Turkish Journal of Agriculture - Food Science and Technology, 8(3): 610-615, 2020
DOI: https://doi.org/10.24925/turjaf.v8i3.610-615.3068

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology

Tillage, Crop Residue and Nitrogen Management Effects on Nitrogen Uptake, Nitrogen Use Efficiency and Yield of Rice

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ARTICLE INFO

Research Article

Received : 08/11/2019
Accepted : 20/12/2019

Keywords:
Tillage
Residue
Nitrogen uptake
Nitrogen use efficiency
Rice yield

ABSTRACT

Field experiment was conducted in three factorial strip split plot design to evaluate the effect of two establishment methods (EM) i.e. transplanted in puddled soil (Pu-TPR) and direct seeded in zero tillage (ZT-DSR), two residue levels i.e. residue kept at 3 t ha $^{-1}$ (RK) and no residue (RR) with two nitrogen doses i.e. recommended dose (100 kg N ha $^{-1}$) (RD) and farmers' dose (50 kg N ha^{-1}) (FD) with six replications with individual plot size of 5.4 m × 6.3 m on rice variety Ramdhan during the year 2016. Nitrogen uptake, nitrogen use efficiencies and yield of rice were recorded. Straw nitrogen uptake was significantly higher in ZT-DSR than Pu-TPR. Similarly, grain straw and total nitrogen uptake were significantly higher in residue applied and recommended dose of nitrogen than no-residue applied and farmers-nitrogen dose treatments respectively. Nitrogen efficiency ratio and physiological efficiency index were significantly higher in Pu-TPR and no-residue applied treatments while partial factor productivity was higher in residue applied treatment. All nitrogen use efficiencies like partial factor productivity, nitrogen efficiency ratio and physiological efficiency index were significantly influenced by nitrogen dose and seen higher in recommended dose of nitrogen. Establishment methods had no significant effect on grain yield but straw yield was significantly higher in ZT-DSR but harvest index was seen higher in Pu-TPR. Grain yield and straw yield were significantly higher in residue applied treatment and recommended nitrogen but harvest index was higher in farmers-nitrogen dose.

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Introduction

Rice *(Oryza sativa* L.) is the world's third crop on the basis of volume of production (503.2 million tons) after wheat and maize (FAO, 2017). It is the staple food of more than 60% of the world's population and about 95% of global rice is grown and consumed in Asian region (Alam et al., 2009). In Nepal, it can be cultivated under all agro-climatic zones and covers 1.55 million ha with total production of 5.23 million tons and productivity of 3.37 t ha^{-1} (MoAD, 2016). Rice is the most important staple food crop, extensively cultivated in Nepal. It only accounts for more than 50% of the total calories of Nepalese people (Gadal et al., 2019; Devkota et al., 2019). It is grown in three agro-ecological regions (terai and inner terai, mid hills and high hills) under irrigated, rain-fed lowland and upland production environment. Terai is the main rice cultivation area produced 70 percent of the total rice, while the hills and mountain contribute 26 percent and 4 percent respectively (Adhikari et al., 2018). Rice is generally cultivated by two methods: transplanting in puddled soil and direct seeding (DSR). Puddling adversely affects soil physical properties by dismantling soil aggregates, reducing permeability in subsurface layers (Sharma et al., 2003). Therefore, it is suggested that alternate method of planting i.e. Dry-DSR is gaining popularity regarding its high-water use, labor use and energy use efficiencies (Kumar and Ladha, 2011). Crop residue is useful for conserving and sustaining soil productivity. Sehgal and Abrol (1994) have reported no addition of crop residue as one of the major reason of degradation of marginal lands. Wheat stalk, maize stover and rice straw are usually removed from fields for use as cattle feed and for purposes such as livestock bedding, thatching material for houses or for fuel, leaving little for incorporation into the soil (Singh, 2003).

