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Nitrogen use efficiency indices as influenced by planting time and schedule of N application in rice (*Oryza sativa* L.)

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Abstract
A field experiment was conducted at Rice Research Station, Kaul (Kaithal), India during *kharif* season of 2017 and 2018 to study the effect of transplanting time as well as of dose and time of fertilizer nitrogen (N) in rice crop on nitrogen use efficiency (NUE) indices viz. agronomical efficiency (AE), physiological efficiency (PE), agro physiological efficiency (APE), apparent recovery efficiency (ARE), utilization efficiency (UE), partial production efficiency (PPE), nutrient increment efficiency (NIE), partial nutrient balance (PNB), nutrient harvest index (NHI) and nutrient efficiency ratio (NER). The experimental treatments consisted of three transplanting schedules (P_1: 3rd week of June, P_2: 1st week of July, P_3: 3rd week of July), four levels of N fertilizer (N_1: 90, N_2: 120, N_3: 150, N_4: 180 kg/ha) and four schedules of N fertilizer application (T_1: ½ at transplanting + ½ at 21 DAT, T_2: ½ at 21 DAT + ½ at 42 DAT, T_3: 1/3 at transplanting + 1/3 at 21 DAT + 1/3 at 42 DAT and T_4: LCC based). The nitrogen use efficiencies viz. AE, PE, APE, UE, PPE, NIE and NER were higher with late planting (3rd week of July). Application of N at 120 kg/ha was found most suitable as it resulted into maximum increase in most of the efficiency indices over 90 kg/ha and also exhibited the highest AE, APE, and PPE. Most of the efficiencies were higher when N fertilizer was applied in two equal splits at 0 and 21days after transplanting (DAT).

Keywords: Rice, split application, nitrogen level, nitrogen use efficiency indices, transplanting time

Introduction

Rice (*Oryza sativa* L.) is one of the major food crops and is a staple food for more than half of the world population. In view of the current population growth rate, India needs to produce around 125 million tons of rice by 2025 as compared to its present production of around 115 million tons. Therefore, there is need to increase the productivity of rice through manipulation of agronomic practices like planting time and fertilizer management.

Planting time is a major management factor in rice cultivation influencing the growth and yield of rice as it indirectly determines the weather conditions to which the plants are exposed during different development stages (Iqbal *et al*, 2008) [3]. Optimum time of rice planting ensures optimum temperature and photoperiod for vegetative, reproductive or grain filling phases which is required for high yield and good quality of the crop. Rice crop is a heavy feeder of nutrients and responds immensely to application of nutrients, particularly N. In view of the high N requirement of rice and low soil nitrogen status of rice growing areas, it is important to increase the efficiency of applied N in rice to save the costly fertilizer. Hence before making recommendations for the nitrogen fertilizer dose for a crop, one should evaluate the efficiency and optimum rate for different application levels for better growth and yield of rice (Noor, 2017) [6].

The optimum schedule of N fertilizer is also a crucial factor for the productivity of rice. Synchrony of nitrogen supply with crop demand is essential in order to ensure higher nitrogen use efficiency and crop yields (Fageria and Baligar, 2005) [2]. Singh *et al.* (1997) [8] observed that response to N may vary with the date of planting and hence N requirement and its use efficiency may also vary with the time of planting of rice crop.

Improving nitrogen use efficiency (NUE) is one of the most critical and daunting research issues (Thompson, 2012) [10] as it is a critically important concept for evaluating crop production systems and can be greatly affected by fertilizer and other crop management practices. The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field and supporting agricultural system sustainability through contributions to soil health. Therefore, present field experiment was conducted to work out various nitrogen use efficiencies which may help in determining the optimum N application schedule under early, timely or late planted crop.

