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Leaf color chart based nitrogen management in spring rice

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Abstract

A field experiment on LCC-based nitrogen (N) management was carried out at Rajapur, Bardiya during the spring season of 2021 to determine the growth and productivity of spring rice varieties. The experiment was laid out in strip plot design with three replications. The treatment consisted of four varieties (Chaite-5, Hardinath-1, Hardinath 1-F1, and Hardinath-3) in horizontal plots and five levels of LCC-based N management practices (Pure LCC, 25% N (basal) + LCC, Recommended dose of fertilizer in three splits, Farmer's dose, and no nitrogen (i.e. Control) in vertical plots. The results showed that Pure LCC-based nitrogen management produced the highest grain yield (6.24 t ha^{-1}) followed by 25% N basal + LCC (5.77 t ha^{-1}). LCC-based treatments produced a significantly higher yield than recommended dose applied in three splits. The higher yield in pure LCC was because of higher yield attributes like effective tillers m^{-2}, higher thousand-grain weight, lower sterility percentage, longer panicle length, and higher panicle weight. Hardinath-3 and Hardinath 1-F1 with pure LCC produced significantly higher yields than other treatment combinations. The spring rice varieties Hardinath 1-F1 and Hardinath-3 were high yielders than Hardinath-1 and Chaite-5. The higher yield of Hardinath-3 was due to higher number of effective tillers m^{-2}, longer panicle length, and higher panicle weight. Similarly, the higher yield of Hardinath 1-F1 was mainly due to higher thousand-grain weight and higher number of effective tillers m^{-2} as compared to other varieties except for Hardinath-3. The nitrogen use was highest in Hardinath1-F1 (116.25 kg ha^{-1}) followed by Hardinath-3 (108.75 kg ha^{-1}). The varieties Hardinath 1-F1 and Hardinath-3 with pure LCC-based N management were high-yielders in Bardiya-like climatic conditions.

Keywords: Spring rice, leaf color chart (LCC), nitrogen management, rice yield

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1 Introduction

Rice (*Oryza sativa* L.) is a key crop in 89 countries across the world, and it is the primary source of nutrition for half of the world's population. In Nepal, there were 1.4 million hectares under rice farming, with an annual yield of 5.6 million tons of paddy and average productivity of 3.76 MT ha^{-1} (MoALD, 2019). Rice provides 21% of global human per capita energy and 15% of per capita protein. It supplies about 40% of the food calorie intake and contributes 20% to the agriculture gross domestic product (AGDP) and almost 7% to GDP. In Nepal, 116 varieties of main season rice and 7 varieties of spring rice have been registered AICC (2019). The coverage area of spring rice for Mountain, Hill, and Terai is found to be 5.48, 24.85, and 69.67 percent, respectively (CDD, 2015). Spring rice is sown in the last week of February to the first week of March and follows transplanting of 30-40 days old seedlings. It is a short-season rice that is resistant to many diseases and pests and has a high production potential. Higher intensity of light during spring results in a higher yield. Therefore the adoption of enhanced spring rice types has been popular (CDD, 2017).

Domestic production of Nepal is not sufficient to meet the country's demand due to low rice productivity. The low productivity is associated with declining soil fertility, insufficient and imbalanced use of fertilizers, intensive cropping systems, use of traditional varieties, and lack of awareness of improved crop management practices (Baral et al., 2019). One of the major reasons for the yield gap in Nepal is high and inefficient application of N fertilizer (Shukla et al., 2004). Nitrogen use efficiency in rice is only about 30 to 40% and about 1/3rd of applied nitrogen is lost by different ways (Abrol et al., 2007). Excess of nitrogen supply than plant demand may increase the potential of N loss in the environment via volatilization, leaching, nitrification, and denitrification (Kumar and Ladha, 2011). Nitrogen is easily lost to the plant because of its high mobility. Thus, proper application of N fertilizers is vital to improve crop growth and grain yields, especially in intensive agricultural systems (Singh et al., 2007). The losses of NH_3 from different upland and lowland systems were found to be from negligible amount to 50% (Keller and Mengel, 1986). The total applied nitrogen through urea was found to be lost by 23.9 % in volatilization from rice fields (Yu et al., 2013). Sahu and Samant (2006) reported 10-40% of applied nitrogen lost through denitrification whereas Russo (1996) found 15-45% of surface applied ammonium fertilizer loss through a nitrification-denitrification process in rice soils.