Nitrogen is one of the most important essential nutrients for growth of plant as it is important component of RNA, DNA, amino acids, nucleic acids, nucleotides, chlorophyll, enzymes, and hormones. A large portion of applied nitrogen losses from flooded rice field which contribute to the low N use efficiency of rice as compared to another crop (Karkee et al., 2019). The lack of availability of nitrogenous fertilizers at the time of need and lack of capital in the resource poor farmers cause the lower dose of nitrogen application than recommended nitrogen dose. Mahajan and Timsina (2011) observed that DSR required more nitrogen than transplanted rice. In comparison with transplanted rice, nitrogen loss through denitrification, volatilization, leaching and runoff is higher in conservation agriculture (Kumar and Ladha, 2011). The objective of this research was to assess the effects of establishment methods, residue and nitrogen on the nitrogen uptake, nitrogen use efficiency and yield of rice.

Materials and Methods

A field experiment was carried out at agronomy farm of National Maize Research Program, Chitwan, Nepal from June to November, 2016 in sandy loam textured soil with slightly acidic pH. The geographical location of the experiment site was located at 27° 40'N latitude, 84°19' E and 228 meters above sea level and has sub-tropical climate (Gurung et al., 2018). Three factorial strip-split plot design was used with establishment method as horizontal factor, residue as vertical factor and nitrogen levels as sub plot factor with two levels each which were replicated six times. Establishment methods involved (i) zero till direct seeded rice (ZT-DSR) (ii) puddled transplanting rice (PTR). Vertical factor involved (i) residue kept and (ii) residue removed and sub plot factor includes two nitrogen levels (i) recommended dose as 100 kg N ha^{-1} (RD) and (ii) farmers' field practice dose as 50 kg N ha^{-1} (FD). The total rainfall during research was 1646.20 mm. Average relative humidity and average maximum and minimum temperature was 84.58%, 22.98° C and 32.32° C respectively. The soil of experiment locations had organic matter (0.09-2.04%), available phosphorus (19.73-32.3 kg ha^{-1}) and available potassium (67-134 kg ha^{-1}). The variety used in the trial was Ramdhan. Seed were sown at rate of 50 kg ha^{-1} on 22nd of June 2016 for ZT-DSR at the spacing of 20 cm between the lines and for puddled TPR nursery bed preparation was done on same day and 30 days old seedlings were transplanted. Pendimethalin was sprayed on the next day after sowing at the rate of 1 kg active ingredients ha^{-1}. P and K at the rate of 30: 30 kg ha^{-1} and 1/3rd N was applied at basal dose and remaining 1/3rd N at active tillering stage and remaining N 1/3rd at panicle initiation stage. Two hand weeding was done at 20 days after sowing (DAS) and 40 DAS. The irrigation was done to the entire plot at the time of needed on continuous basis. Irrigation was withheld 10 days before crop harvest. All other practices during crop growth period were as per the package of practices for the crops. The crop was harvested and threshed manually and yield was computed at 14% moisture content. Data on grain and straw nitrogen uptake, partial factor productivity, nitrogen efficiency ratio, physiological efficiency index, grain yield, straw yield and harvest index were recorded at the time of crop harvest. The experimental data were processed by using Excel 2010 and analyzed by using Genstat 13.2. The treatment means were compared by the Least Significant Difference (LSD) test at 5% level (Gomez and Gomez, 1984; Shrestha, 2019).

Results and Discussion

Nitrogen Uptake and Nitrogen Use Efficiency

In establishment methods, only straw nitrogen uptake was significantly higher in ZT-DSR but grain and total nitrogen uptake was non-significant but uptake by grain was higher in puddled TPR and total was higher in ZT-DSR. Residue and nitrogen dose significantly affect grain, straw and total nitrogen uptake and all uptakes were higher in residue application and in recommended nitrogen dose respectively (Table 1). Oo et al. (2007) also found significantly higher uptake of nitrogen by grain, straw and also total N uptake in 100 kg N ha^{-1} than in 50 kg N ha^{-1}.

