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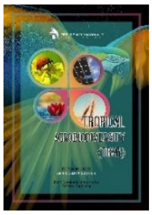

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RESEARCH ARTICLE

NITROGEN USE EFFICIENCY (NUE) AND RICE PRODUCTIVITY AS AFFECTED BY DIFFERENT LEVELS OF NITROGEN APPLICATION IN HILL CONDITIONS OF NEPAL

S. Timilsina, S.P. Vista

Nepal Agricultural Research Council
**Corresponding Author: sandiptimilsina@gmail.com*

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ABSTRACT

In Nepal, rice is the major staple food crop and is ranked first as a cultivated crop. Nitrogen is one of the most important factors limiting its yield. There has been an overuse of nitrogen fertilizer in rice fields resulting in low N use efficiency and high loss of nitrogen. A field experiment was carried out on acidic sandy loam soil of the Directorate of Agricultural Research, Gandaki, Lumle, from June to November 2016 and 2017 to evaluate the performance of cold-tolerant rice (Lumle-2) and nutrient use efficiency as affected by various levels of nitrogen application. The experiment was laid out in a randomized complete block design with five different level of nitrogen as treatments (0, 50, 100, 130, 150 Kg N ha^{-1}) and replicated four times. Phosphorus, potassium and FYM were applied at the recommended dose. A significantly marked increment in grain yield was noticed in both years as the nitrogen level increases up to 130 Kg N ha^{-1}. However, when the nitrogen dose exceeded 130 Kg N ha^{-1} have decreasing effect in grain yield, straw yield and NUE. The productivity (4.35 t ha^{-1}) and NUE of cold tolerant rice (Lumle-2) can be improved significantly by applying an optimum level of N fertilizer up to 130 Kg N ha^{-1}.

KEYWORDS

Cold-tolerant rice, Nitrogen, NUE

1. INTRODUCTION

Rice (Oryza sativa L.) is one of the major staple food crops and plays a dominant role in Nepalese agriculture (Gadal et al., 2019). It occupies the first place in terms of area and total production (MoALD, 2021). Rice yield potential is largely determined by nitrogen, and nitrogenous fertilizer is the most important inputs in rice cultivation (Mae, 1997). Nitrogen fertilization is the most important agronomic practice to ensure rice's productivity, and it should be done at the appropriate dose (Timilsina et al., 2018). Excess fertilizer use results in higher costs, lower returns, and an increased risk of environmental damage. Underuse of nutrients, on the other hand, limits the ability to increase current levels of nutrients to the economically optimal level in order to maximize output potential (Singh et al., 2001). In contrast, crop yields do not increase linearly with N fertilizer application rate, resulting in a decrease in N use efficiency (NUE) and greater N losses (Zhang et al., 2012). A lack of adequate and balanced fertilization of crops results in lower crop yields as well as deterioration of the soil's health (Sharma et al., 2003). The current recommended fertilizer dose for major nutrients in rice is proven to be insufficient for achieving higher yield, and it needs to be revised to more balanced and optimal levels. It is critical to determine the optimal nitrogen application dose for plants to make efficient use of this element and increase rice output. Depending on their agronomic features, different cultivars may respond differently to N fertilizer. Lumle-2 is a pipeline cold-tolerant rice variety developed by DoAR Lumle from the cross between Chhomrong and IR-36 and will be proposed very soon for release from national seed board which is recommended for mid to high hill environments in Nepal ranging from 1400 to 2000 meter above sea level (Timilsina et al., 2018). Therefore, the purpose of this study was to evaluate the nitrogen use efficiency (NUE) and performance of the Lumle-2 variety of cold-tolerant rice in response to different nitrogen levels.

2. MATERIALS AND METHODS

A field experiment was conducted at rice research block of the Directorate of Agricultural Research, Gandaki Province, Kaski (28°17' N, 83°49' E) in acidic sandy loam soil from June to November 2016 and 2017. The soil was sandy loam with pH 4.9, organic carbon 1.9%, total nitrogen of 0.2 %, available $P^{2}O^{5}$ of 204 kg ha-1 and ammonium acetate extractable K_2O of 58 kg ha-1. The experiment was designed in Randomized Complete Block Design (RCBD) consisting of five different nitrogen levels (0, 50, 100, 130 and 150 Kg N ha^{-1}) as treatments and replicated for four times. One month old seedlings of rice were planted at crop geometry of 15 X 15 cm with 2-3 seedlings per hill. Weed control measures included first hand weeding at 30 days and second at 60 days after transplanting. In the field, water was maintained at a depth of 3-5 cm until one week before harvesting. The field was drained before the application of fertilizers and one week before harvest. The application of nitrogenous fertilizers through urea was applied in accordance with the treatment.

