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Growth, yield, economics, and nitrogen use efficiency of transplanted rice (*Oryza sativa* L.) as influenced by different nitrogen management practices through neem (*Azadirachta indica*) coated urea

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Abstract
Although neem coated urea (NCU) has been found to increase nitrogen use efficiency in transplanted rice, there is a lack of information regarding its dose and split schedule. Keeping this in view, a field experiment was conducted at G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. Results showed that the maximum increment in growth, yield, and economics of rice was achieved with the application of 125% RDN through NCU with 50:25:25 split schedule at basal, AT and PI stages over application of 100% RDN through prilled urea with the same split schedule (existing practice). Further, application of 100% RDN through NCU with 50:25:25 or 33.3:33.3:33.3 split schedule at basal, AT and PI stages was found to enhance AE and PFP of applied nitrogen fertilizer over existing practice with improved growth, yield, and economics of rice.

Keywords: Growth, yield, economics, nitrogen use efficiency, neem coated urea, transplanted rice

Introduction
Rice (*Oryza sativa* L.) is the most important staple crop of the world feeding more than 50% of its population on a daily basis. Approximately, 750 million poorest people in the world depend on rice for their survival (Zeigler, 2007) [1]. It also occupies a pivotal place in Indian agriculture with respect to area and fertilizer use (Shivay *et al.*, 2016) [2]. Nitrogen (N) is an important element in the soil and the biosphere (O'Hara *et al.*, 2002) [3]. It is a very crucial nutrient required for rice growth and yield, and in its absence, the yield reduces drastically (Hirzel *et al.*, 2011) [4]. In the soil, nitrogen is lost through nitrate-nitrogen (NO_3-N) leaching, ammonia (NH_4^+) volatilization, surface runoff, and denitrification that is why the efficiency of applied nitrogen fertilizer is only 20-50% (Shivay *et al.*, 2005) [5]. This low nitrogen use efficiency in the rice fields is of great concern (Fageria *et al.*, 2003; Ladha *et al.*, 2005; Shivay *et al.*, 2016) [6, 7, 2]. Approximately, 90% of the nitrogenous fertilizers applied worldwide contain nitrogen in NH_4^+ form or is converted to NH^+ after urea hydrolysis which is rapidly oxidized to NO_3^- by soil nitrifying bacteria (Strong and Cooper, 1992) [8]. The NO_3^- formed is subjected to leaching and denitrification losses and is lost from the root zone (Subbarao *et al.*, 2006) [9]. So, the fast transformation is the principal cause of lower use efficiency of both applied and soil nitrogen. These losses can be minimized if it is preserved in ammonium form for a fairly long period of time. Addition of nitrification inhibitors with N fertilizers is one of the important methods of maintaining nitrogen in NH_4^+ form (Kumar *et al.*, 2015) [10]. Though a number of NIs (nitrapyrin, dicyandiamide, ammonium thiosulphate *etc.*) has been developed, they are still unpopular among resource-poor Asian farmers due to their high cost and limited availability (Kumar *et al.*, 2010) [11]. On the other hand, neem coated urea (NCU) which is an indigenous nitrification inhibitor and have been reported to increase the growth, yield, uptake, and use efficiency of applied nitrogen fertilizer in rice (Shivay *et al.*, 2001; Singh and Shivay, 2003; Kumar and Shivay, 2009; Thind *et al.*, 2010) [12, 13, 14, 15]. Recently with the decision of the government of India in 2015 to produce the entire amount of urea produced in the country as NCU, there is a need to quantify its rate of application in transplanted rice. In addition, altering

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the split doses according to the crop growth stages may synchronize the supply of nitrogen with that of the plant demand, and help augment NUE and productivity. But there is lack of information regarding the dose and split schedule of neem coated urea in transplanted rice. Hence, the present study was undertaken with the objectives (i) to study the different N management strategies on growth and yield of transplanted rice, and (ii) to study the effect of different N management strategies on economics of cultivation and nitrogen use efficiency in rice transplanted rice.

Materials and Methods
Description of experimental site
A field experiment was conducted during the *Kharif* (rainy) season of 2016 in the A_2 block at N. E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India. Geographically, it is located at 29˚N latitude, 79˚29' E longitude and at an altitude of 243.84 m above mean sea level. This region enjoys sub-humid, sub-tropical climate with dry summer and cool winter. The maximum temperature exceeds 42.5ºC during hot summer in the month of May and June, and minimum temperature occasionally falls below 1ºC during winter in the month of December and January. The mean annual rainfall is about 1410 mm, of which 90% is received from June to September.