Table 1. Grain, straw and total nitrogen uptake by rice as influenced by establishment methods, residue and nitrogen dose in Chitwan during 2016

Treatment	Grain nitrogen uptake (kg ha^{-1})	Straw nitrogen uptake (kg ha^{-1})	Total nitrogen uptake (kg ha^{-1})
Establishment methods			
ZT-DSR	54.95	53.42^{a}	108.37
Pu-TPR	57.78	43.37^{b}	101.15
SEm (±)	1.93	1.30	2.89
LSD (0.05)	ns	4.73	ns
CV(%)	8.40	6.60	6.80
Residues			
With Residue	58.94^{a}	54.86^{a}	113.80^{a}
Without Residue	53.79^{b}	41.93^{b}	95.72^{b}
SEm (±)	0.76	1.48	2.05
LSD (0.05)	2.77	5.39	7.47
CV(%)	3.30	7.50	4.80
Nitrogen Dose			
RD	66.85^{a}	60.95^{a}	127.80^{a}
FD	45.88^{b}	35.84^{b}	81.72^{b}
SEm (±)	1.16	0.83	1.68
LSD (0.05)	3.43	2.43	4.97
CV(%)	10.10	8.30	7.90
Grand Mean	56.36	48.40	104.76

Note: ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; ns, non-significance. Treatments means followed by different letter (s) are significantly different among each other based on DMRT at 5% level of significance

Table 2. Nitrogen use efficiencies of rice as influenced by establishment methods, residue and nitrogen dose in Chitwan during 2016

Treatment	Partial factor productivity (kg grain/kg N)	Nitrogen efficiency ratio (kg biomass/kg N uptake)	Physiological efficiency index (kg grain /kg N uptake)
Establishment methods			
ZT-DSR	53.88	84.38[b]	35.42[b]
Pu-TPR	58.96	87.52[a]	41.78[a]
SEm (±)	1.77	0.18	0.38
LSD (0.05)	ns	0.66	1.39
CV(%)	7.70	0.50	2.40
Residues			
With Residue	60.25[a]	84.44[b]	37.80[b]
Without Residue	52.59[b]	87.47[a]	39.40[a]
SEm (±)	1.21	0.16	0.33
LSD (0.05)	4.40	0.59	1.22
CV(%)	5.30	0.50	2.10
Nitrogen Dose			
RD	45.56[b]	83.67[b]	35.94[b]
FD	67.28[a]	88.23[a]	41.26[a]
SEm (±)	1.30	0.13	0.28
LSD (0.05)	3.83	0.38	0.81
CV(%)	11.30	0.70	3.50
Grand Mean	56.42	85.95	38.60

Note: ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; ns, non-significance. Treatments means followed by different letter (s) are significantly different among each other based on DMRT at 5% level of significance

Partial factor productivity, nitrogen efficiency ratio and physiological efficiency index was seen higher in Puddled TPR as compared to ZT-DSR and also higher in residue removed plot over residue kept plot except partial factor productivity and all the efficiencies were seen significantly higher in lower nitrogen dose as compared to recommended nitrogen dose (Table 2). Kumar and Ladha (2011) mentioned that nutrient use efficiencies are lower in DSR compared to puddled TPR. The organic matter which have high C: N ratio is subjected to ammonification in anaerobic condition which enhance the higher ammonium release despite of higher decomposition in the aerobic condition (Patrick and Wyatt, 1964). Reddy et al. (1984) described that ammonium N accumulated in anaerobic condition i.e. in puddled field condition contributed to 60% of rice nitrogen need and higher uptake under this condition. The other reason of lower ammonium N might be due to nitrification of ammonium and subsequent denitrification under anaerobic condition (Zia et al., 2001) leading to lower uptake under DSR and lower use efficiencies of applied nitrogen compared with puddled TPR. Haque et al. (2016) observed that nitrogen use efficiency was significantly higher in plots applied 60 kg N ha^{-1} and lower in 100 kg N ha^{-1}.

Partial factor productivity was significantly influenced by the interaction between residue and nitrogen dose (Figure 1A). In farmers-nitrogen dose residue application had significantly higher partial factor productivity than no residue application but in recommended dose both residue application practices had statistically similar partial factor productivity. Establishment methods and residue also had significant interaction on nitrogen efficiency ratio (Figure 1B). In ZT-DSR without residue application had significantly higher nitrogen efficiency ratio than residue application treatment but in puddled TPR both residue application treatment had statistically similar nitrogen efficiency ratio.

