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Effect of Neem Oil Coated and Common Urea with Different Nitrogen Levels on Rice Yield and Nitrogen Use Efficiency (NUE) in Kaski, Nepal

Sandip Timilsina[1,a,*], Asmita Khanal[1,b], Shree Prasad Vista[2,c]

[1]*Nepal Agricultural Research Council, DoAR Gandaki Province, Lumle, Kaski, Nepal*
Horticulture Research Station, Pokhara, Kaski, Nepal
[2]*National Soil Science Research Centre, Khumaltar, Lalitpur, Nepal*
[*]*Corresponding author*

A R T I C L E I N F O

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A B S T R A C T

Rice is the most important staple food crop and plays a vital role in ensuring national food security in Nepal. Rice yield is largely determined by nitrogen management strategy and improving the effectiveness of nitrogenous fertilizer for grain production has long been a challenge. A field experiment was conducted in the sandy loam soil of Lumle, Kaski, Nepal in 2019 and 2020 to assess the effect of neem oil-coated urea (NCU) and common urea (CU) with varying levels of nitrogen (N) on rice yield and nitrogen use efficiency (NUE). The experiment with 7 treatments comprising the combinations of two types of nitrogen source (CU and NCU), three N levels (50, 100, and 150 kg/ha) and one control treatment without N, were allocated in a randomized complete block design with three replications. Increased nitrogen rates up to 100 kg/ha supplied through NCU significantly improved grain yield, yield components, and nitrogen use efficiency of rice. Application of NCU reduced nitrogen fertilizer use by up to 33 % while producing maximum yield and significantly increased agronomic nitrogen use efficiency (ANUE) and nitrogen partial factor productivity (NPFP) compared with CU. This suggests that the use of NCU with an optimum rate can be a viable option for appropriate N management in rice production.

[a] *sandiptimilsina@gmail.com* *https://orcid.org/0000-0001-6157-919X*
[b] *asmitakhanal47@gmail.com* *https://orcid.org/0009-0007-4628-2671*
[c] *spvista002@gmail.com* *https://orcid.org/0000-0002-9008-7001*

Introduction

Rice (*Oryza sativa L.*) is one of the most important staple food crops in Nepal and plays a vital role in ensuring national food security (Gadal et al., 2019; Timilsina and Vista, 2022). It occupies the first place in terms of area and total production (MoALD, 2021). Rice yield potential is greatly affected by the presence of nitrogen; however, increasing the nitrogen (N) consumption rate of the rice plant and the effectiveness of absorbed nitrogen for grain production has long been a challenge. Nitrogen input is one of the most important factors in maximizing rice yields but the application of urea as a major source of nitrogen is inefficient and more amount of applied N is being lost due to leaching, denitrification and volatilization resulting in lower nitrogen use efficiency (NUE).

Nepal does not have a manufacturing plant for chemical fertilizers. All chemical fertilizers are imported, and they are frequently given as aid from other countries. The major inorganic source of nitrogen is common ordinary urea across the country by which the N requirement of the crop is fulfilled. Rice crop consumes the majority of the common ordinary urea (CU) sold in the country. Due to heavy losses of nitrogen through leaching and denitrification, nitrogen use efficiency (NUE) is very low (Yadav et al., 2017). To meet the demand for N, a farmer needs to apply a huge amount of urea to the crops. Excess use of urea results in higher costs, lower returns, and an increased risk of environmental pollution (Timilsina and Vista, 2022). In contrast, crop yields do not increase linearly with the nitrogen application rate, resulting in a decrease in N use efficiency (NUE) and greater N losses (Zhang et al., 2012). A lack of appropriate management and balanced fertilization of crops results in lower crop yields as well as deterioration of the soil's health (Sharma et al., 2003). Therefore, effective N management is a key strategy for improving NUE and rice yield while lowering production costs and soil pollution in rice agroecosystems.

Different N management strategies like multiple split applications and deep placement of N fertilizer can increase rice productivity and NUE while lowering N losses (Baral et al, 2020; Chen et al., 2020). However, compared to conventional procedures, these methods need more labour and expertise in N management and they are constrained by limited knowledge. To improve the efficiency of fertilizer application and minimize N losses, slow-releasing fertilizers are used (Yang et al, 2012; Guo et al, 2016; Rehman et al. 2021). The slow-releasing fertilizers comprise layers of various substances (oils, nutrients), which slow down the fertilizer's quick hydrolysis, prolong the availability of the nutrients, and consequently raise crop production (Naz and Sulaiman, 2016).