The soil of experimental field was silt loam in texture, of alluvial origin and classified as Aquic hapludoll (Deshpande *et al.*, 1971) [16]. The chemical analysis of upper 20 cm soil showed that it had 224 kg ha^{-1} alkaline $KMnO_4$ oxidizable nitrogen (Subbiah and Asija 1956) [17], 20.6 kg ha^{-1} available phosphorus (Olsen *et al.*, 1954) [18], 211 kg ha^{-1} 1 N neutral ammonium acetate exchangeable potassium (Hanway and Heidel, 1952) [19] and 0.88% organic carbon (Walkley and Black, 1934) [20]. The pH of the soil was 7.6 (1:2.5 soil: water ratio) (Jackson, 1973) [21].

Experimental treatments and design
Ten treatments (Table 1) were tested in a randomized block design with 3 replications. The gross and net experimental plots were of size 5.0 m × 4.0 m and 4.2 m × 2.4 m, respectively.

Application of treatments and fertilizers
The experimental field was ploughed once by disc plough followed by two cross disc harrowing and levelling. The individual plot was first prepared with power tiller and then manually by spade. Two days before transplanting, the layout was shaped and bunds were prepared. The individual plot was flooded with water and then puddling followed by levelling was done manually. Phosphorus @ 60 kg ha^{-1} P_2O_5 was applied through single super phosphate (SSP) and potassium @ 40 kg ha^{-1} K_2O was applied through muriate of potash. The full dose of phosphorus and potassium fertilizer and nitrogen as per the treatment (Table 1) were applied just before transplanting on drained puddle surface and incorporated into the top 20 cm soil manually with the help of spade. The remaining quantity of nitrogen was top dressed as per the treatment (Table 1) at active tillering (24 days after transplanting (DAT)) and panicle initiation (46 DAT) stages.

Crop management
Four-week-old seedlings of rice variety "HKR-47" was transplanted in rows with the help of nylon rope at a spacing of 20 cm × 20 cm keeping two seedlings per hill on 25th June 2016. It is a medium duration (135 days), semi-dwarf high yielding indica rice variety with long slender grains of golden yellow colour. The yield potential of this variety is 45-50 q ha^{-1}. After 10 and 20 days of transplanting, the missing hills in the plots were replanted (gap filled) with the seedling of the same age so as to maintain required plant population. A thin film (2-3 cm) of water was maintained during the initial stage up to the seedling establishment, thereafter the water level was gradually raised to 5 cm and irrigation was applied 2 days after the disappearance of ponded water. All other crop management was done with recommended package of practices.

Studies on growth and yield attributing characters
Growth observations were taken from the selected 3rd and 4th hills from 3rd and 4th row from four corners of experimental plot thus, they constitute 16 hills (4 units of 2 × 2 hills location in the third and fourth row at the four corners of the plot). Plant height was measured at 30, 60 and 90 DAT and at harvest on the selected 16 hills and averaged to express it in cm. This was measured with the help of a meter scale from the base of the hill to the tip of top most leaf up to flowering stage but to the tallest tip of the panicle at harvest. The number of tillers of these selected 16 hills was counted and converted to 1 m[2] at 30, 60 and 90 DAT and at harvest stage of the crop. At harvest, the selected 16 hills were cut close to the ground level and used for taking data on yield parameters. Panicles from the 16 hills were counted and then converted to one m[2]. The length of 10 randomly selected panicles from the selected hills was measured starting from the base (last node of culm) of the first branch of rachis to the top of the panicle and averaged to report panicle length (cm). To work out grain weight per panicle, the total grain weight of 16 hills was divided by the total number of panicles and reported as grain weight panicle[-1]. After counting the number of panicles, the spikelets (filled and unfilled) were threshed and cleaned manually. The filled and unfilled spikelets were separated and weighed separately. A sample of 1000 grains taken from both filled spikelets as well as unfilled spikelets and weighed separately. The number of filled and unfilled spikelets and spikelet sterility percentage was obtained by the following formula:

$$\text{(a)} \quad \text{Number of filled spikelets m}^{-2} = \frac{\text{Weight of filled spikelets per m}^2}{\text{Weight of 1000 filled spikelets}} \times 1000$$

$$\text{(b)} \quad \text{Number of unfilled spikelets m}^{-2} = \frac{\text{Weight of unfilled spikelets per m}^2}{\text{Weight of 1000 unfilled spikelets}} \times 1000$$

$$\text{(c)} \quad \text{Spikelet sterility (\%)} = \frac{\text{Number of sterile spikelets per m}^2}{\text{Total (filled + unfilled) number of spikelets per m}^2} \times 100$$

For 1000-grain weight, a thousand grains were drawn from the bulk of filled grains of the selected 16 hills of individual plot and the weight was recorded and expressed as 1000-grain weight

Yield and harvest index of rice

Harvesting was done manually when more than 90 percent of grains in the panicle were fully ripe and free from greenish tint. After removing border plants as well as sampling area, the individual net plots (10.08 m^2) were measured and harvested manually. After sun drying for 3-4 days, the harvested produce of individual plot was threshed by a Pullman thresher. The grains were collected separately in cloth bags during threshing and after that cleaning and drying of grains were done and grain yield was recorded in kg per plot and later converted into kg ha^{-1} at 14 percent moisture. On the basis of grain to straw ratio, obtained from the plant sample of 16 hills, straw yield was calculated from the grain yield of the individual plot and was expressed as kg ha^{-1}. The total biological yield was obtained by adding grain and straw yield of individual plot and expressed as kg ha^{-1}. Harvest index (HI) was calculated as follow:

HI (%) = (Grain yield (kg ha^{-1}) × 100)/ (Total biological yield (kg ha^{-1}))

Economics

During experimentation, added cost due to different treatments was calculated considering the price of seed, fertilizer, herbicides, weeding *etc.* Total man-days required were worked out considering 8 hours' work of one man equivalent to one man per day. The actual man-days required for spraying and weeding were recorded at the time of treatments. Labour charges were also calculated during crop growth duration. Cost of cultivation under different treatments was calculated considering added cost due to fertilizers and other inputs and uniform cost of other cultural operations and inputs. Gross return was calculated by adding the sale price of grain and straw. Grains were sold as per the minimum support price declared by the government of India (INR 1470/quintal) and straw was sold at a prevailing price of INR 150/quintal at the farm. The net return (INR ha^{-1}) and benefit: cost ratio was calculated with the help of the following formula:

Net return (INR ha^{-1}) = Gross return (INR ha^{-1}) - Cost of cultivation (INR ha^{-1})

$$\text{Benefit: cost ratio} = \frac{\text{Net return (INR. ha}^{-1})}{\text{Cost of cultivation (INR ha}^{-1})}$$

Nitrogen use efficiency

Nitrogen use efficiency was expressed by partial factor productivity (PFP) and agronomic efficiency (AE) of applied fertilizer nitrogen, which were calculated as per Singh and Shivay (2003) [13].

PFP (kg grain kg^{-1} N applied) = (Yf)/(Na)

AE (kg grain increase kg^{-1} N applied) = (Yf – Yc)/(Na)

Where Yf and Yc are the grain yield in nitrogen fertilized and control plots, respectively and Na is the amount of nitrogen applied (kg ha^{-1}).

Statistical analysis

The observations recorded during the course of the investigation were analyzed in randomized complete block design as described by Gomez and Gomez (1984) [22]. The significance of treatments was tested by 'F' test. The difference in the treatment means was tested by using least significance difference (LSD) at 5% level of significance. Graphs were prepared using Microsoft Office Excel 2007.

Results and Discussion
Growth attributes
Plant height

The plant height was significantly influenced by different nitrogen management practices at 30, 60, 90 DAT and at harvest (Figure 1). The plant height increased continuously with the advancement of crop age up to 90 DAT and thereafter, it reduced slightly. This might be due to shrinkage of panicle at the time of full maturity. At all the growth stages, application of 150 kg N ha^{-1} through NCU as 50% basal, 25% at AT and 25% at PI (^{150}NCU$_{50, 25, 25}$) recorded the highest plant height except for 30 DAT. At 30 DAT, the highest plant height was recorded with ^{120}NCU$_{100, 0, 0}$ treatment where the entire dose of 120 N ha^{-1} was applied as basal. This might be due to rapid elongation and multiplication of cells in the presence of a large amount of nitrogen supplied to the plant (Kumar and Shivay, 2009) [14]. However, this was at par with the application of 150 kg N ha^{-1} through NCU as 50% basal, 25% at AT and 25% at PI (^{150}NCU$_{50, 25, 25}$), ^{120}NCU$_{75, 25, 0}$ and ^{120}NCU$_{50, 25, 25}$. At 60 DAT, significantly higher plant height was recorded with ^{150}NCU$_{50, 25, 25}$ which was statistically at par with ^{150}NCU$_{33.3, 33.3, 33.3}$ but both were significantly superior over application of 120 kg N ha^{-1} through PU with a split schedule of 50% as basal + 25% at AT + 25% at PI (existing practice). At 90 DAT, the maximum plant height was recorded with ^{150}NCU$_{50, 25, 25}$ but it was comparable with ^{150}NCU$_{33.3, 33.3, 33.3}$ and with the application of 120 kg N ha^{-1} through NCU in two or three splits, and existing practice. At harvest stage, plant height recorded in ^{150}NCU$_{50, 25, 25}$ was statistically at par with ^{150}NCU$_{33.3, 33.3, 33.3}$, ^{120}NCU$_{33.3, 33.3, 33.3}$ and ^{120}NCU$_{50, 25, 25}$ treatment and the existing practice. An adequate supply of nitrogen in ^{150}NCU$_{50, 25, 25}$ might have resulted in increased metabolic processes and performed better mobilization of synthesized carbohydrates into amino acid and protein, which in turn stimulated the rapid cell division and cell elongation, and allowed the plant to grow faster (Kumar and Shivay, 2009) [14]. Higher plant height in NCU treatment than PU at the same dose and split schedule might be due to the gradual release of nitrogen through NCU and maintenance of higher available nitrogen in soil throughout the crop growth period (Shivay *et al.*, 2001) [12].