Three way interactions of establishment methods, residue management and nitrogen dose was recorded for nitrogen efficiency ratio (Table 3). In no residue application treatment both establishment methods had statistically at par nitrogen efficiency ratio in both the nitrogen dose but in residue application treatment puddled TPR had significantly higher nitrogen efficiency ratio than ZT-DSR in both nitrogen dose.

Establishment methods and residue had significant interaction on physiological efficiency index (Figure 2A). In ZT-DSR no residue application had significantly higher physiological efficiency index than residue application treatment but in puddled TPR both reside application had at par physiological efficiency index. There was also significant interaction of residue and nitrogen dose on physiological efficiency index (Figure 2B). In recommended nitrogen dose residue applied plot had significantly lower physiological efficiency index than no residue application plot but in farmers-nitrogen dose both residue treatment had statistically similar physiological efficiency index.

Grain Yield, Straw Yield and Harvest Index

In our experiment establishment methods had no significant effect on grain yield of rice (Table 4). Sah et al. (2014) also had the similar findings where they observed non-significant effect on grain yield by establishment methods in year 2010/11. The results are in contrasting with the result found by Ehsanullah et al. (2000). Sah et al. (2014) in their trial during 2011/12 observed significantly higher grain yield in transplanting methods. Grain yield was found significantly higher in residue kept plot than residue removed plot in our experiment. Sah et al. (2014) in year 2011/12 observed significantly higher grain yield in residue retention treatment than residue removable. Hobbs et al. (2002) observed higher grain yield in residue kept treatment than residue removed treatment.

Recommended dose of nitrogen significantly produced higher grain yield of rice than farmers' dose. Sah et al. (2014), observed significantly higher grain yield with abundant nitrogen dose than farmers-nitrogen dose. Sharma and Ghosh (2000) also obtained that with successive increase in nitrogen dose up to 120 kg N ha^{-1} grain yield also increased significantly. Residue incorporation also significantly influenced the straw yield and found higher yield in residue kept than residue removed. As stated earlier residue benefits by soil moisture conservation, minimizing weed growth and organic matter addition in the soil which makes good crop growth and biomass. Sharma and Mitra (1992) also observed that wheat straw applied at the rate of 5 - 10 t ha^{-1} alone gave higher grain yield of rice than the plots with no residue applied. Arshadullah et al. (2012) also found the similar findings. Nitrogen dose also significantly affect the straw yield and higher yield was obtained in recommended nitrogen dose. Oo et al. (2007) also observed significantly higher straw yield in 100 kg N ha^{-1} over 50 kg N ha^{-1} and control plots but 100 kg N ha^{-1} and 150 kg N ha^{-1} had statistically similar straw yield. Togari et al. (1954) and Fageria (2014) stated that higher nitrogen helps in the metabolism of protein and ultimately the metabolism of carbohydrate in the latter stages of growth which might be the cause for significantly higher production of total above ground biomass and ultimately higher production of straw. Harvest index was also significantly influenced by the establishment methods and found higher harvest index in puddled-TPR than ZT-DSR. Ehsanullah et al. (2000) also reported significantly higher harvest index in transplanted rice than others direct seeding methods of rice cultivation.

Table 3. Nitrogen efficiency ratio as influenced by interaction between establishment methods, residue and nitrogen dose in Chitwan during 2016

Establishment methods	With Residue		Without Residue	
	Recommended dose	Farmers' dose	Recommended dose	Farmers' dose
ZT-DSR	79.10^{e}	84.09^{d}	85.63^{c}	88.72^{b}
Pu-TPR	83.85^{d}	90.71^{a}	86.13^{c}	89.41^{b}
Sem (±)	0.30			
LSD (0.05)	0.90			

Note: ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; ns, non-significance. Treatments means followed by different letter (s) are significantly different among each other based on DMRT at 5% level of significance