Different types of decision support tools, such as the Green Seeker (GS) optical sensor, Soil Plant Analysis Development (SPAD), Leaf Color Chart (LCC), Urea Super Granules(USG), and split application have been introduced for real-time N management and to increase nitrogen use efficiency in rice (Lee, 2021). The decision to utilize one of these tools is determined by the cost, user-friendliness, and time required to use the tool (Baral et al., 2021). Among the non-destructive methods of leaf nitrogen content estimation, Leaf Color Chart is inexpensive, easy to carry out, saves N, and increases the N use efficiency (IRRI, 2020). Nitrogen management using leaf color chart trial will help in the real-time and the right amount of N application and help to increase productivity and profitability of rice.

Considering this, an experiment was carried out on LCC based nitrogen management for different spring rice varieties at Rajapur, Bardiya Nepal from February to June with the objective to increase the productivity of spring rice through real time nitrogen management, to increase the growth, productivity of spring rice and to determine the interaction effect of LCC based Nitrogen management and varieties in growth and yield of rice.

2 Materials and Methods

2.1 Experimental site

The experimental site was located at Rajapur municipality, Bardiya which is commanded by Rice Superzone under the PMAMP. Geographically, Rajapur is located between 81°3′ to 81°41′ longitude and 28°7′ to 28°39′ latitude with elevation of 145 meter from sea level. The experimental soil was loam having the following characteristics in the top 20 cm profile; clay 16.76%, silt 49.70%, sand 33.54%, and pH 5.69. Similarly, the soil had 2.02% soil organic matter, 0.10% total N, 27.69 kg ha^{-1} available P, and 227.8 kg ha^{-1} available K which were under the medium category based on the rating chart. The available nitrogen and phosphorus were medium whereas, the available potassium was low based on the rating chart (Jaishy, 2000).The experimental site was characterized by cool climate (February), and mild spring (March-May) and rainy (July). The relative humidity (RH) ranged from 68% in February to 63% in June (harvesting) with an average of 52.6%. The highest maximum temperature recorded in may (36.50 °C) , and lowest temperature recorded in February (10.70 °C) during the crop period.

2.2 Experimental treatments and design

The experiment was conducted in 2 factorial experiments in strip plot design in the field. Horizontal factor i.e. varieties and Vertical factor i.e. LCC based nitrogen management practices. 4 varieties i.e. Hardinath -1, Hardinath hybrid-1, chaite-5, Hardinath- 3 along with 5 LCC based nitrogen management practices, i.e. Pure LCC, 25% N (basal)+ LCC, Recommended dose of fertilizer, Farmer's dose, and Control with 3 replications were confirmed for the research. In first treatment recommended fertilizer dose 100:30:300 NPK kgt ha^{-1} was supplied through the application of Urea, DAP and MOP. DAP (50.86 g), MOP (39 g) and 50% split dose of Urea (74.83 g) was applied as a basal dose before the transplantation. The further 2 split dose of urea (37.41 g) was applied at 25-30 DAT and panicle initiation. Similarly, in second treatment, farmers dose 65: 40.48: 13.8 kg NPK/ha was supplied through the application of Urea, DAP, MOP. DAP (68.64 g), MOP (17.94 g) and 50% split dose of Urea (41.68 g) was applied as a basal dose before the transplantation. The further 2 split dose of urea (20.83 g) was applied at 25- 30 DAT and panicle initiation. Similarly, in 3rd treatment, 25% basal dose N was supplied through the application of urea along with LCC was used. 25% N i.e. 37.41 g in the form of urea, 50.87 g DAP and 39 g MOP was supplied before the transplantation. The total experimental field was 799.5 m^2 (19.5 × 41 m^2). There was a bund of 0.5 m width between two experimental plots and each replication was separated by 0.75 m width. The row spacing was kept to 20 cm, with 15 rows in each plot. For harvesting and phenological purposes, the center ten rows were considered as net plot rows. For tiller count and height measurement, one row on each side was maintained. Also, the outside two rows, one on each side, were left as guard rows for the whole plot. Field was kept irrigated with the distributors of Rajapur Irrigation Canal System. Hand weeding was done carefully at 25 DAT and 15 days after first hand weeding in order to reduce crop and weed competition for nutrients and spaces.