The other essential nutrients were supplied through di-ammonium phosphate (DAP), muriate of potash (MOP) and farmyard manure (FYM) as per the recommended dose i.e. 30: 30 kg $P^{2}O^{5}$ and $K^{2}O$ ha^{-1} and 6 ton ha^{-1} FYM uniformly in all the treatment except control. The entire amount of FYM, DAP, MOP and half amount of urea were applied at basal dose. The remaining amount of urea was applied in two splits at the start of active tillering and panicle initiation stages. Throughout the crop's growth, the experiments received consistent plant protection and cultural management approaches. Growth, yield characteristics, and yield data were collected in accordance with standard protocol. Plant height at fully matured stage was measured from the soil surface to the tip of each panicle in five hills per plot. For each plot, grain yield was calculated from 1 m^2 of area and adjusted to 14 % moisture; panicles were counted from

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five hills from the center rows and filled grain per panicle and panicle length was estimated from gathering five primary panicles. The straw yield was calculated from 1 m^2 in each plot just after 1-day sun drying.

This study used two parameters of NUE, agronomic N use efficiency (ANUE) and N partial factor productivity (NPFP). Based on grain yield advantage divided by nitrogen application rate, ANUE was estimated (Cassman et al., 1996). In other words, it eliminates the contribution of indigenous N in soil-floodwaters to NUE.

$$ANUE = \frac{Y_N - Y_0}{\text{Nitrogen Rate}}$$

Where, Y_N= Grain yield in kg ha-1 for plots fertilized with nitrogen, Y_0= Grain yield in kg ha-1 of plots not fertilized with nitrogen and the nitrogen rate in kg ha^{-1}.Partial factor productivity was estimated by dividing kg crop production by kg of applied nutrient in each treatment (Ladha et al., 2005). For analysis of variance, R-Studio and STAR were used, and the significance was determined using Fisher's least significant difference at $p<0.05$ (Gomez and Gomez, 1984).

3. Results

The application of varying amounts of nitrogen significantly affected most of the yield components, including plant height, tillers number, panicle length, seeds per panicle, straw yield, and grain yield.

3.1 Plant Height

Significant differences were observed in the plant height of the rice crop when the field was applied with different doses of nitrogen. In the first year of testing, the tallest plant (112 cm) was found to be treated at 150 Kg ha^{-1}, and the smallest (101 cm) was obtained from control treatment. Similarly, the tallest plant (109 cm) was acquired from treatment of 150 Kg N ha^{-1}, which was statistically similar to 130 Kg N ha^{-1}, and the smallest (99 cm) was obtained from control treatment during the second year of the experiment. After pooling the data from two years, it was noted that plant height from 150 Kg N ha^{-1} was significantly higher (110 cm) followed by 130 Kg N ha^{-1} and significantly lower (100 cm) from treatment control (Table 3).

Table 1: Effect of cold tolerant rice (Lumle-2) under different N dose at Lumle, Kaski in 2016.

Treatments	Plant Height (cm)	No of Tillers/Plant	Panicle Length (cm)	No of Filled Grain/ Panicle	Straw Yield (t ha^{-1})	Grain Yield(t ha^{-1})
Control	101^{c}	5	21^{d}	110^{c}	6.98^{c}	2.99^{d}
50:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	104^{bc}	5	23^{cd}	121^{bc}	7.05^{c}	3.72^{c}
100:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	107^{b}	5	25^{bc}	128^{ab}	9.10^{b}	3.83^{bc}
130:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	109^{ab}	6	26^{b}	139^{a}	11.21^{a}	4.03^{a}
150:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	112^{a}	6	30^{a}	135^{a}	9.76^{b}	3.88^{ab}
Mean	**107**	**5.23**	**25**	**126.64**	**8.82**	**3.70**
CV (%)	**2.5**	**11.9**	**5.88**	**6.12**	**7.6**	**2.8**
P-Value	**0.001**	**0.12**	**0.001**	**0.001**	**0.001**	**>0.00**
$LSD_{0.05}$	**4.08**	**NS**	**2.27**	**11.94**	**1.03**	**0.16**

3.2 No of Tillers

During first year of experiment, the highest effective tillers (6) per hill was obtained from 130 and 150 Kg N ha^{-1}, statistically similar to other treatments and the lowest tiller (5) was recorded up to 100 Kg N ha^{-1}. Different nitrogen doses showed significant variation in effective tillers number per hill during second year of experiment. The maximum effective tillers per hill (8) were recorded from 150 Kg N ha^{-1}, which was statistically similar to 100 and 130 Kg N ha^{-1} and a minimum (5) was recorded in treatment without nitrogen application during 2017.