Coating urea granules with neem oil (oil extracted from *Azadirachta indica*) to produce neem-coated urea (NCU) has good nitrification inhibitory actions (Singh et al., 2019). NCU slows down the release of nitrogen from urea and makes nitrogen available over a longer period with minimum loss of nitrogen thereby improving NUE and crop productivity (Kumar et al., 2010; Singh et al., 2019; Ghafoor et al., 2021). NCU help to inhibit nitrogen loss besides being absorbed by plants due to volatilization, leaching, runoff and denitrification (Ramappa et al., 2022). When common prilled urea is applied to the soil, amide form of urea is quickly transformed to ammonical nitrogen and consequently to nitrite and nitrate form by the act of nitrifying bacteria. If the process of nitrification is too fast; nitrogen will escape to atmosphere and plants will not be able to recover it from urea efficiently. This implies that there is a need to regulate the urea hydrolysis and nitrification to improve the crop production and nitrogen use efficiency. Thus the objective of this study was to compare the effects of neem oil-coated urea (NCU) and commonly used ordinary prilled urea (CU) with varying levels of nitrogen on rice yield and nitrogen use efficiency.

Materials and Methods

Experimental Site

A field experiment was conducted at the Directorate of Agricultural Research, Gandaki Province, Lumle, Kaski (28°17’ northern latitude, 83°49’ eastern longitude and 1740 meter above sea level) in sandy loam soil from June to November 2019 and 2020 under irrigated conditions. The soil was highly acidic with a sandy loam texture, medium to high range of organic carbon and total nitrogen, high content of available P_2O_5 and medium range of available K_2O and Zn and low content of secondary nutrients and micronutrients except for iron, boron and copper (Table 1).

The monthly variation in rainfall (mm), maximum–minimum and average mean temperatures (°C) during the study period are depicted in Figure 1.

Table 1. Soil physico-chemical properties at the experimental site

Soil parameter	Soil test value	Analysis Method
Soil texture class	Sandy Loam	Hydrometer (Bouyoucos, 1927)
Soil pH	4.9	Potentiometric 1:2.5 (Jackson, 1973)
Soil organic matter (%)	5.4	Walkely Black (Walkely and Black, 1934)
Total nitrogen (%)	0.30	Kjeldahl (Bremner, 1982)
Available P_2O_5 (kg/ha)	405	Modified Olsen’s (Olsen et al., 1954)
Extractable K_2O (kg/ha)	143	Ammonium acetate (Jackson, 1967)
Extractable calcium (mg/kg)	440	EDTA Titration (El Mahi et al.,1987)
Extractable magnesium(mg/kg)	48.9	EDTA Titration (El Mahi et al.,1987)
Available Sulphur (mg/kg)	3.96	Turbidimetric (Verma, 1977)
Available Boron (mg/kg)	2.29	Hot water (Berger and Truog, 1939)
Available Iron (mg/kg)	132.7	DTPA (Lindsay and Norvell, 1978)
Available Zinc (mg/kg)	2.53	DTPA (Lindsay and Norvell, 1978)
Available Manganese (mg/kg)	2.79	DTPA (Lindsay and Norvell, 1978)
Available Copper (mg/kg)	22.53	DTPA (Lindsay and Norvell, 1978)