2.3 Observations

Plant height and number of tillers m^{-2} were measured and recorded starting from 15 DAS to 90 DAS at 15 days interval. The number of tillers obtained from counting was converted into a number of tillers per square meter. In LCC-based treatments, ten LCC readings were taken in each plot by randomly selecting the topmost fully expanded leaves. Nitrogen at the rate of 30 Kg/ha was applied through urea when 6 leaves out of 10 showed the LCC reading below or equal to critical value 4. LCC data was taken from the 15 days of sowing every one week and continued this process up to 5 days after panicle initiation. Readings were taken on by placing its middle part on the color stripes of the LCC. Likewise, grain and straw yields were calculated in kg ha^{-1}. The grain yield was adjusted at a 14% moisture level and the harvest index was calculated by the following formula given by Shahidullah et al. (2009):

$$Y = \frac{(100 - MC) \times Y_p \times 10000}{(100 - 14) \times A \times 1000} \tag{1}$$

where Y = grain yield (t ha^{-1}) of rice at 14% moisture content, MC = moisture content (%) of grain just before weighing, Y_p = grain yield (kg) of the plot, A = area of the plot (m^{-2}), $(100-MC)/(100-14)$ = conversion factor for grain yield at 14% moisture content, $A/10000$ = conversion factor for the actual harvested area on a hectare basis, and $Y_p/1000$ = conversion factor for actual harvested yield into ton (t) basis.

$$HI = \frac{Y_G}{Y_B} \times 100 = \frac{Y_G}{(Y_G + Y_S)} \times 100 \tag{2}$$

where HI = harvest index (%), Y_G grain yield (t ha^{-1}), Y_S = straw yield (t ha^{-1}).

2.4 Statistical analysis

All the collected data were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT) for mean separations in R-Studio software. Microsoft Word 2010 was used for word processing, and MS excels for tables, graphs, and simple statistical analysis.

3 Results and Discussion

3.1 Growth parameters

3.1.1 Plant height

Plant height was significantly influenced by varieties as well as LCC-based nitrogen management practices. The mean plant height of the varieties increased over time ranging from 40.25 cm to 91.44 cm within the period of 30 to 90 DAT (Table 1). The plant height of Hardinath-3 was found highest (99.40 cm) at 90 DAT which had a statistically similar value with Hardinath 1-F1 but a significantly higher value than Hardinath-1 and Chaite-5 at all observations. The plant height was highest in Pure LCC treatment at all observations while the shortest plant height was observed in control. The plant height increased significantly with the growth of a crop. At the 90 DAT, the highest plant height (104 cm) was observed in Pure LCC treatment followed by 25 % N basal + LCC (97.37 cm) (Table 1). The highest plant height in pure LCC was because nitrogen is intimately associated to plant metabolism and vegetative development. Thus, greater nitrogen treatment results in enhanced vegetative growth due to meristematic development, cell division, and cell elongation of internodes, resulting in a faster growth rate of the stem (Bhavana et al., 2020). There were significant interactions in the plant height of spring rice due to interaction between varieties and LCC-based nitrogen management practices. The plant height was observed highest (95.86 cm) due to the interaction between Hardinath-3 and Pure LCC treatment (Table 2).

3.1.2 Number of total tillers m^{-2}

The number of tillers m^{-2} increased continuously up to 60 DAT and after it decreased among the varieties as well as LCC-based N management practices (Table 3). A lower number of tillers m^{-2} (303.6) was observed at 30 DAT which increased to a maximum (475.55) at 60 DAT and then decreased (287.13) at 90 DAT. The maximum number of tillers m^{-2} (526.53, 490.40, 461.26, and 424.00) was observed at 60 DAT and decreased to (341.53, 295.93, 275.86, and 235.20) at 90 DAT in Hardinath-3, Hardinath1- F1, Chaite-5 and Hardinath-1 respectively. The number of tillers m^{-2} was highest in Pure LCC because higher levels of nitrogen in leaves, impart a positive effect on leaf development, and tillering, and increase leaves' photosynthetic activity durability (Fageria and Baligar, 2005). Similar findings were obtained by Budhar and Tamilselvan (2003) who explained that increased plant height and more number of tillers at LCC 4 and LCC 5 might be due to a steady supply of N applied at the seedling stage that helped to produce a favorable effect on growth attributes. There were significant interactions in the number of tillers m^{-2} of spring

Table 1. Plant height of spring rice as influenced by variety and LCC based nitrogen management at Rajapur, Bardiya, 2021