3.3 Panicle Length

Different doses of nitrogen showed a difference significantly in panicle length of rice. Among the various nitrogen doses, 150 Kg nitrogen ha^{-1} resulted in the longest panicle (30cm), which was statistically superior to the other treatments in 2016. The second-year data revealed that the longest panicle (24 cm) was obtained from 130 and 150 Kg N ha^{-1} which was statistically similar to 100 Kg N ha^{-1} and shortest (21 cm) was recorded without nitrogen application (Table 2).

3.4 Number of Filled Grains

The application of 130 Kg N ha^{-1} resulted in the highest number of filled grains per panicle in both years which was statistically like 100 and 150 Kg N ha^{-1}, whereas control treatment resulted the lowest number of filled grains. The two years of data after pooled analysis (Table 3) revealed that the increased N rate from 100 to 130 Kg significantly enhanced the filled grains number per panicle and the highest amount of filled grains per panicle (144) was obtained in the treatment with 130 Kg N ha^{-1}.

Table 2: Effect of cold tolerant rice (Lumle-2) under different N dose at Lumle, Kaski in 2017.

Treatments	Plant Height (cm)	No of Tillers/Plant	Panicle Length (cm)	No of Filled Grain/ Panicle	Straw Yield (t ha^{-1})	Grain Yield (t ha^{-1})
Control	99^{b}	5^{c}	21^{c}	117^{a}	3.65^{d}	2.71^{d}
50:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	103^{ab}	6^{bc}	22^{bc}	132^{bc}	5.27^{c}	3.47^{c}
100:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	104^{ab}	7^{ab}	23^{ab}	136^{ab}	6.62^{b}	4.12^{b}
130:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	109^{a}	7^{ab}	24^{a}	150^{a}	7.00^{ab}	4.65^{a}
150:30:30 kg $N:P_2O_5:K_2O$ ha^{-1}	109^{a}	8^{a}	24^{a}	143^{ab}	7.75^{a}	3.79^{bc}
Mean	**104**	**6.25**	**23**	**136**	**6.06**	**3.75**
CV (%)	**4.5**	**19.15**	**4.3**	**7.65**	**11.98**	**8.56**
P-Value	**0.05**	**0.02**	**0.001**	**0.007**	**0.001**	**0.001**
$LSD_{0.05}$	**7.05**	**1.85**	**1.52**	**16**	**1.12**	**0.45**

3.5 Straw Yield

Different nitrogen doses showed significant variations in straw yields during both growing seasons. In 2016, the treatment with 130 kg N ha^{-1} showed the highest straw yield (11.21 t ha^{-1}) and the control treatment with the lowest (6.98 t ha^{-1}). In 2017, the highest straw yield (7.75 t ha^{-1}) was obtained when treated with 150 kg N ha^{-1}. This is statistically equivalent to the 130 kg N ha^{-1} application, but statistically superior to rest of other treatment and the minimum (3.65 t ha^{-1}) were found in the control treatment. After pooling the data for 2 years, the straw yield was significantly higher (9.1 t ha-1) from plot supplied with 130 kg N ha-1 followed by 150 kg N ha-1 and the lowest (5.32 t ha-1) from control (Table 3).

3.6 Grain Yield

Significant changes in grain yields were observed at various nitrogen levels during both growing periods. Increased nitrogen rates up to 130 Kg considerably increased grain yield, with 130 Kg N ha-1 application yielding the maximum and treatment without nitrogen application yielding the lowest in both years. In the first growing season of experiment, the highest grain yield (4.03 t ha-1) was obtained with the fertilization of 130 kg N ha-1, that was statistically equivalent to 150 kg nitrogen ha-1, and the lowest (2.99 t ha-1) was obtained in the control treatment. Similarly, the maximum yield (4.65 t ha-1) was obtained from the 130 Kg N ha-1 treatment which was statistically superior to rest of the treatments and the lowest (2.71 t ha-1) was obtained from the control treatment during the second year of the experiment. The grain yield data of two years after pooled analysis revealed that the grain yield from 130 Kg N ha-1 was significantly higher (4.35 t ha-1) followed by 100 Kg N ha-1 N and the lowest (2.85 t ha-1) in control treatment (Table 3).