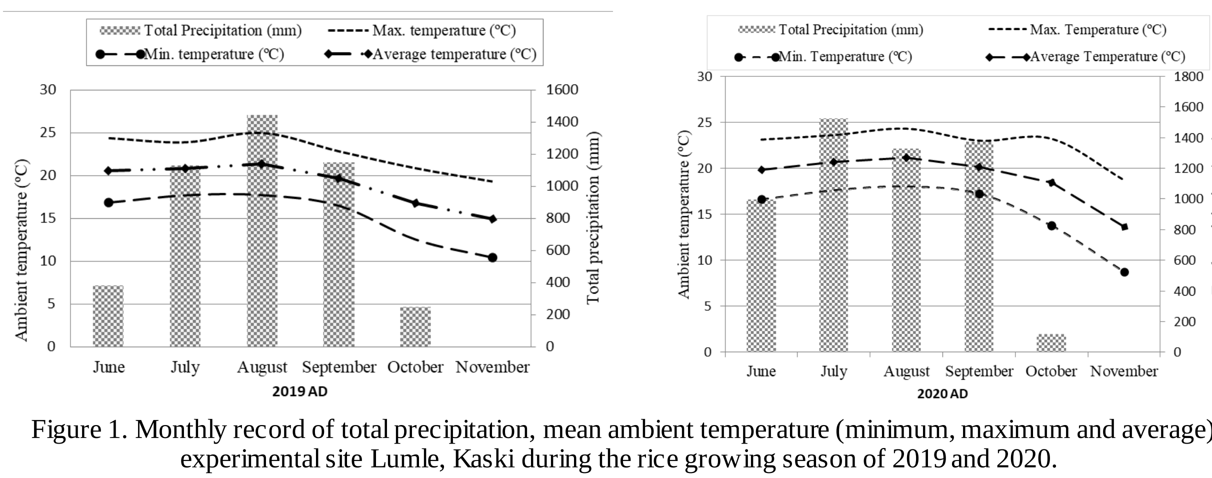

Figure 1. Monthly record of total precipitation, mean ambient temperature (minimum, maximum and average) of experimental site Lumle, Kaski during the rice growing season of 2019 and 2020.

Table 2. Treatment details of the experiment

S.N	Treatment symbol	Treatment details
1	T1	Application of 50 kg/ha N as common urea (CU)
2	T2	Application of 50 kg/ha N as neem coated urea(NCU)
3	T3	Application of 100 kg/ha N as CU
4	T4	Application of 100 kg/ha N as NCU
5	T5	Application of 150 kg/ha N as CU
6	T6	Application of 150 kg/ha N as NCU
7	T7	No application of N from chemical fertilizer (Control)

Experimental Setup and Crop Management

The experiment set up consisted of seven treatments comprising combinations of two types of sources of nitrogen (common urea and neem oil-coated urea) and three N levels (50, 100, and 150 kg N ha^{-1}) plus one control treatment without nitrogen from the chemical source (Table 2) were allocated in a randomized block design with three replication. One of the popular cold tolerant rice variety 'Chhomrong' was transplanted in the second week of July at a crop geometry of 20 cm × 16 cm in each experimental unit of 8 m^2 plot size. The rice variety 'Chhomrong' is a coarse grain variety recommended for mid to high-hill areas of Nepal with a cold climate. Two to three seedlings of 30 days' age were transplanted per hill in 2–3 cm standing water. The basal dose of 10 t ha^{-1} Farm Yard Manure (FYM), 30 kg ha^{-1} phosphorus (P_2O_5) as single supper phosphate (SSP) and 30 kg ha^{-1} potassium (K_2O) as muriate of potash (MOP) was applied just before puddling in all experimental units.

Neem oil coated urea (NCU) and common ordinary urea (CU) were used as nitrogen source. Urea, also known as carbamide, is an organic compound with chemical formula $CO(NH_2)_2$. Neem coated urea (NCU), which has various slow-release properties and delayed nitrification, is made by coating urea granules with neem oil (Singh et al., 2019). A negligible quantity of neem oil as a bio-based material is used to coat on urea (Ramappa et al., 2022). Both types of urea contain 46% N. Three doses of nitrogen, 50, 100, and 150 kg/ha were used in three splits, ½ N as basal, ¼ N at tillering, and ¼ N at panicle initiation stages as CU and only 2 splits, i.e. ½ N as basal and ½ at tillering stage as NCU. A depth of 5 ± 2 cm of water was maintained and adequate measures were followed to minimize the seepage and overflow losses of applied water to the adjacent plots. Throughout the crop's growth period, the experiments received consistent plant protection and other cultural management practices.

Data Recording and Analysis

Yield and yield components such as grain yield, straw weight, number of tillers per plant, panicle length, plant height and parameters used for measuring nutrient use efficiency were recorded at respective crop growth stages. Composite soil samples and plant straw samples were taken after crop harvest for the determination of total nitrogen content in soil and plant tissue as described by Bremner (1982). This study used two parameters of NUE, agronomic N use efficiency (ANUE) and N partial factor productivity (NPFP). ANUE was estimated based on grain yield advantage divided by nitrogen application rate (Cassman et al., 1996). This eliminates the contribution of indigenous N in soil-floodwaters to NUE.

