 and 388.4 at 30, 60, 90, DAT and at harvest) which was statistically at par with LCC<5+25% N as basal through FYM and was significantly higher over rest of the LCC scores and RDN at all the crop growth stages. Sathiya and Ramesh, (2009) [18] reported that LCC value of 4, produced significantly higher tillers (369.3 m^{-2}) at maximum tillering stage, plant height (81.7 cm) at maturity, dry matter at flowering (5.71 t ha^{-1}) than LCC value of 3. Increasing level of nitrogen positively affected the dry matter accumulation at all the stages. LCC<5+25 % N as basal through urea accumulated highest dry matter at all the crop growth stages (353.7, 881.6, 1034.0 and 1136.1 gm^{-2} at 30, 60, 90, DAT and at harvest) and was significantly higher over rest of the LCC scores and RDN except LCC<5+25 % N as basal through FYM. This might be due to more number of tillers m^{-2} and increased plant height which ultimately increased the size and number of green leaves associated with high photosynthetic efficiency leading to enhanced photosynthates accumulation and their translocation and together accounted for high dry matter production. Bhatia *et al.* (2012) [4] also reported similar results.

Yield attributes

Yield and yield attributing characters of different rice cultivars differed significantly as influenced by different LCC scores. PA-6444 recorded maximum number of panicles (307.62 m^{-2}) which was 5.65 % higher over PHB-71 and 11.70 % over NDR-359. It might be due to the profuse tillering ability and less mortality of shoots in PA-6444 and PHB-71. Among LCC scores, LCC<5+25% N as basal through urea recorded highest number of panicles m^{-2} (311.94) followed by LCC<5+25% N as basal through FYM (307.65) and these both the treatment were statistically at par and recorded 5.45 % and 4.02 % higher number of panicles respectively over RDN. The improvement in the yield attributes of rice is might be due to the adequate supply of photosynthates to sink under higher levels of nitrogen. Among the rice cultivars NDR-359 recorded significantly longest panicle (28.80 cm) which significantly longer over PA-6444 (27.31cm) and PHB-71 (27.37cm) respectively. Among nitrogen levels LCC<5+25% N as basal through urea recorded longest panicle (28.71cm) which significantly longer than RDN but were at par with, LCC<5+25% N as basal through FYM, LCC<4+25% N as basal through urea and LCC<4+25% N as basal through FYM. Kavitha *et al*. (2009) [11] also reported that application of 10 t ha^{-1} green manure along with 200 kg ha^{-1} inorganic nitrogen improved the yield and yield attributes of rice hybrids. Rice cultivars NDR-359 recorded highest number of grain per panicle (229.97) which was significantly higher over PA-6444 and PHB-71, while, PA-6444 was at par with PHB-71. LCC<5+25% N as basal through urea recorded highest number of grains per panicle (241.56) over rest of the nitrogen levels. Similarly, LCC<5+25% N as basal through FYM (235.77) also found significantly superior over rest of the nitrogen levels, but was at par with LCC<5+25% N as basal through urea.

Yield

Grain yield, straw and biological yield, straw: grain ratio of rice, as influenced by rice cultivars and different LCC based nitrogen levels differed significantly during both the years. PA-6444 recorded higher grain yield (59.21 q ha^{-1}) over PHB-71 (53.98 q ha^{-1}) and NDR-359 (50.4 q ha^{-1}) which was 9.68% and 17.48% higher over PHB-71 and NDR-359 respectively. In case of nitrogen levels, LCC<5+25% N as basal through urea recorded significantly higher grain yield (62.8 q ha^{-1}) over all the nitrogen levels except LCC <5+25% N as basal through FYM (61.61 q ha^{-1}). Sen *et al*. (2011) [19] also reported that number of panicles m^{-2}, panicle length, panicle weight, filled spikelets per panicle, grain filling percentage, test weight, grain and straw yields were found to be higher with LCC≤5 among the LCC scores except in HUBR 2-1 where LCC≤4 out yielded LCC≤5. PA-6444 recorded significantly higher straw yield (80.90 q ha^{-1}) over PHB-71 (73.91 q ha^{-1}) and NDR-359 (68.77q ha^{-1}). PHB-71 also recorded significantly higher straw yield over NDR-359. It may be due to plant height and more number of plants per unit area. LCC <5+25% N as basal through urea recorded significantly higher straw yield (85.63 q ha^{-1}) over all the nitrogen levels except LCC<5+25% N as basal through FYM (84.14 q ha^{-1}). Among rice cultivars, PA-6444 recorded highest biological yield (140.10 q ha^{-1}) and was significantly higher over PHB-71 (127.91 q ha^{-1}) and NDR-359 (119.21 q ha^{-1}) and PHB-71 also recorded significantly higher biological yield over NDR-359. LCC<5+25% N as basal through urea recorded significantly higher biological yield (148.6 q ha^{-1}) over all the nitrogen levels except LCC <5+25% N as basal through FYM. Evaluating usefulness of critical LCC score in rainfed direct seeded rice in southern India, Jayanthi *et al*. (2011) [10] observed that need based application of 20 kg N ha^{-1} at bi-weekly intervals favourably influenced grain yield when N was applied from 21 days after rice emergence up to reproductive phase (panicle initiation to 10% flowering). Gupta *et al.* (2007) [9] reported that need based nitrogen management using LCC at 350 locations in Punjab (India) during 2002-2005, showed that LCC based nitrogen management (from 9.4-54.2 kg N ha^{-1}) average of about 25 % less fertilizer given similar yield as compared to blanket nitrogen at fixed time intervals. Regarding straw: grain ratio table 3 showed that rice cultivars didn't differ significantly. Nitrogen levels through LCC scores, showed significant difference regarding straw: grain ratio. Among nitrogen levels, recommended N dose, recorded significantly higher ratio (1.39) over LCC <3+25% N as basal through FYM and LCC <3+25% N as basal through urea, while rest nitrogen levels were found at par to RDN. Harvest index didn't differ significantly among rice cultivars. NDR-359 recorded highest harvest index followed by PA-6444 and PHB-71. It is obvious from the data (table 3) that nitrogen levels through LCC scores didn't showed significant difference regarding harvest index.