Table 3: Combined analysis of two-year effect of cold tolerant rice (Lumle-2) under different N dose at Lumle, Kaski.

Treatments	Plant Height (cm)	No of Tillers/plant	No of Filled Grain/ Panicle	Straw Yield (t ha-1)	Grain Yield (t ha-1)
Control	100c	5c	113d	5.32d	2.85d
50:30:30 kg N:P_2O_5:K_2O ha-1	104b	5bc	127c	6.17c	3.59c
100:30:30 kg N:P_2O_5:K_2O ha-1	106b	6ab	132bc	7.86b	3.97b
130:30:30 kg N:P_2O_5:K_2O ha-1	109a	6ab	144a	9.1a	4.35a
150:30:30 kg N:P_2O_5:K_2O ha-1	110a	7a	139ab	8.76a	3.84bc
Mean	**105**	**6**	**131**	**7.44**	**3.72**
CV (%)	**3.54**	**16.62**	**7**	**9.4**	**6.5**
P-Value	**>0.00**	**0.001**	**>0.00**	**0.001**	**>0.00**
$LSD_{0.05}$	**3.86**	**0.98**	**10**	**0.72**	**0.25**

3.7 Nitrogen Use Efficiency

3.7.1 Agronomic Nitrogen Use Efficiency (ANUE)

Nitrogen application had a significant effect on agronomic nitrogen use efficiency (ANUE) which increased with increasing N level up to 50 Kg N ha-1, then decreased with increasing N rate in the first year of the experiment. The highest value of ANUE (14.6) was obtained from 50 Kg N ha-1 which is significantly higher than rest of the treatments in 2016. The maximum ANUE value was obtained in the second year of the experiment with the application of 50 kg N ha-1 which is statistically similar to 100 and 130 kg N ha-1 and the lowest ANUE value was recorded with the application of highest nitrogen rates. The combined analysis of two year data revealed that Agronomic nitrogen use efficiency (NUE) in rice increased from 6.58 to 14.9 with decreasing N application rate from 150 to 50 Kg ha-1 but there is no significant difference in N rate from 50 to 130 Kg ha-1 .

3.7.2 N partial factor productivity (NPFP)

During both years of the experiment, nitrogen application had a significant effect on N partial factor productivity (NPFP), which grew with increasing N rate up to 50 Kg ha-1 and decreased with further increasing N doses. The maximum NPFP value (74.4) was achieved from 50 Kg N ha-1, which is significantly higher than the other treatments and it drops to 25.90 when the N dose is increased to 150 Kg ha-1 in 2016. The NPFP value was maximum (69.4) in the second year of the experiment when 50 kg N ha-1 was applied, which is significantly higher and as the nitrogen level was increased further, the NPFP value decreased. The combined analysis of two years data revealed that N partial factor productivity (NPFP) in rice increased from 25.59 to 71.9 with decreasing N application from 150 to 50 Kg ha-1.