Number of tillers m^{-2}

Different nitrogen management practices significantly affected number of tillers m^{-2} at different growth stages (Figure 2). The number of tillers m^{-2} increased only up to 60 DAT and then it declined till maturity. Mortality of tillers is a natural phenomenon which might be attributed to the limited available resources to plants, which are required to produce sufficient photosynthates to maintain all the tiller produced (Kumari *et al.*, 2014) [23]. At 30 DAT, the maximum number of tillers m^{-2} was recorded with the application of ^{120}NCU$_{100, 0, 0}$, which was statistically at par with rest of the treatments except ^{90}NCU$_{50, 25, 25}$, ^{120}NCU$_{33.3, 33.3, 33.3}$ and control (^{0}N). The higher number of tillers with ^{120}NCU$_{100, 0, 0}$ treatment might be due to the supply of full dose of nitrogen as basal which might have increased its availability during the initial growth period. At 60 DAT, significantly higher number of tillers m^{-2} was recorded with ^{150}NCU$_{50, 25, 25}$ treatment, which was statistically at par with application of the same dose through 33.3:33.3:33.3 split schedule, and with application of 120 kg through three splits at basal, AT and PI stages (^{120}NCU$_{50, 25, 25}$ and ^{120}NCU$_{33.3, 33.3, 33.3}$).

But these treatments produced 12.71, 11.44, 4.66 and 6.35% higher tiller, respectively than existing practice. The beneficial effect of NCU over PU on the number of tillers plant[-1] in transplanted rice at 60 DAT at the same dose of 120 kg N ha^{-1} with the same split schedule was also observed by Suresh and Piria (2008). However, among N-containing treatments, the lowest number of tillers was recorded with [120]NCU[100, 0, 0]. A similar trend was observed at 90 DAT. At harvest, the maximum number of tillers m[-2] was recorded with [150]NCU[50, 25, 25] which was statistically at par with the rest of the treatments except [90]NCU[50, 25, 25], [120]NCU[100, 0, 0] and [0]N. The treatments [120]NCU[50, 25, 25], [120]NCU[33.3, 33.3, 33.3], [150]NCU[50, 25, 25] and [150]NCU[33.3, 33.3, 33.3] produced a higher number of tillers m[-2] than existing practice with corresponding increments of 3.84, 3.84, 5.29 and 4.81%, respectively. The beneficial effect of neem based modified urea products *viz.*, neem-bitter coated urea and pusa neem golden urea over prilled urea on the number of tillers hill[-1] have also been reported (Kumar and Shivay, 2009) [14]. The higher number of tillers in [150]NCU[50, 25, 25] might be due to an adequate supply of nitrogen which resulted in the better partitioning of photosynthates to the mother culm which supplies carbohydrate and other nutrients to developing tillers at early stages (Kumar and Shivay, 2009) [14]. Other researchers have also found an increased number of tillers with increasing nitrogen doses (Shivay *et al.*, 2001; Kumar and Shivay, 2009) [12, 14]. Khandey *et al.* (2017) [24] reported that application of application of 100% and 125% RDN through NCU in three equal splits as basal, maximum tillering and PI stages increased the number of tillers m[-2] at harvest stage over 100% RDN through PU with the same split schedule.

Yield attributing characters
Different nitrogen management practices caused significant variation in yield attributes such as no. of panicles m[-2], panicle length, grain weight panicle[-1], filled and unfilled spikelets, spikelets sterility percentage and 1000-grain weight (Table 2). The maximum number of panicles m[-2] was recorded with [150]NCU[50, 25, 25] followed by application of the same dose with equal splitting at the three stages, which were statistically comparable to existing practice. Similarly, [120]NCU[50, 25, 25] produced 4.5% higher panicles m[-2] over PU with the same dose and splitting which further increased to 5% with three equal splits ([120]NCU[33.3, 33.3, 33.3]). Further, [150]NCU[50, 25, 25] recorded the highest panicle length, grain weight panicle[-1], number of filled and unfilled spikelets m[-2] which was followed by application of the same dose with equal splitting at the three stages, which were significantly higher than existing practice except for grain weight panicle[-1] and number of unfilled spikelets m[-2]. The corresponding increments in these treatments in terms of panicle length, grain weight panicle[-1], and number of filled and unfilled spikelets over existing practice were 7.1 and 3.7, 6.5 and 3.4, 12.5 and 10.0, and 11.1 and 11.1%, respectively. However, the lowest yield attributes such as number of panicles m[-2], panicle length, grain weight panicle[-1], filled and unfilled spikelets were recorded in [0]N. The highest spikelet sterility percentage was observed with [0]N. Among NCU treatments, application of 120 kg N ha^{-1} with split schedule of 33.3% each at basal, AT and PI stages caused a decrease in spikelets sterility percentage to 6.7 from 7.9 in existing practice followed by application of same dose with split schedule of 50% as basal + 25% at AT + 25% at PI with a decrease of 1%, though these decrements in these two NCU treatments were not significant. The highest 1000-grain weight was recorded with [150]NCU[50, 25, 25] followed by [150]NCU[33.3, 33.3, 33.3], [120]NCU[33.3, 33.3, 33.3] and [120]NCU[50, 25, 25]. Highest yield attributes under application of 150 kg N ha^{-1}through neem