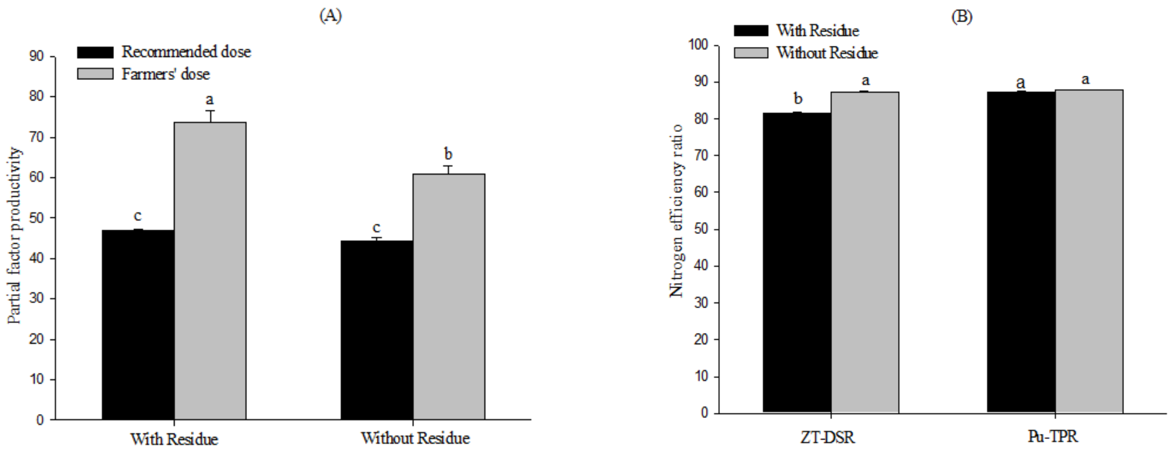

Figure 1. Partial factor productivity as influenced by interaction between residue and nitrogen dose (A) and nitrogen efficiency ratio as influenced by interaction establishment methods and residue (B) in Chitwan during 2016

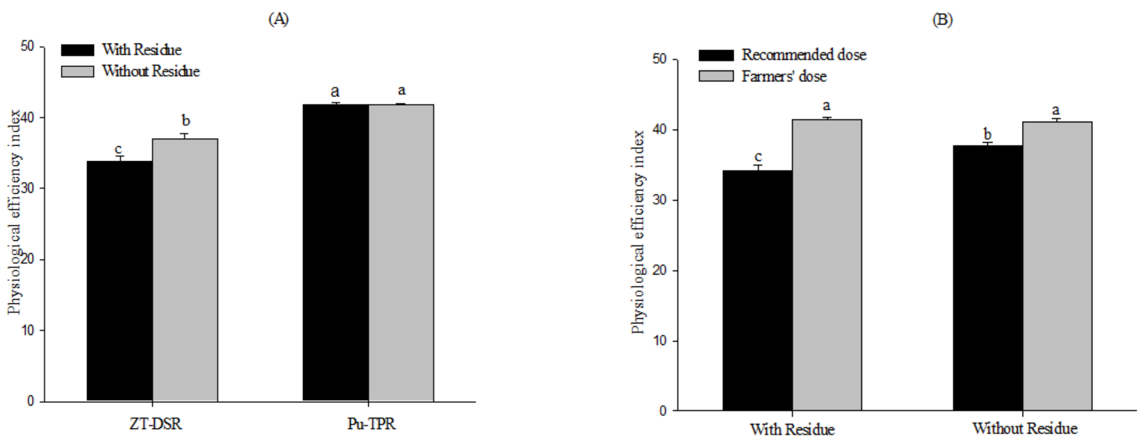

Figure 2. Physiological efficiency index as influenced by the interaction between establishment methods and residue (A) and residue and nitrogen dose (B) in Chitwan during 2016

Table 4. Grain yield, straw yield, and harvest index of rice as influenced by establishment methods, residue and nitrogen dose in Chitwan during 2016