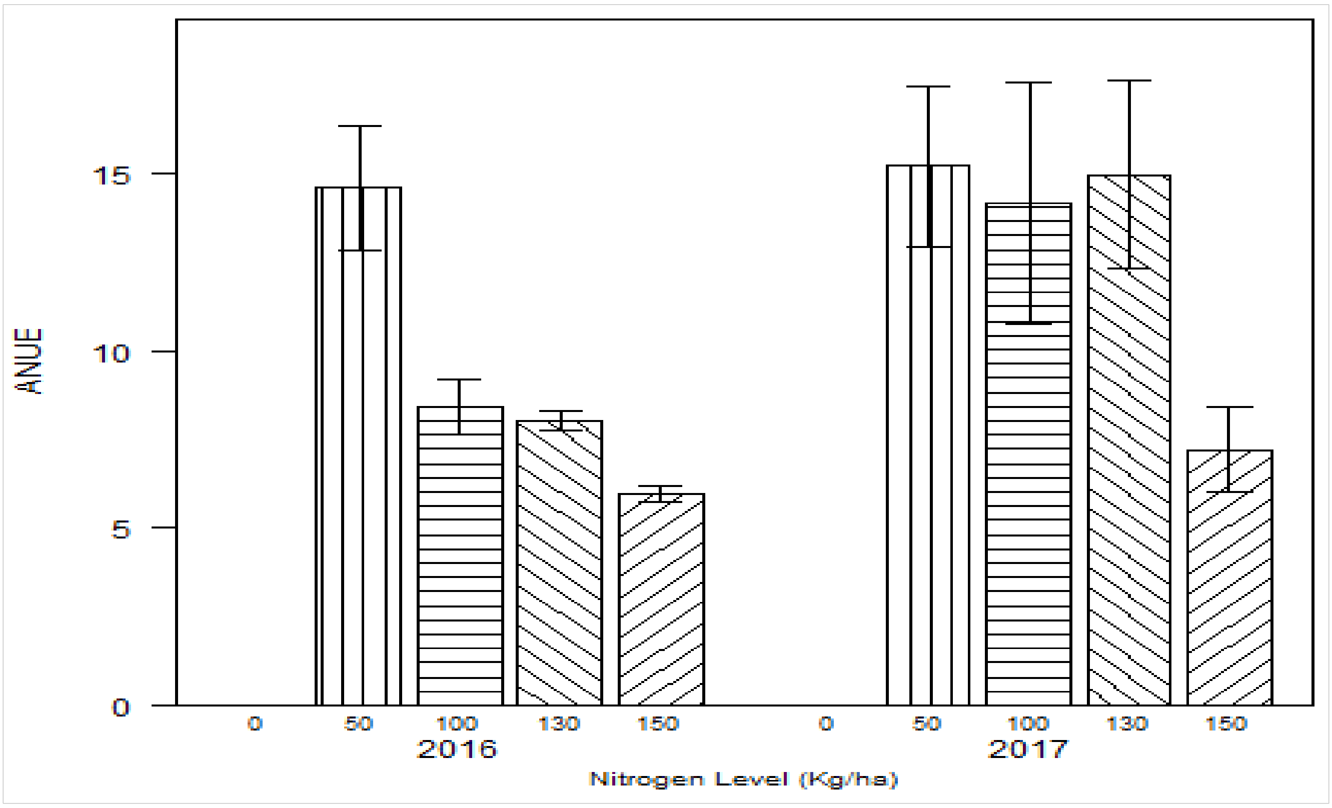

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Figure 1: Effects of different nitrogen doses on ANUE in 2016 and 2017 at Lumle, Kaski.