coated urea in three splitting *i.e.* 50% as basal + 25% at AT + 25% at might be attributed to reduced losses associated with sufficient amount of nitrogen through NCU at critical stages which would have maintained continuous supply of nitrogen into the soil solution to match the requisite absorption pattern of crop specially at later stages crop to meet the physiological processes. A lesser number of yield attributes under prilled urea treated plot might be due to a reduction in the availability of nitrogen at reproductive stage. Khandey *et al.* (2017) [24] from Raipur, India in a vertisol also reported that application of 100% (120 kg N ha^{-1}) and 125% (120 kg N ha^{-1}) RDN through NCU in three splits as basal, maximum tillering and PI stages improved yield attributing characters such as number of panicles m[-2], panicle length, number of filled grains panicle and 1000-grain weight of rice than application of 100% RDN through PU with the same split schedule. Singh and Shivay (2003) [13] found that application of pusa neem oil micro-emulsion coated urea improved the yield attributes of rice like the number of effective tillers m[-2], panicle length, panicle weight and 1000-grain weight than prilled urea at a dose of 120 kg N ha^{-1}. Improvement in yield attributes (number of panicles m[-2], panicle weight, panicle length, 1000-grain weight) up to 150 kg N ha^{-1} (Kumar and Shivay, 2009) [14] and significant increment in yield attributes of rice (number of effective tillers m[-2], panicle length and panicle weight) up to 180 kg N ha^{-1} (Singh and Shivay, 2003) [13] have been reported from New Delhi, India. In the present study, the split schedule of 50:25:25 and 33.3:33.3:33.3 were comparable at the same dose. This finding confirms the result of Zhang *et al.* (2014) [25] from China who found that application of 240 N kg ha^{-1} through 50:25:25 and 33.3: 33.3:33.3 split schedule at basal, tillering and booting stage did not differ significantly with respect to yield attributes of rice (panicle length, panicle number, and 1000 grain weight) with higher yield attributes under equal splits.

Yield and harvest index
Data pertaining to yield and harvest index presented in Table 2 indicates that different treatments had a significant effect on the grain and straw yield of rice. The significantly higher grain and straw yield were recorded with [150]NCU[50, 25, 25] which was statistically at par with [150]NCU[33.3, 33.3, 33.3] with corresponding increments of 10.95 and 12.36 and 10.67% and 11.86%, respectively over the existing practice. The increase in grain and straw yield with [120]NCU[50, 25, 25] over PU with the same dose and splitting (existing practice) was higher by 4.1 and1.64%, respectively, which further increased to 4.5 and 2.87% under three equal splits schedule. Khandey *et al.* (2017) [24] reported that application of 100% and 125% RDN through NCU in three splits as basal, maximum tillering and PI and produced 5.2% and 5.3%, and 15.8% and 29.5% higher grain and straw yield, respectively over 100% RDN through PU with the same split schedule. In this study, [120]NCU[50, 25, 25] produced higher grain yield than PU with the same dose and splitting (existing practice). This might be due to slow nitrogen releasing property of NCU, which made the N available for plants for a longer time and it was utilized by plants even during reproductive phase, and thus, helped the plants to produce higher number of productive tillers that resulted in higher grain yield (Kumar *et al.*, 2014) [26]. Improvement in grain and straw yield with NCU over PU at the same dose and three split schedules have also been reported (Suresh and Piria, 2008; Thind *et al.*, 2010) [27, 15]. Similarly, Bhatt (2012) [28] found that application of 120 kg N ha^{-1} through neem coated urea in three equal splits at basal, 21 DAT and 42 DAT produced 12.8% higher grain yield than prilled urea with the same split schedule in Punjab, India. Singh and Shivay

(2003) [13] also found at 120 kg N ha⁻¹ application of pusa neem oil micro-emulsion coated urea was statistically comparable to prilled urea with 4.56% increment in grain yield in a sandy loam soil at New Delhi, India. Effect of different nitrogen management practices on harvest index was found to be non-significant. However, lower harvest index was observed in 150 kg N ha⁻¹ through NCU where it was applied either as 50: 25:25 or 33.3:33.3:33.3 split schedule at basal, AT and PI stages than the application of the same source and schedules at 120 kg N ha⁻¹ and over existing practice. Harvest index is the ratio of grain yield to biological yield. Increased nitrogen availability with 150 kg N ha⁻¹ through NCU either applied as 50:25:25 or 33.3:33.3:33.3 split schedule might have produced higher biological yield than grain yield due to greater biomass production and resulted in the decline of harvest index values (Chaudhary *et al.*, 2014) [29].