Treatment	Plant height (cm) at different DATs				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Variety (V)					
Hardinath-1	36.60bc	60.67bc	72.76bc	76.67b	88.16bc
Chaite-5	32.49c	55.38c	66.99c	80.26b	83.37c
Hardinath-F1	43.58ab	66.74ab	78.77ab	88.12a	94.82ab
Hardinath-3	48.32a	71.57a	83.40a	92.70a	99.40a
LSD (0.05)	7.76	7.13	7.23	6.4	6.91
CV (%)	19.9	12.6	10.7	8.5	8.5
N management (N)					
Pure LCC	49.91a	75.95a	88.07a	97.30a	104.00a
25% N basal + LCC	46.90b	69.57b	81.40b	90.13b	97.37b
RDF	40.27c	62.94c	74.77c	83.43c	90.74c
Farmers dose	35.30d	57.97d	69.80d	78.72c	85.77c
Control	28.85e	51.51e	63.35e	72.61d	79.31d
LSD (0.05)	4.44	4.88	4.44	4.79	5.01
CV (%)	7.9	8.1	6.3	6	5.8

Treatment means followed by common letter (s) in the same column are not significantly different from DMRT at $p < 0.05$

Table 2. Plant height (at 60 DAT), number of total tillers m^{-2}, and grain sterility (%) of spring rice as influenced by the interaction of variety and LCC based nitrogen management at Rajapur, Bardiya, 2021

Interaction (V × N)	Plant height (cm)	Tillers m^{-2}	Sterility (%)
V1 × N1	89.83b	319.33d	25.90f
V1 × N2	80.60cd	286.33e	28.60de
V1 × N3	69.96fgh	257.33f	29.01cde
V1 × N4	65.40hi	224.00g	30.91bc
V1 × N5	58.00j	194.00h	33.20a
V2 × N1	75.30ef	347.33c	22.73g
V2 × N2	71.30fg	317.00d	25.61f
V2 × N3	67.33ghi	288.66e	28.55de
V2 × N4	63.00i	263.66f	30.66bcd
V2 × N5	58.03j	223.00g	33.09a
V3 × N1	91.30ab	394.00b	20.26h
V3 × N2	84.20c	354.66c	24.37fg
V3 × N3	78.13de	318.66d	25.56f
V3 × N4	73.60ef	286.66e	28.71de
V3 × N5	66.63ghi	231.33g	32.19ab
V4 × N1	95.86a	426.33a	18.65h
V4 × N2	89.53b	393.66b	23.04g
V4 × N3	83.66c	352.66c	26.16f
V4 × N4	77.23de	322.33d	28.28e
V4 × N5	70.73fgh	271.00f	31.37ab
LSD (0.05)	4.87	14.78	1.94
CV (%)	3.8	2.9	4.2

V1: Hardinath-1, V2: Chaite-5, V3: Hardinath-F1, V4: Hardinath-3, N1: Pure LCC 25% N basal + LCC, N2: RDF, N3: Farmers dose, and N5: Control; Treatment means followed by common letter (s) in the same column are not significantly different from DMRT at $p < 0.05$

Table 3. Tiller production of spring rice as influenced by variety and LCC based nitrogen management at Rajapur, Bardiya, 2021

Treatment	Number of tillers m^{-2} at different DATs				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Variety (V)					
Hardinath-1	256.20a	354.86 c	424.00c	247.73c	235.20c
Chaite-5	287.93bc	383.93bc	461.26b	289.80b	275.86b
Hardinath-F1	317.06ab	413.06ab	490.40ab	307.26b	295.93b
Hardinath-3	353.20a	449.20a	526.53a	352.86a	341.53a
LSD (0.05)	39.29	38.39	37.1	34.53	33.62
CV (%)	14.5	10.7	8.7	12.9	13.1
N management (N)					
Pure LCC	371.75a	470.08a	543.58a	365.83a	349.75a
25% N basal + LCC	337.91b	434.91b	508.41b	331.83b	320.50b
RDF	304.33c	400.33c	475.91c	300.41c	289.08c
Farmers dose	274.16d	370.16d	446.66d	269.50d	258.16d
Control	229.83e	325.83e	403.1e	229.50e	218.16e
LSD (0.05)	22.61	20.16	23.55	180.75	21.11
CV (%)	7.9	5.3	5.2	6.6	7.8

Treatment means followed by common letter (s) in the same column are not significantly different from DMRT at $p < 0.05$

rice due to interaction between varieties and LCC-based nitrogen management practices. The number of tillers m^{-2} was observed highest (426.33) due to interaction between Hardinath-3 and Pure LCC treatment (Table 2).