Materials and Methods

A field experiment was conducted at Rice Research Station, Kaul (Kaithal), Haryana (India) during *kharif* season of 2017 and 2018. Soil of the experimental field was loam in texture, alkaline in reaction (pH 7.8), low in available N (160 kg N/ha), medium in available P (26 kg P/ha) and high in available K (832 kg K/ha). The experimental treatments consisted of three timings of transplanting (P_1: 3rd week of June, P_2: 1st week of July, P_3: 3rd week of July), four levels of nitrogen fertilizer (N_1: 90, N_2: 120, N_3: 150, N_4: 180 kg/ha) with four different schedule of nitrogen application (T_1: ½ at transplanting + ½ at 21 DAT, T_2: ½ at 21 DAT + ½ at 42 DAT, T_3: 1/3 at transplanting + 1/3 at 21 DAT + 1/3 at 42 DAT and T_4: LCC based) laid out in split plot design with planting time and N levels in main plots and time of N application in sub-plots. Data on grain yield, straw yield and biological yield (grain + straw yield) was recorded at crop maturity. Samples of grain and straw of the crop were taken at maturity and were subjected to standard analytical methods to determine their N concentration. Uptake of N in above ground plant parts (grain and straw) was worked out by multiplying their N concentration by the respective grain or straw yield. Different nitrogen use efficiency indices were worked out as per the following formulae given by Dobermann (2007) [1].

Agronomical efficiency (AE): It denotes yield increase per unit of nitrogen applied and is expressed as:

$$AE = \frac{(Y - Y_o)}{F}$$

Y = Yield of harvested portion of crop obtained with a given level of N applied;
Y_{oo}= Yield obtained with reference level of N applied (90 kg/ha);
F = Amount of additional N applied

Physiological efficiency (PE): It is the additional biological yield obtained with a given N level over the yield obtained with reference N level per unit of additional nutrient uptake over the reference N level.

$$PE = \frac{(BY_n - BY_o)}{(U_n - U_o)}$$

BY_n= Biological yield obtained with a given N level;
BY_0= Biological yield obtained with reference N level (90 kg/ha);
U_n = N uptake in aboveground crop biomass with a given N level;
U_0= N uptake in aboveground crop biomass with reference N level

Agro physiological efficiency (APE): It is the additional grain or economic yield obtained with a given N level over that obtained with the reference N level per unit of additional N uptake over the reference N level.

$$APE = \frac{(Y - Y_o)}{(U - U_o)}$$

Y = Yield (economic yield) of crop obtained with a given N level;
Y_o= Yield obtained with reference N level (90 kg/ha);
U = N uptake in aboveground crop biomass with given N level;
U_o= N uptake in aboveground crop biomass with reference N level

Apparent Recovery Efficiency (ARE): It is the difference in nutrient uptake in above-ground parts of the plant with a given N level and the reference N level relative to the quantity of N applied.

$$ARE = \frac{(U - U_o)}{F}$$

U = N uptake in aboveground crop biomass with given N level;
U_o= N uptake in aboveground crop biomass with reference N level (90 kg/ha);
F = Amount of additional N applied;

Utilization efficiency (UE): It is the additional biological yield obtained with given N level over that with reference N level per unit of nutrient applied.

$$UE = \frac{(BY_n - BY_o)}{F}$$

BY_n= Biological yield obtained with given N level;
BY_o= Biological yield obtained with reference N level (90 kg/ha);
U = N uptake in aboveground crop biomass with given N level;
F = Amount of additional N applied;

Partial Nutrient Balance (PNB): It is expressed as nutrient output per unit of nutrient input (a ratio of "removal to use").

$$PNB = \frac{U_H}{F}$$

F = amount of additional nitrogen applied;
U_H= nitrogen content of harvested portion of the crop;

Nutrient Efficiency Ratio (NER): It is the total biomass produced per unit of nitrogen uptake.

$$NER = \frac{BY}{U}$$

BY= Biological yield;
U = N uptake in aboveground crop biomass with given N level.

Nutrient Harvest Index (NHI): It is the ratio (of nutrient uptake by grain or economic part) to total nutrient uptake by plant.

$$\text{NHI} = \frac{\text{Nutrient uptake by grain}}{\text{Total nitrogen uptake by crop biomass}}$$

Nutrient Increment Efficiency (NIE): It is the additional grain (economic) yield obtained with a given N level over that obtained with the previous N level per unit of preceding N level.

$$\text{NIE} = \frac{Y_n - Y_{n_{-1}}}{Y_{n_{-1}}}$$

Y_n= Grain yield obtained with N_n amount of nitrogen,
Y_{n-1}= Grain yield obtained with N_{n-1} amount of nitrogen

Partial Production Efficiency (PPE): It is the additional grain yield over the previous N level per unit of additional N applied over preceding N level. It is expressed in kg/kg.