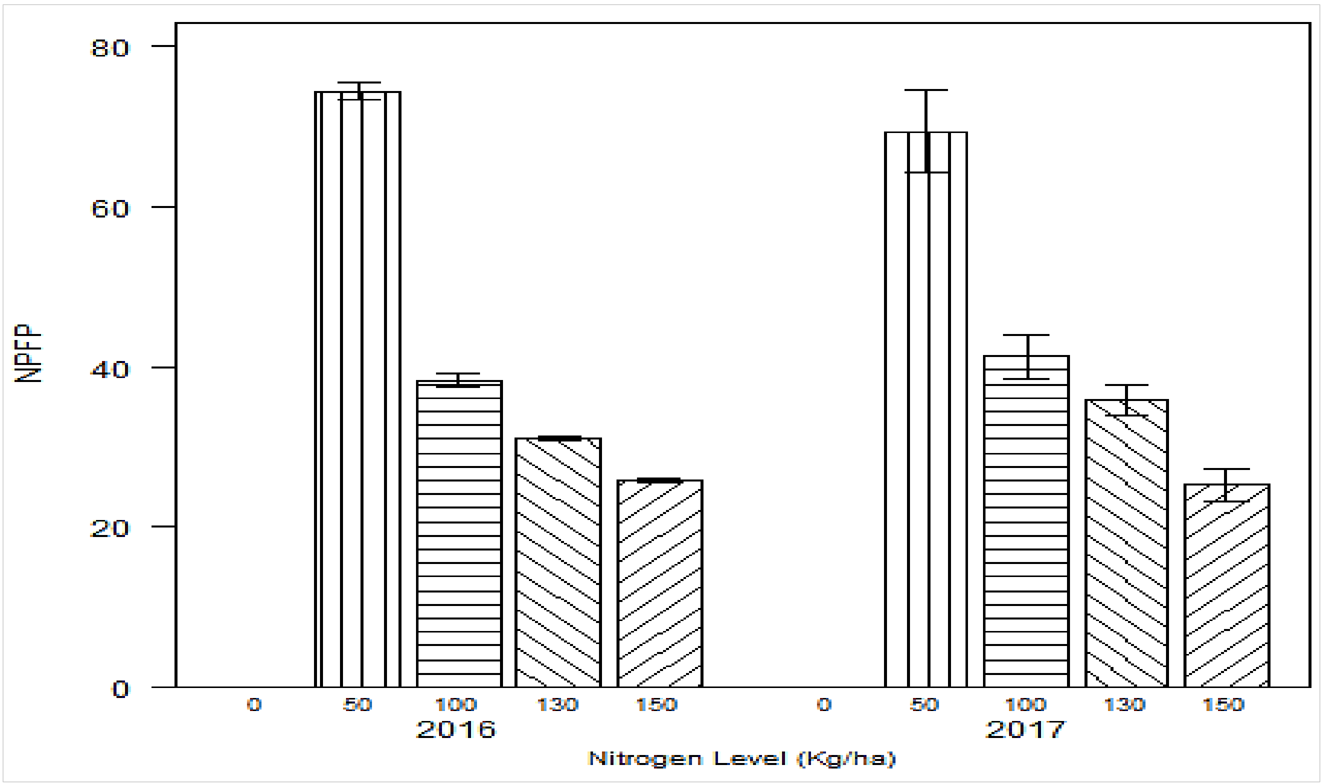

Figure 2: Effects of N doses on NPFP in 2016 and 2017 at Lumle, Kaski.

4. Discussion

Nitrogen is found in amino acids, proteins, enzymes, nucleic acids and chlorophyll, and it is the most yield-limiting nutrient in rice cultivation (Prasad et al., 2017). Enhanced nitrogen levels improved plant growth, which could be linked to nitrogen's stimulating effect on numerous physiological processes like cell division and cell elongation (Kumar et al., 1995; Rea et al., 2019). The number of tillers in each hill increased with the increase of nitrogen contents in the soil (Islam et al., 2008). Adequacy of N most likely favored the cellular activities throughout the panicle formation and development that led to an increased number of tillers (Rea et al., 2019). According to the findings of this study, panicle length increased as nitrogen rates were increased, and the similar result were also reported (Idris and Matin, 1990). As the rate of N fertilizer increases, more nitrogen is contributed to the development, elongation, and length of the panicle (Islam et al., 2008). A sufficient nitrogen supply contributed to plant growth and grain development, which likely enhanced the filled grains number per panicle with increasing N rate up to 130 kg ha^{-1} N. The result found in other similar research clearly supported the current findings, who found that 120 kg N ha^{-1} produced the largest number of grains per panicle (Chander and Pandey, 1996).

The increase in grain yield could be attributable to nitrogen application to boost dry matter production, improve plant growth rate, promote internode elongation, and raise activity of gibberellin (Ghoneim et al., 2018). Increased grain yields, on the other hand, could be linked to nitrogen's function in improving grain yield components such as panicle counts in each hill, length of panicle, filled grains number in each panicle, and their weight (Ghoneim et al., 2018). The production of straw increased as the amount of nitrogen increased (Singh et al., 2000). According to some studies, increasing the dose of N increased rice grain and straw yields (Shah et al., 2013; Gautam et al., 2008). The optimum use of nitrogen in soil had a significant effect on ANUE and NPFP, with higher NUE found at lower N doses. A group researchers came up with a similar finding. Reduced N application rate improves ANUE and NPFP in rice (Saleque et al., 2004; Liu et al., 2016).

5. Conclusion

One of the crucial aspects in increasing rice productivity in Nepal is the application of optimum levels of nitrogen fertilizer. Optimal N application rates can result in increased yield and N use efficiency. Increased nitrogen rates up to 130 kg ha^{-1} significantly improved grain yield, yield components, and nitrogen use efficiency of cold-tolerant rice (Lumle-2) according to the findings of this study. Thus 130 Kg N ha^{-1} can be recommended as optimum dose for profitable cultivation of cold tolerant rice (Lumle-2) for the mid to high hill regions of Nepal.

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