Economics
Data pertaining to economics (Table 3) show that among NCU treatments, the cost of cultivation recorded the highest with $^{150}NCU_{50, 25, 25}$ and application of the same dose with three equal splits each at basal, AT and PI while gross and net return was the highest in the previous treatment. The corresponding increments in gross and net return in $^{150}NCU_{50, 25, 25}$ over existing practice were 11.07 and 18.10%, respectively. Higher gross and net return in $^{150}NCU_{50, 25, 25}$ is attributed to higher grain and straw yield obtained in this treatment. Similarly, $^{120}NCU_{50, 25, 25}$ and $^{120}NCU_{33.3, 33.3, 33.3}$ also recorded higher gross and net return than existing practice. However, the maximum B: C ratio was recorded in $^{150}NCU_{50, 25, 25}$ and $^{150}NCU_{33.3, 33.3, 33.3}$ which was higher than existing practice. Sarangi *et al.* (2016) [30] who found that application 100% RDN as 50% at basal, 25% at tillering and 25% at PI through NCU gave significantly higher gross and net return than PU with improved B:C ratio and reduced cost of cultivation.

Nitrogen use efficiency
Data showed that PFP and AE of applied fertilizer nitrogen decreased with increasing dose of nitrogen (Table 3). Application of 90 kg N ha⁻¹ through NCU applied as 50% at basal, 25% at AT and 25% at PI recorded the highest PFP and AE, which received the lowest dose of nitrogen (90 kg ha⁻¹). Application of 120 kg N ha⁻¹ through NCU as 50% at basal, 25% at AT and 25% at PI improved the PFP (45.62 kg grain kg⁻¹ N applied) and AE (22.57 kg grain increase kg⁻¹ N) over the existing practice (43.83 kg grain kg⁻¹ N applied and 20.78 kg grain increase kg⁻¹ N, respectively) with same dose and split schedule. PFP and AE of applied nitrogen further increased slightly when 120 kg N ha⁻¹ was applied through NCU in three equal splits. Improved nitrogen use efficiency in rice due to the application of NCU over PU might be attributed to reduced leaching losses as a result of nitrification retardation (Thind *et al.*, 2010) [15]. Thind *et al.* (2010) [15] found that application of 120 kg N ha⁻¹ through NCU in three equal split schedules at almost similar growth stages to the present study increased the agronomic efficiency to 24.0 from 21.0 kg grain/kg N applied through PU with the same split schedule. The lowest nitrogen use efficiencies (PFP and AE) were observed with $^{150}NCU_{33.3, 33.3, 33.3}$ followed by $^{150}NCU_{50, 25, 25}$ (Table 3). The decrease in nitrogen use efficiency with increasing fertilizer rates is due to the fact that grain yield rises less than the N supply from soil and fertilizer (Lopez and Lopez, 2001) [31]. Declining trend of AE and PFP of N with increasing dose of nitrogen has also been reported (Shivay *et al.*, 2016). Zhang *et al.* (2014) found that PFP was under 33.3:33.3:33.3 split schedule than 50:25:25 split schedule at basal, tillering and booting stages when 240 kg N ha⁻¹ was applied. But further equal splitting of nitrogen up to panicle stage reduced PFP at the same dose.

Table 1: Details of experimental treatments

Treatments	Treatment details (Dose, source and split schedule)
T₁= $^{120}PU_{50,25,25}$	100% RDN as PU (50% basal + 25% AT + 25% PI) (existing practice)
T₂= $^{120}NCU_{100,0,0}$	100% RDN as NCU (100% as basal)
T₃= $^{120}NCU_{75,25,0}$	100% RDN as NCU (75% basal + 25% AT)
T₄= $^{120}NCU_{50,50,0}$	100% RDN as NCU (50% basal + 50% AT)
T₅= $^{90}NCU_{50,25,25}$	75% RDN as NCU (50% basal + 25% AT + 25% PI)
T₆= $^{120}NCU_{50,25,25}$	100% RDN as NCU (50% basal + 25% AT + 25% PI)
T₇= $^{150}NCU_{50,25,25}$	125% RDN as NCU (50% basal + 25% AT + 25% PI)
T₈= $^{120}NCU_{33.3,33.3,33.3}$	100% RDN as NCU (33.3% basal + 33.3% AT + 33.3% PI)
T₉= $^{150}NCU_{33.3,33.3,33.3}$	125% RDN as NCU (33.3% basal + 33.3% AT + 33.3% PI)
T₁₀= ^{0}N	Zero-N (Control)