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

Where Y_N= Grain yield in kg ha^{-1} for plots fertilized with nitrogen,

Y_0= Grain yield in kg ha^{-1} of plots non fertilized with nitrogen and

Nitrogen rate = Amount of N used 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, the Statistical tool for agricultural research (STAR) version 2.0.1 were used, and the significance was determined using Fisher's least significant difference at $P<0.05$ (Gomez and Gomez, 1984).

Results

In the experiment yield attributing characters viz; plant height, no of tillers per plant, straw yield and grain yield were found significant while panicle length was insignificant due to the effect of neem oil coated or common urea in different levels of nitrogen.

Plant Height

The plant height of rice increased significantly with each successive level of nitrogen up to 150 kg/ha in both consecutive years of the experiment but neem oil coated and common ordinary urea have a similar effect on plant height. In the first year of the experiment, the highest plant height (137.07 cm) was observed in treatment with 150 kg/ha nitrogen as NCU which was statistically identical to treatments with 100 kg/ha as CU, 100 kg/ha as NCU and 150 kg/ha as CU but superior over treatments with N control 50 kg/ha nitrogen either from CU or NCU. The application of 100 to 150 kg/ha N produced the tallest plants which were significantly taller than the application of 50 kg/ha and the shortest from the control treatment. Types of urea have insignificant effects in the second year of the experiment.

Number of Tillers Per Plant

A significant increase in no of tillers per plant was recorded only when N dose exceeding 50 kg/ha. The application of 150 kg/ha N as NCU produced the maximum no of tillers (9.40) in the first year and 100 kg/ha N as NCU produced maximum tillers (9.87) in the second year which were statistically similar to 100 and 150 kg/ha N application but significantly higher from the application of 50 kg/ha N irrespective of coating and non-coating urea.

Panicle Length

Panicle lengths were not significantly affected by the use of neem oil coated and general urea with different levels of nitrogen in both years. The pooled analysis of two years of data revealed that the application of neem oil-coated urea at 100 kg/ha produced the longest panicle (23.87 cm) but that was statistically similar with other treatments and the shortest panicle (21.9 cm) observed at control treatment (Table 3).

Straw Yield

The straw yield of rice increased significantly with nitrogen levels up to 50 kg/ha and above that level, results were similar in both types of urea during the first year of the experiment. The application of NCU at 150 kg/ha produced the highest straw yield (12.80 t/ha) in the 2nd year of the experiment which was significantly higher from the other treatments. From the pooled analysis of data from two years, the highest straw yield was obtained at application of 150 kg/ha N as NCU which was significantly higher (13.67 t/ha) than control and similar to 50 to 100 kg/ha N as CU or NCU (Table 3).

Grain Yield

Both N sources (CU and NCU) in different N Levels made significant effects on rice grain yield. Increased nitrogen rates from 0 to 100 kg/ha N considerably increased grain yield, with NCU at 100 kg/ha application yielding the maximum grain yield and treatment without nitrogen application (control) yielding the lowest grain yield in both years (Table 3). In the first year of the experiment, the highest grain yield (5.01 t/ha) was obtained from the application of NCU at 100 kg/ha, which was statistically equivalent to the grain yield from the application of 50 to 150 kg NCU and 100 to 150 kg CU but significantly higher from CU at 50 kg/ha N and control treatment (Table 3). Similarly, the highest grain yield (6.01 t/ha) was obtained from NCU at 100 kg/ha which was statistically similar to 150 kg/ha N from CU and NCU but significantly superior to the rests of the treatments and the lowest (3.49 t/ha) was obtained from the control treatment at the second year of the experiment. The grain yield data of two years after pooled analysis revealed that the grain yield from NCU at 100 Kg/ha N was significantly higher (5.51 t/ha) followed by 150 kg N from NCU, 100 kg N from CU and 150 kg N from CU and the lowest (3.31 t/ha) in the control treatment (Table 3).