$$\text{PPE} = \frac{GY_n - GY_{n_{-1}}}{N_n - N_{n_{-1}}}$$

GY_n= Grain yield obtained with N_n amount of nitrogen,
Y_{n-1}= Grain yield obtained with N_{n-1} amount of nitrogen

Results and Discussion

A perusal of the data in the Table 1 showed that planting time had a significant effect on various nitrogen use efficiency indices. The indices viz. agronomical efficiency (AE), physiological efficiency (PE), agro physiological efficiency (APE), utilization efficiency (UE), partial production efficiency (PPE), nutrient increment efficiency (NIE) and nutrient efficiency ratio (NER) were significantly higher when rice crop was planted late (3rd week of July) than when planted earlier (3rd week of June and 1st week of July). The higher values of these indices under late planting is attributable to greater increase in yield of aboveground plant parts and comparatively less increase in N uptake by the crop due to increase in N application rate as compared to that under early plantings. But reverse was true for apparent recovery efficiency (ARE), partial nutrient balance (PNB) and nutrient harvest index (NHI).

Table 1: Various Nitrogen Use Efficiencies of rice crop as influenced by transplanting time and schedule of N application (Pooled data of two years)

Treatment	AE	PE	APE	ARE	UE	PPE	NIE	PNB	NHI	NER
Date of transplanting										
P_1	12.60	27.33	12.93	26.73	9.66	12.60	0.11	0.95	131.05	104.06
P_2	12.99	25.26	12.37	26.96	10.00	12.99	0.12	0.96	130.57	104.14
P_3	22.46	61.46	29.73	20.54	17.00	22.46	0.43	0.82	127.21	127.68
CD (p= 0.05)	3.6	6.6	2.95	2.06	2.3	3.6	0.03	0.11	0.5	0.63
Levels of N (kg/ha)										
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	133.35	137.83
120	26.44	49.98	52.10	26.85	13.56	26.44	0.20	0.94	127.95	110.75
150	21.62	51.51	24.69	37.45	18.12	21.62	0.32	0..91	127.59	101.19
180	16.01	50.57	23.10	34.68	17.20	16.01	0.37	0.88	129.56	98.43
CD (p= 0.05)	4.1	7.6	3.41	2.38	2.7	4.1	0.03	NS	0.5	0.72
Time of N application										
T_1	19.12	41.67	19.79	27.55	14.56	19.12	0.32	0.88	128.83	123.58
T_2	15.45	34.07	16.14	27.11	11.97	15.45	0.21	0.90	130.11	117.75
T_3	14.59	36.14	18.37	21.85	10.86	14.59	0.18	0.94	129.51	103.94
T_4	14.92	40.18	19.08	22.47	11.50	14.91	0.18	0.93	130.01	102.93
CD (p= 0.05)	3.6	NS	2.66	2.4	2.7	3.6	0.06	NS	0.5	0.96

All the indices, except PNB, were also influenced significantly due to levels of N application in rice crop. Maximum increase in AE, PE, APE, ARE, UE, PPE and NIE was observed when N application level was increased from 90 to 120 kg/ha. This is because of maximum increase in crop yield (grain and straw) and N uptake by the crop with increase in N level. The highest values of AE, APE and PPE were observed when N was applied at 120 kg/ha and these efficiencies decreased when N level was increased further to 150 or 180 kg/ha whereas NHI and NER were highest with the lowest level of N (90 kg/ha). Since grain yield response to applied N follows law of diminishing returns, a number of workers (Kour *et al.*, 2007 and Singh *et al.*, 2007) [4, 7] have reported a decreasing trend in AE with increasing N rate.

Nitrogen application levels above 120 kg/ha, however, increased the efficiencies viz. ARE, UE and NIE while NER was decreased with increase in N levels above 90 kg/ha. The differences in various efficiency indices due to N levels could be explained on the basis of relative increases in their yield and N uptake. Mazid-Miah *et al.* (1998) [5] reported similar findings. The indices viz. AE, APE, ARE, UE, PPE, NIE and NER were highest when N fertilizer was applied in two equal splits at 0 and 21 days after transplanting (T_1) whereas NHI was the lowest with T_1.

Conclusion

Based on the findings of this study it may be concluded that compared to early planting, the late planting of rice, despite giving lower yield, can exhibit higher nitrogen use efficiencies viz. AE, PE, APE, UE, PPE, NIE and NER. Most of the nitrogen use efficiencies were higher when N was applied to the crop at 120 kg/ha.

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