RDN- recommended dose of nitrogen (120 kg N ha⁻¹); PU- prilled urea; NCU- neem coated urea; AT- active tillering and PI- panicle initiation
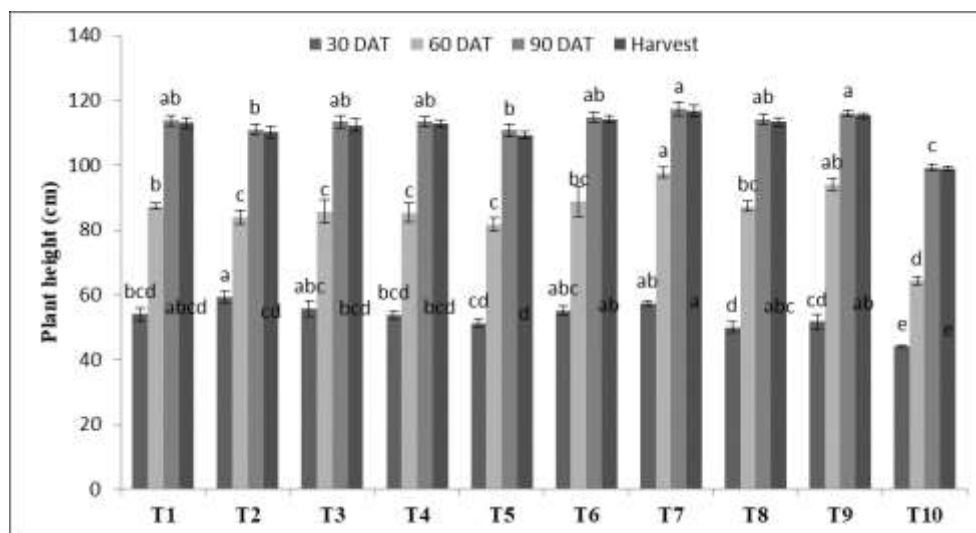
$T_1 = {}^{120}PU_{50,25,25}$; $T_2 = {}^{120}NCU_{100,0,0}$; $T_3 = {}^{120}NCU_{75,25,0}$; $T_4 = {}^{120}NCU_{50,50,0}$; $T_5 = {}^{90}NCU_{50,25,25}$; $T_6 = {}^{120}NCU_{50,25,25}$; $T_7 = {}^{150}NCU_{50,25,25}$; $T_8 = {}^{120}NCU_{33.3,33.3,33.3}$; $T_9 = {}^{150}NCU_{33.3,33.3,33.3}$; $T_{10} = {}^{0}N$

Fig 1: Effect of different nitrogen management practices through neem coated urea on plant height of transplanted rice at different growth stages. Means marked by at least a common letter do not differ significantly according to LSD test (P=0.05). Vertical error bar represents standard error of the mean (n=3)
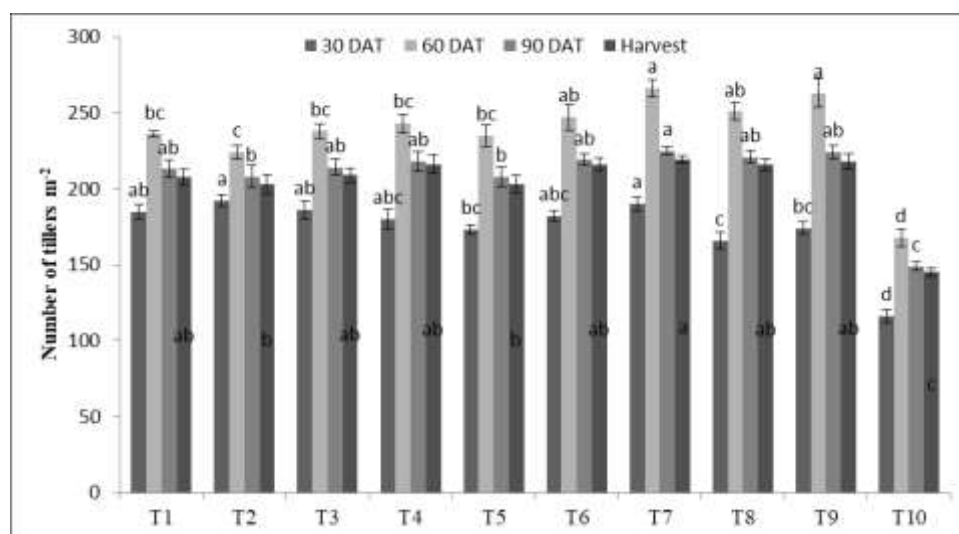
$T_1 = {}^{120}PU_{50,25,25}$; $T_2 = {}^{120}NCU_{100,0,0}$; $T_3 = {}^{120}NCU_{75,25,0}$; $T_4 = {}^{120}NCU_{50,50,0}$; $T_5 = {}^{90}NCU_{50,25,25}$; $T_6 = {}^{120}NCU_{50,25,25}$; $T_7 = {}^{150}NCU_{50,25,25}$; $T_8 = {}^{120}NCU_{33.3,33.3,33.3}$; $T_9 = {}^{150}NCU_{33.3,33.3,33.3}$; $T_{10} = {}^{0}N$