Table 3. Performances of neem-oil coated (NCU) and common urea (CU) with different N-levels on yield and yield attributing components of rice at Lumle, Kaski

Treatments	Plant Height (cm)	No of Tillers /plant	Panicle Length (cm)	Straw Yield (t/ha)	Grain Yield (t/ha)
1st Year of Experiment (2019)					
T1	116.13 cd	7.73 bc	22.33	13.47 a	4.13 b
T2	122.80 bc	7.20 bc	22.53	13.43 a	4.74 a
T3	131.53 ab	8.27 ab	23.80	14.63 a	4.79 a
T4	125.67 abc	7.87 ab	23.40	14.97 a	5.01 a
T5	135.87 ab	9.33 a	23.53	14.50 a	4.61 a
T6	137.07 a	9.40 a	23.93	14.53 a	4.67 a
T7	105.27 d	6.20 c	22.87	9.23 b	3.13 c
Mean	124.9	8.00	23.34	13.54	4.44
CV%	5.96	11.00	4.24	12.12	5.66
P Value	0.02	0.008	0.21	0.01	0.001
$LSD_{0.05}$	13.23	1.56	NS	2.92	0.45
2nd Year of Experiment (2020)					
T1	127.97 b	7.93 c	22.67	9.73 c	4.71 c
T2	131.00 b	8.13 bc	22.67	10.33 bc	4.84 c
T3	139.07 a	9.60 a	23.13	11.43 ab	5.45 b
T4	139.23 a	9.87 a	23.33	10.73 bc	6.01 a
T5	141.47 a	9.00 abc	22.40	11.77 ab	5.74 ab
T6	140.00 a	9.33 ab	22.13	12.80 a	5.82 ab
T7	117.67 c	6.00 d	20.93	6.63 d	3.49 d
Mean	133.77	8.55	22.47	12.01	5.15
CV%	10.53	8.75	3.91	19.97	4.38
P Value	0.001	0.005	0.09	0.004	0.0001
$LSD_{0.05}$	3.64	1.33	NS	1.55	0.45
Combined analysis of 2019 and 2020					
T1	122.05 c	7.83 bc	22.60	11.60 a	4.42 c
T2	126.9 bc	7.67 c	22.60	11.88 a	4.79 bc
T3	135.30 ab	8.93 ab	23.47	13.03 a	5.12 ab
T4	132.45 ab	8.87 abc	23.87	12.85 a	5.51 a
T5	138.67 a	9.20 a	22.87	13.13 a	4.17 ab
T6	138.53 a	9.33 a	23.03	13.67 a	5.42 ab
T7	111.47 d	6.10 d	21.90	7.93 b	3.31 d
Mean	129.34	8.28	22.90	12.01	4.79
CV%	5.66	12.54	4.95	19.97	10.40
P Value	0.001	0.001	0.10	0.004	0.001
$LSD_{0.05}$	13.23	1.21	NS	2.91	0.58

Table 4. Total N content in rice plant tissue and soil after rice harvest as affected by neem-oil coated and common urea with different N-levels at Lumle, Kaski during 2019 and 2020.

Treatments	Total N in soil after rice harvest (%)			Total N in plant tissue during harvesting (%)		
	2019	2020	Average	2019	2020	Average
T1	0.33 cd	0.29 b	0.31 b	1.28 bc	1.29 b	1.29 c
T2	0.32 d	0.30 ab	0.31 b	1.47 ab	1.40 ab	1.44 b
T3	0.34 bcd	0.31 ab	0.33 ab	1.51 ab	1.49 a	1.51 ab
T4	0.35 abc	0.32 a	0.33 ab	1.55 a	1.52 a	1.52 ab
T5	0.36 ab	0.31 ab	0.34 ab	1.55 a	1.54 a	1.55 a
T6	0.37 a	0.32 a	0.35 a	1.56 a	1.55 a	1.55 a
T7	0.28 e	0.26 c	0.27 c	1.06 c	0.99 c	1.03 d
Mean	0.33	0.30	0.32	1.43	1.40	1.41
CV%	3.36	3.38	6.63	8.88	6.31	6.83
P Value	0.001	0.006	0.001	0.003	0.001	0.001
$LSD_{0.05}$	0.02	0.02		0.22	0.16	0.11