It is has been observed that rice cultivar PA-6444, as it has recorded highest plant height, shoot population, dry matter accumulation, grain, straw and biological yield found best with LCC<5+25% N as basal through urea. But LCC<5+25% N as basal through urea found statistically at par with LCC<5+25% N as basal through FYM regarding almost all parameters. Hence, LCC<5+25% N as basal through FYM with PA-6444 can be used as a low cost technology to sustain the rice production per unit area.

Table 1: Plant height, shoot number and plant dry matter as influenced by rice cultivars and LCC based nitrogen management practices (pooled mean of 2 years data).

Treatments	Plant height (cm)				Shoot Numbers (m^{-2})				Dry matter production (gm^{-2})			
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
Cultivars												
PA-6444	77.84	108.4	113.22	115.32	481.4	683.4	831.4	373.75	298.5	802.2	961.5	1090.3
PHB-71	75.24	105.23	108.67	110.12	442.9	629.2	763.7	370.10	284.0	784.6	924.3	1013.5
NDR-359	73.72	104.19	107.68	109.54	286.0	405.9	492.2	354.26	237.2	648.9	773.0	854.5
SE(d)	0.81	1.415	1.41	1.485	19.52	28.74	36.8	2.57	8.63	15.88	12.1	7.44
CD (P=0.05)	2.245	3.935	3.92	4.13	54.19	79.79	102.3	7.14	23.95	44.08	33.6	20.67
Nitrogen levels												
Recommended N dose	74.92	107.52	109.79	112.08	384.6	545.5	661.7	371.0	260.6	716.6	853.6	958.9
25% N(FYM)+LCC<3	70.68	96.645	101.06	102.34	315.6	448.1	548.7	334.1	226.8	576.4	702.7	825.4
25% N(Urea)+LCC<3	72.55	101.87	104.74	106.98	361.6	513.1	622.4	342.9	236.6	619.4	725.9	830.3
25% N(FYM)+LCC<4	75.44	106.31	110.55	112.44	408.6	580.3	704.2	369.3	271.3	767.3	915.5	984.8
25% N(Urea)+LCC<4	76.30	107.65	111.54	112.10	414.2	588.6	714.4	372.2	275.1	807.3	964.7	1042.6
25% N(FYM)+LCC<5	78.08	109.41	113.61	115.38	459.4	652.4	791.6	384.2	288.9	848.3	1007.8	1124.4
25% N(Urea)+LCC<5	81.22	112.31	117.69	120.31	480.1	681.9	827.6	388.4	353.7	881.6	1034.0	1136.1
SE(d)	1.665	2.595	2.405	2.525	20.62	29.46	36.39	4.40	20.65	37.63	24.075	13.43
CD (P=0.05)	3.37	5.265	4.875	5.12	41.83	59.73	73.81	8.93	41.87	76.32	48.82	27.24

Table 2: Yield attributing characters, yield and economics as influenced by rice cultivars and LCC based nitrogen management practices (pooled mean of 2 years data).

Treatments	No. of Panicle (m^{-2})	Panicle length (cm)	No. of grains /ear	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Total yield (q ha^{-1})	Straw: Grain ratio	Harvest Index (%)
Rice cultivars								
PA-6444	307.62	27.31	216.405	59.21	80.90	140.10	1.37	42.26
PHB-71	291.17	27.37	211.405	53.98	73.91	127.91	1.37	42.21
NDR-359	275.38	28.80	229.975	50.40	68.77	119.21	1.37	42.27
SE(d)	0.87	0.40	2.284	0.47	0.60	1.06	0.01	0.09
CD (P=0.05)	2.40	1.09	6.343	1.31	1.66	2.94	NS	NS
Nitrogen levels								
Recommended N dose	295.78	27.57	214.225	53.15	73.87	127.01	1.39	41.83
25% N(FYM)+LCC < 3	265.47	26.68	193.055	45.28	61.77	107.05	1.36	42.29
25% N(Urea)+LCC < 3	267.89	27.05	197.83	46.14	62.89	109.02	1.36	42.32
25% N(FYM)+LCC < 4	294.32	27.95	224.44	55.26	75.13	130.38	1.37	42.38
25% N(Urea)+LCC < 4	296.68	28.26	227.945	57.48	78.39	135.86	1.37	42.31
25% N(FYM)+LCC < 5	307.65	28.54	235.775	61.61	84.14	145.59	1.38	42.31
25% N(Urea)+LCC < 5	311.94	28.71	241.56	62.80	85.63	148.59	1.38	42.26
SE(d)	2.53	0.41	2.955	0.91	1.17	2.025	0.01	0.19
CD (P=0.05)	5.13	0.82	5.995	1.84	2.37	4.105	0.02	NS

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