Fig 2: Effect of different nitrogen management practices through neem coated urea on the number of tillers m^{-2} of transplanted rice at different growth stages. Means marked by at least a common letter do not differ significantly according to LSD test (P=0.05). Vertical error bar represents standard error of the mean (n=3)

Table 2: Effect of different nitrogen management practices through neem coated urea on yield attributing characters and yield of transplanted rice

Treatments	Yield attributing characters							Yield (kg ha⁻¹)		
	Number of panicles m⁻²	Panicle length (cm)	Grain weight panicle⁻¹ (g)	Spikelets			1000-grain weight (g)	Grain	Straw	Harvest index (%)
				Filled (m⁻²)	Unfilled (m⁻²)	Sterility (%)				
$T_1 = {}^{120}PU_{50,25,25}$	198	24.1	2.92	23143	1970	7.9	24.92	5259	5609	48.4
$T_2 = {}^{120}NCU_{100,0,0}$	194	23.5	2.81	21954	1936	8.1	24.80	4977	5363	48.1
$T_3 = {}^{120}NCU_{75,25,0}$	201	24.5	2.86	23120	1924	7.7	24.88	5160	5591	48.0
$T_4 = {}^{120}NCU_{50,50,0}$	206	24.1	2.87	23807	1837	7.2	24.90	5425	5731	48.6
$T_5 = {}^{90}NCU_{50,25,25}$	197	24.1	2.78	22085	1946	8.1	24.82	5033	5442	48.1
$T_6 = {}^{120}NCU_{50,25,25}$	207	24.5	2.90	23966	1790	6.9	24.98	5475	5701	49.0
$T_7 = {}^{150}NCU_{50,25,25}$	212	25.8	3.11	26025	2189	7.8	25.28	5835	6302	48.1
$T_8 = {}^{120}NCU_{33.3,33.3,33.3}$	208	24.7	2.91	24245	1732	6.7	25.02	5498	5770	48.8
$T_9 = {}^{150}NCU_{33.3,33.3,33.3}$	211	25.0	3.02	25447	2189	7.9	25.07	5820	6274	48.1
$T_{10} = {}^{0}N$	138	21.8	2.22	12684	1291	9.4	24.30	2766	3025	47.7
S.Em ±	5	0.5	0.10	774	97	0.4	0.10	100	137	5
LSD (P = 0.05)	14	1.4	0.30	2300	288	1.2	0.30	298	408	NS

NS-Non-significant

Table 3: Effect of different nitrogen management practices through neem coated urea on economics and nitrogen use efficiency of transplanted rice

Treatments	Economics				Nitrogen use efficiency	
	Cost of cultivation (INR ha^{-1})	Gross return (INR ha^{-1})	Net return (INR ha^{-1})	B: C ratio	PFP (kg grain kg^{-1} N applied)	AE (kg grain increase kg^{-1} N applied)
$T_1= {}^{120}PU_{50,25,25}$	35954	85726	49773	1.38	43.83	20.78
$T_2= {}^{120}NCU_{100,0,0}$	35612	81211	45599	1.28	41.48	18.43
$T_3= {}^{120}NCU_{75,25,0}$	35822	84239	48417	1.35	43.00	19.95
$T_4= {}^{120}NCU_{50,50,0}$	35822	88344	52522	1.46	45.21	22.16
$T_5= {}^{90}NCU_{50,25,25}$	35619	82154	46534	1.31	55.93	25.19
$T_6= {}^{120}NCU_{50,25,25}$	36032	89030	52998	1.47	45.62	22.57
$T_7= {}^{150}NCU_{50,25,25}$	36443	95223	58781	1.61	38.90	20.46
$T_8= {}^{120}NCU_{33.3,33.3,33.3}$	36032	89481	53449	1.48	45.82	22.77
$T_9= {}^{150}NCU_{33.3,33.3,33.3}$	36443	94960	58518	1.61	38.80	20.36
$T_{10}= {}^{0}N$	28834	45198	16364	0.57	-	-

Conclusion

From the present study, it can be concluded that nitrogen management through neem coated urea can play a crucial role in augmenting productivity, economics, and nitrogen use efficiency of transplanted rice. Application of 100% RDN through neem coated urea with 50:25:25 or 33.3:33.3:33.3 split schedule at basal, AT and PI stages can improve the performance of transplanted rice in terms of growth, yield, economics with better nitrogen use efficiency (agronomic efficiency and partial factor productivity) over existing practice *i.e.* application of 100% RDN through prilled urea with 50:25:25 split schedule. Further, application of neem coated urea @ 125% RDN with 50:25:25 split schedule can maximize the growth, yield, and economics of transplanted rice over the existing practice in *Tarai* region of Uttarakhand, India.

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