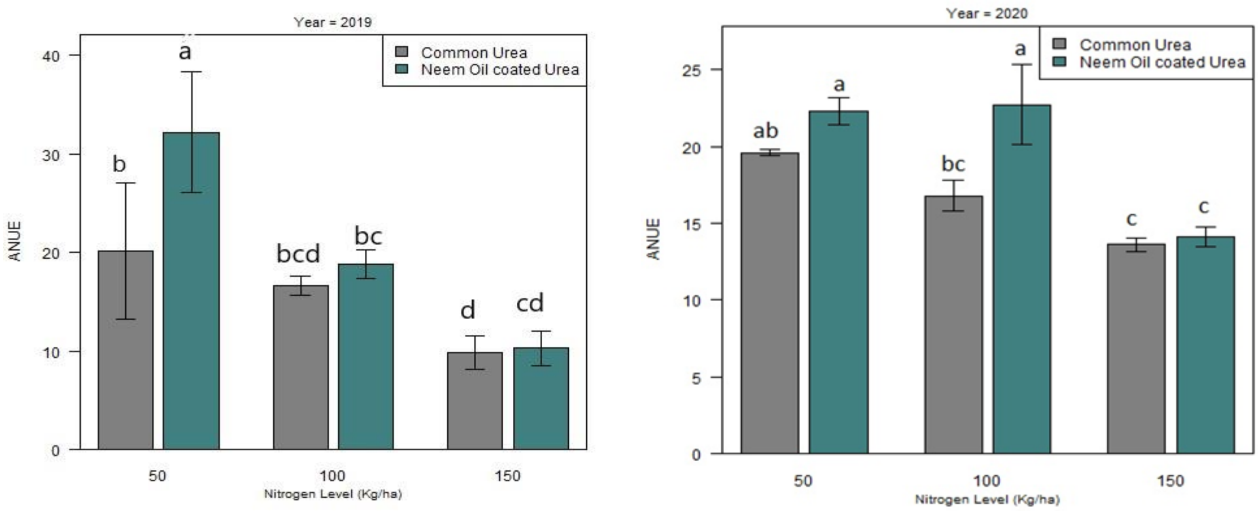

Figure 2. Effects of neem-oil coated (NCU) and common urea (CU) with different N-levels on agronomic nitrogen use efficiency (ANUE) in rice during 2019 and 2020 at Lumle Kaski.

Nitrogen Content in Soil and Rice Plant Tissue

Total nitrogen content in the soil after rice harvest significantly increased with each successive level of nitrogen application and the highest values were recorded at 150 kg/ha N supplied through NCU in both consecutive years of the experiment (Table 4). NCU-applied soil had the highest total nitrogen concentration as compared to CU-applied soil and total N content in soil significantly increased with an increased levels of nitrogen. Similarly, the total N content in rice plant tissue at the time of harvest significantly differed with the use of neem oil coated and common urea with different level of N. The N content in rice plant tissue increased significantly from control to application of 100 kg/ha N that similar to 150 kg/ha N application. In contrast, fertilizer application at ≥100 kg/ha N had a similar effects on N concentration in plant tissue but below that level, NCU-applied soil had a significant effect on N concentration of rice plant tissue and recorded significantly higher values than common urea (Table 4).

Nitrogen Use Efficiency

Agronomic nitrogen use efficiency (ANUE)

The application of neem oil coated (NCU) and common urea (CU) in different N levels significantly affected the agronomic nitrogen use efficiency in rice. The use of NCU had a significantly higher ANUE values as compared to CU in all levels of N (Figure 2). Nitrogen levels had a significant effect on agronomic nitrogen use efficiency (ANUE) which increased with N level up to 50 kg/ha N, then decreased with increasing N application rates at the first year of the experiment in the case of both types of urea. The highest value of ANUE (32.20) was obtained with the application of 50 kg/ha N from NCU which is significantly higher than the rest of the treatments in 2019. The maximum ANUE value was obtained in the second year of the experiment with the application of NCU at 100 kg/ha N which was statistically similar to NCU at 50 kg/ha N and the lowest ANUE value was recorded with the application of the highest nitrogen rates irrespective of source. The combined analysis of two-years data revealed that Agronomic nitrogen use efficiency (NUE) in rice increased from 11.73 to 19.87 in the case of CU and from 12.19 to 27.27 in the case of NCU with decreasing N application rate from 150 to 50 kg/ha but NCU at 50 kg/ha N have significantly the highest value of ANUE among the treatments.

N partial factor productivity (NPFP)

During both years of the experiment, nitrogen application supplied from CU and NCU with different rates had significant effects on N partial factor productivity (NPFP), which increased with N level up to 50 kg/ha and decreased with increasing N application rate.