3.2 Yield attributing parameters

3.2.1 Number of effective tillers m^{-2}

Number effective tillers m^{-2} were significantly influenced by varieties and LCC-based N management but were not significantly influenced due to their interaction. The mean number of effective tillers per square meter of rice in the experiment was 246.58 (Table 4). The highest number of effective tillers per square meter was recorded for spring rice Hardinath-3 (300.13) which was significantly higher than other tested varieties in the experiment followed by Hardinath 1-F1 (253.53) and Chaite-5(229.33). Both the varieties Hardinath 1-F1 and Chaite-5 had statistically similar but significantly lower effective tillers per square meter than Hardinath-3. The highest number of effective tillers per square meter was recorded for Pure LCC treatment (311.75) while the lowest effective tillers per square meter were recorded for Control (184.08).

3.2.2 Sterility percentage

Sterility percentage was significantly influenced by varieties as well as LCC-based N management (Table 4). Higher panicle sterility was observed in Hardinath -1 followed by Chaite-5, Hardinath 1- F1, and Hardinath-3 with an average of 27.34%. Hardinath-3 had the lowest panicle sterility (25.50%).Similarly, statistically higher panicle sterility was found in N control than N applied treatments either through LCC combination or split application. The panicle sterility in LCC-based treatments ranged from 21.88% to 25.40 % whereas it was 32.46% in N control. The sterility percentage was significantly influenced due to interaction between varieties and LCC-based N management practices (Table 2). The highest sterility percentage of spring rice was 33.20% due to the interaction between Hardinath 1 and control. The sterility percentage showed decreasing trend due to interaction between varieties and LCC-based Nitrogen management.

3.2.3 Thousand-grain weight

The average thousand-grain weight of rice in the experiment was 24.27 g (Table 4). The thousand-grain weight of rice was significantly influenced by varieties, LCC based nitrogen management but was not significantly influenced due to interaction between varieties and LCC-based nitrogen management. The thousand-grain weight of spring rice Hardinath 1-F1 was the highest (28.66 g) followed by Hardinath -3 (26.46 g). The thousand-grain weight was found lowest in Chaite-5 (20.23 g) and Hardinath-1 (21.73g). Both the above varieties were statistically similar to each other. The thousand-grain weight was found highest in Pure LCC treatment (26.00 g) while it was lowest in no application of Nitrogen (22.62 g).

Table 4. Yield attributes of spring rice as influenced by variety and LCC based nitrogen management at Rajapur, Bardiya, 2021

Treatment	Eff. tillers m^{-2}	Sterility (%)	TGW (g)	PL (cm)	PW (g)	Grains $panicle^{-1}$
Variety (V)						
Hardinath-1	203.33c	29.52a	21.73c	23.24b	4.54c	218.46
Chaite-5	229.33bc	28.13ab	20.23c	23.66b	5.22b	217.9
Hardinath-F1	253.53b	26.22bc	28.66a	25.13b	5.68ab	219.6
Hardinath-3	300.13a	25.50c	26.46b	28.10a	5.94a	205.27
LSD (0.05)	32.44	2.15	1.76	2.55	0.63	NS
CV (%)	14.72	8.8	8.1	11.4	13.3	16.7
N management (N)						
Pure LCC	311.75a	21.88c	26.00a	32.12a	6.56a	211.78
25% N basal + LCC	276.50b	25.40d	24.87b	27.62 b	5.85b	226.57
RDF	243.83c	27.30c	24.25bc	24.35c	5.24c	216.72
Farmers dose	216.75d	29.64b	23.62c	21.54d	4.78d	191.3
Control	184.08e	32.45a	22.62d	19.54e	4.27e	230.16
LSD (0.05)	18.56	1.51	0.74	1.72	0.53	NS
CV (%)	7.99	5.9	3.3	7.3	5.8	28

Treatment means followed by common letter (s) in the same column are not significantly different from DMRT at $p < 0.05$; TGW: 1000-grain weight, PL: panicle length, PW: panicle weight

Table 5. Panilce length, number of grains $panicle^{-1}$, and grain yield of spring rice as influenced by the interaction of variety and LCC based nitrogen management at Rajapur, Bardiya, 2021