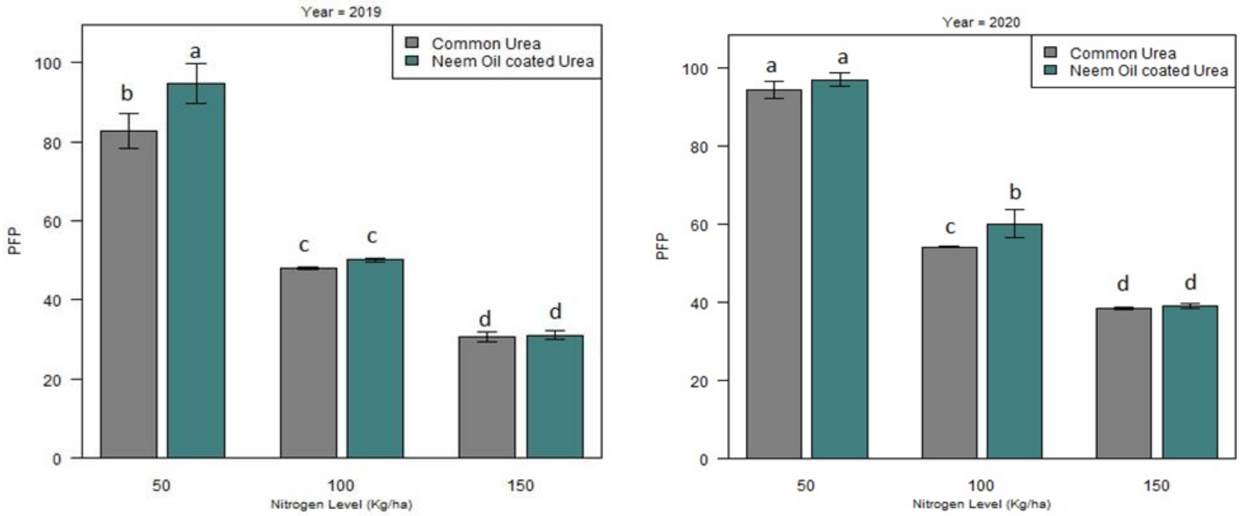

Figure 3. Effects of neem-oil coated (NCU) and common urea (CU) with different N-levels on N partial factor productivity (NPFP) in rice during 2019 and 2020 at Lumle, Kaski.

The maximum NPFP value (94.73) was achieved at application of 50 kg/ha as NCU, which was significantly higher than the other treatments and it dropped to 31.11 when the N level was increased to 150 kg/ha^{1} in 2019. The NPFP value was maximum (96.93) in the second year of the experiment when 50 kg/ha N was applied as NCU, which was significantly higher and as the N 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 34.60 to 95.83 with decreasing N application rates from 150 to 50 kg/ha. In contrast at the same level of N at 50 kg/ha, NCU had 8.32 % more NPFP value as compared to CU.

Discussion

Optimizing nitrogen rate and management strategy increased N use efficiency in rice and hence reduced N fertilizer requirements and improved yields. The results of our study show that the application of N in the form of NCU has a higher potential to raise the yield as well as nitrogen use efficiency and the yields recorded in N fertilized plots were much higher when compared with the control treatment. The application of NCU reduced nitrogen fertilizer use by up to 33 % while producing the maximum yield of rice compared to CU. The studies conducted by Singh et al. (2019) and Nagabhushanam and Bhatt (2020) reported that NCU was found to be beneficial compared to CU in improving the growth parameters, yield attributing characters and yield of rice. Increased rice grain yield despite the lower level of N fertilizer is due to the continuous supply of N as coated urea releases N slowly and available for a long period of crop growing season. As NCU is coated with neem oil, which releases nitrogen in soils very slowly, the rate of N release synchronizes with the plant's requirement (Trenkel, 1997; Wang et al. 2020). Due to proper synchrony between plant demand and N availability in the soil, nitrogen uptake by rice plants increases leading to increased grain yield (Geng et al., 2016; Wang et al., 2018; Chen et al., 2020). The coatings of different emulsions help to retain urea in the field for a long time to increase the yield and improve the crop qualities (Singh et al., 2019). In a study conducted by Pandit et al. (2021) have a similar result and they reported the application of polymer-coated urea reduced N fertilizer use by 22-50 % while increasing crop yield compared to conventional urea. Moreover, Baral et al. (2020) reported maximum rice yield with the application of urea briquette at 22 % less nitrogen rate compared with the conventional practice of urea use. Chen et al. (2020) also reported reductions in the application rates of N fertilizer by 20% with the use of control release urea (CRU) compared to conventional practice and that improved nitrogen use efficiency in rice.