Interaction (V*N)	Panicle length (cm)	Grains $panicle^{-1}$	Grain yield (t ha^{-1})
V1*N1	28c	220.10abcd	5.51de
V1*N2	25.33def	218.18abcd	5.13f
V1*N3	22.90fghi	207.68abcde	4.67hi
V1*N4	20.83ijk	196.18bcde	4.17j
V1*N5	19.16jk	250.15abc	3.65k
V2*N1	31b	263.33a	5.64cde
V2*N2	25.66cde	207.20abcde	5.30ef
V2*N3	22.66ghi	194.23cde	4.72ghi
V2*N4	20.66ijk	190.11de	5.07fg
V2*N5	18.3k	234.61abcd	4.52ij
V3*N1	33.16b	203.98bcde	6.87a
V3*N2	28c	227.48abcd	6.29b
V3*N3	24.16efg	241.41abcd	5.71cd
V3*N4	21ij	186.16de	5.26ef
V3*N5	19.33jk	238.98abcd	4.60i
V4*N1	36.33a	159.71e	6.93a
V4*N2	31.50b	253.43ab	6.37b
V4*N3	27.66cd	223.58abcd	5.93c
V4*N4	23.66efgh	192.75cde	5.55cde
V4*N5	21.33hij	196.90bcde	4.99fgh
LSD (0.05)	2.26	49.37	0.35
CV (%)	5.4	13.6	3.9

V1: Hardinath-1, V2: Chaite-5, V3: Hardinath-F1, V4: Hardinath-3, N1: Pure LCC 25% N basal + LCC, N2: RDF, N3: Farmers dose, and N5: Control; Treatment means followed by common letter (s) in the same column are not significantly different from DMRT at $p < 0.05$

3.2.4 Panicle length

The average panicle length of rice in the experiment was 25.03 cm (Table 4). The panicle length was significantly influenced by varieties, LCC-based nitrogen management practices, and interactions between varieties and LCC-based nitrogen management. The panicle length of spring rice was the highest (29.94 cm) in Hardinath -3. Varieties like Hardinath1-F1, Chaite-5, and Hardinath-1 had statistically similar but significantly lower panicle lengths than Hardinath -3. The LCC-based nitrogen management also had a significant influence on the panicle length of spring rice. The panicle length was found longest in Pure LCC treatment (32.12 cm) while it was shortest in no application of Nitrogen (19.54 cm). The panicle length of spring rice was significantly influenced due to interaction between varieties and LCC-based nitrogen management practices. The longest panicle length (36.33 cm) was found due to interaction between the varieties Hardinath-3 and Pure LCC treatment followed by interaction between the varieties Hardinath –F1 and Pure LCC treatment (Table 5).

3.2.5 Panicle weight

The mean panicle weight of rice in the experiment was 5.34 g (Table 4). The panicle weight of rice was significantly influenced by varieties and LCC-based nitrogen management practices. The panicle weight of spring rice Hardinath-3 was the highest (5.94 g) followed by Hardinath 1- F1. Both of the above varieties had statistically similar but significantly higher panicle weight than Hardinath-1 (4.54 g) and Chaite-5 (5.22 g). Chaite-5 had a significantly higher panicle weight than Hardinath-1. The highest panicle weight (6.56g) was obtained in Pure LCC treatment which was significantly higher than all other doses of nitrogen application. The lowest panicle weight (4.27 g) was obtained with no application of nitrogen. The panicle weight was not significantly influenced due to interaction between varieties and LCC-based N management practices (data not presented).

3.2.6 Number of grains panicle^{-1}

There was a non-significant influence observed in a number of grains panicle^{-1} by rice varieties and LCC-based nitrogen management. The average number of grains panicle^{-1} of rice in the experiment was 215.31 (Table 4). There were significant interactions in the number of grains panicle^{-1} of spring rice due to varieties and LCC-based nitrogen management (Table 5). The number of grains panicle^{-1} was found highest (263.33) due to interaction between the varieties Chaite-5 and Pure LCC treatment followed by Hardinath-1 and Hardinath 1 –F1. All the above varieties were statistically similar due to the interaction between the varieties and Pure LCC treatment but were highly superior to Hardinath-3. The number of grains panicle^{-1} was found statistically similar in all LCC-based treatments among different varieties.