The yield and yield attributing parameters recorded were superior in N-fertilized plots up to a certain level compared to control treatments. The plant height was increased with the increasing levels of N. The application of N improves various physiological processes including cell division and cell elongation of the rice plant induced maximum vegetative growth and increase plant height (Rea et al., 2019). A similar result at the same location was found by Timilsina et al. (2018), who found that the plant height increased with increasing levels of N up to 150 kg/ha and the shortest from control. The number of tillers per hill increased with the increases in nitrogen levels. CU has a higher number of tillers per hill up to 100 kg/ha N level and that may be due to the fast availability of N during the early stage of crop growth compared to NCU but that does not have a significant effect on grain yield. Adequacy of nitrogen probably favoured the cellular activities and development that led to an increased number of tillers per hill (Rea et al., 2019). Panicle length increased with increasing nitrogen rates. Nitrogen contributed to panicle formation, elongation and length increase with increasing rates of N fertilizer. Timilsina et al. (2018) reported similar results. Pushpanathan et al. (2005) reported NCU improved the yield attributing parameters like productive tillers, panicle length, fertile spikelets per panicle and 1000 grain weight when applied at the proper time and dose. The increase in grain yield could be attributable to nitrogen application to boost dry matter production, improve rice growth rate, promote internode elongation, and raise gibberellin activity (Ghoneim et al., 2018). These results are supported by the findings of Singh et al. (2000). Increased grain yields, on the other hand, could be linked to nitrogen's function in improving grain yield components such as panicle numbers per hill, panicle length, number of filled grains per panicle, and panicle weight (Ghoneim et al., 2018). The production of straw increased as the amount of nitrogen in the soil increased. Timilsina et al. (2018) and Singh et al. (2000) discovered similar results. The results of Shah et al. (2013) and Gautam et al. (2008) also showed that increasing nitrogen rates increased rice grain and straw yields.

Our study determined that coated urea improved ANUE and NPFP compared with common urea in both years. These results are in close agreement with previous studies (Baral et al., 2020; Chen et al., 2020; Pandit et al., 2022). The study carried out by Baral, et al. (2020) reported that ANUE and NPFP increased 34% and 44% from the use of urea briquette with 22% less N supply respectively in rice compared with the recommended practice of conventional urea. Increased NUE was due to the slow release of N, the synchrony between N supply and plant demand and reducing the losses of nitrogen to the environment (Geng et al., 2016; Wang et al., 2018; Chen et al., 2020). According to Chen et al. (2020), polymer-coated urea saved 20% N fertilizer and improved agronomic NUE from 15 to 84% without any yield penalty. Similar research conducted by Pandit et al. (2022) reported that polymer-coated urea and urea briquette significantly increased ANUE and NPFP compared with CU. Nitrogen application rate had a significant effect on agronomic nitrogen use efficiency (ANUE) and nitrogen partial factor productivity (NPFP), with higher NUE found at lower N doses. Similar results were reported by Timilsina and Vista. (2022), where ANUE and NPFP in rice increased with decreasing N application rate from 150 to 50 kg/ha. Liu et al. (2016) reported reduced N application rate improves ANUE and NPFP in rice.

Conclusion

This study suggests that the application of neem oil-coated urea (NCU) has a higher potential to increase yield as well as nitrogen use efficiency in rice production. The application of NCU could reduce the optimum rate of N fertilizers while producing a maximum yield of rice as compared to the conventional practice of common urea (CU) application. Increased nitrogen rates up to 100 kg/ha supplied through NCU significantly improved grain yield, yield components, and nitrogen use efficiency of rice in the hilly areas of Nepal. The result indicates that the use of NCU can be a viable option for appropriate N management and has the potential to improve nitrogen use efficiencies. However, further research is needed to conduct across different commodities, cropping systems, agro ecological zones and agronomic practices to endorse this result.

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