3.3 Grain yield

The grain yield was significantly influenced by the varieties as well as LCC-based Nitrogen management. The average grain yield of rice in the experiment was 5.44 t ha^{-1} (Table 6). The grain yield was highest in Hardinath-3 (5.95 t ha^{-1}) followed by Hardinath 1-F1 (5.74 t ha^{-1}). Both the above varieties were statistically similar but significantly higher than Hardinath-1 (4.62 t ha^{-1}) and Chaite-5 (5.05 t ha^{-1}). The higher yield of Hardinath-3 was because of a higher number of effective tillers m^{-2}, longer panicle length, and higher panicle weight. The higher yield in Hardinath-3 is because this variety is newly released and its potential has been reported 5.55 t ha^{-1} which is superior to previously released other varieties for the spring season (AICC, 2019). The higher yield in Hardinath 1- F1 is because this is a hybrid variety and has a heterosis effect which leads higher yield than inbred varieties. Higher grain yield in hybrids than in improved varieties was also observed (Bari et al., 2014).

The highest grain yield (5.24 t ha^{-1}) was obtained in pure LCC treatment followed by 25%N (basal) + LCC treatment (4.77 t ha^{-1}) (Table 6). The higher yield in pure LCC was because of higher yield attributes like effective tillers m^{-2}, higher thousand-grain weight, lower sterility percentage, longer panicle length, and higher panicle weight. The higher yield in Pure LCC might be due to adequate N supply during the reproductive growth phase which is highly responsible for enhancing yield parameters and in turn the yield. Duttarganvi et al. (2014) also found higher grain yield under LCC-based N management than the blanket recommendation. Gharib et al. (2011) found that increasing nitrogen level from 50 to 200 kg N t ha^{-1} caused a significant increase in each panicle weight, panicle length, number of filled grains panicle^{-1}, grain, and straw yields. Similarly, recommended dose (4.25 t ha^{-1}) and the farmer's dose (4.01 t ha^{-1}) were statistically similar but significantly higher than the control (3.44 t ha^{-1}). The variety Hardinath-3 was found significantly superior over Hardinath 1- F1 for effective tiller m^{-2}, panicle length, panicle weight, and sterility percentage. However, the thousand-grain weight of spring rice Hardinath 1-F1 was the highest (28.66 g) followed by Hardinath -3 (26.46 g).

The grain yield of spring rice was significantly influenced due to interaction between varieties and LCC-based Nitrogen management (Table 5). The highest grain yield of spring rice was 6.93 t ha^{-1} due to the interaction between pure LCC treatment and Hardinath-3. These yields were statistically similar due to the interaction between varieties Hardinath

Table 6. Grain yield, straw yield and harvest index of spring rice as influenced by the interaction between variety and LCC based nitrogen management at Rajapur, Bardiya, 2021

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Variety (V)			
Hardinath-1	4.62c	4.59b	50.1
Chaite-5	5.05b	5.48a	48.08
Hardinath-F1	5.74a	5.76a	49.95
Hardinath-3	5.95a	5.93a	50.26
LSD (0.05)	0.39	0.52	NS
CV (%)	8.2	10.8	5.2
N management (N)			
Pure LCC	6.24a	6.37a	49.51
25% N basal + LCC	5.77b	5.96a	49.25
RDF	5.25c	5.34b	49.6
Farmers dose	5.01c	4.95bc	50.33
Control	4.44d	4.58c	49.31
LSD (0.05)	0.33	0.49	NS
CV (%)	6.7	9.6	3.1

Treatment means followed by common letter (s) in the same column are not significantly different from DMRT at $p < 0.05$

1-F1 and pure LCC treatment. Similarly, the grain yield was statistically similar due to the interaction between the varieties Hardinath-3 and Hardinath 1-F1 and 25% Nitrogen (basal) + LCC treatment. The grain yield showed an increasing trend due to interaction between varieties and LCC-based Nitrogen management. All other grain yields due to interaction between varieties and LCC-based Nitrogen management were intermediate.

4 Conclusion

Hardinath1-F1 and Hardinath-3 with Pure LCC and 25% N basal + LCC produced the highest yield than other treatments. Therefore, Hardinath-1 F1 and Hardinath-3 are the potential high yielding varieties for Rajapur, Bardiya. Similarly, Pure LCC produced a better yield followed by 25% N basal + LCC-based Nitrogen management. Therefore, the LCC-based treatment is the best option for nitrogen management.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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