Treatments	Grain Yield (t ha $^{-1}$)	Straw Yield (t ha $^{-1}$)	Harvest Index (%)
Establishment methods			
ZT-DSR	4.30	5.31^{a}	41.88^{b}
Pu-TPR	4.80	4.62^{b}	47.70^{a}
SEm (±)	0.2	0.1	0.7
LSD (0.05)	ns	0.5	2.6
CV(%)	8.4	6.3	3.9
Residues			
With Residue	4.81^{a}	5.34^{a}	44.6
Without Residue	4.27^{b}	4.60^{b}	45.0
SEm (±)	0.1	0.1	0.6
LSD (0.05)	0.2	0.5	ns
CV(%)	3.5	7.1	3.1
Nitrogen Dose			
RD	5.24^{a}	6.11^{a}	42.88^{b}
FD	3.85^{b}	3.83^{b}	46.70^{a}
SEm (±)	0.1	0.1	0.4
LSD (0.05)	0.2	0.2	1.2
CV(%)	7.3	7.8	4.1
Grand Mean	4.5	5.0	44.8

Note: ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; ns, non-significance. Treatments means followed by different letter (s) are significantly different among each other based on DMRT at 5% level of significance

Table 5. Harvest index of rice as influenced by establishment methods, residue and nitrogen dose in Chitwan during 2016

Establishment methods	With Residue		Without Residue	
	Recommended dose	Farmers' dose	Recommended dose	Farmers' dose
ZT-DSR	37.39^{e}	45.28^{bc}	41.30^{d}	43.56^{c}
Pu-TPR	46.38^{b}	49.29^{a}	46.46^{b}	48.67^{a}
Sem (±)	1.058			
LSD (0.05)	3.171			

Note: ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; ns, non-significance. Treatments means followed by different letter (s) are significantly different among each other based on DMRT at 5% level of significance

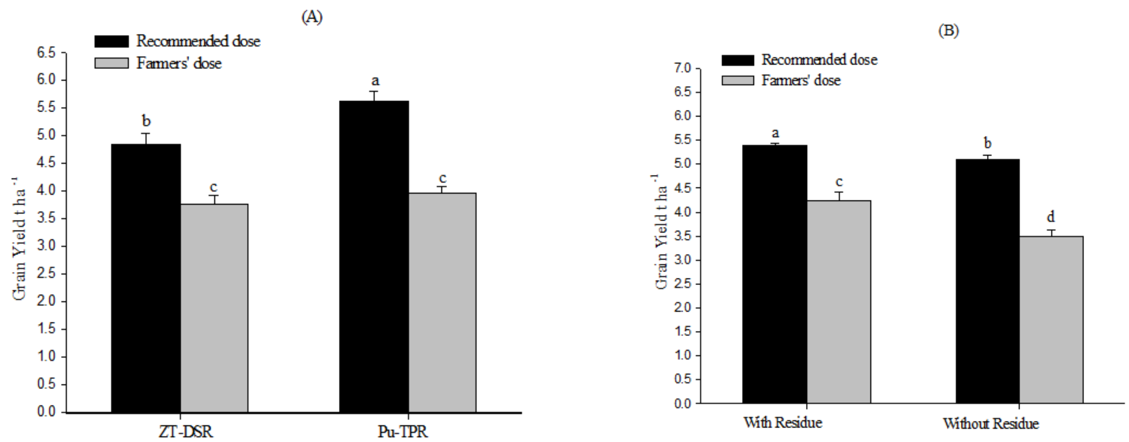

Figure 3. Grain Yield as influenced by interaction between establishment methods and nitrogen dose (A) and residue and nitrogen dose (B) in Chitwan during 2016

There was significant interaction of establishment methods and nitrogen dose on grain yield of rice (Figure 3A). In both establishment methods farmers' dose had statistically similar yield but in the recommended dose Pu-TPR had significantly higher grain yield than ZT-DSR. Similarly, there was also significant interaction of residue and nitrogen dose on grain yield of rice (Figure 3B). Residue with recommended dose had significantly higher grain yield which was followed by without residue in recommended dose and by with residue in farmers' dose and without residue in farmers' dose had statistically lower grain yield.

Three way interactions of establishment methods, residue management and nitrogen dose were recorded for harvest index (Table 5). In puddled TPR, harvest index recorded for farmers' dose was significantly higher than for the recommended dose under both residue kept and removed. But in ZT-DSR, harvest index was significantly higher for residue removed as compared to residue retained treatments under recommended nutrient dose while similar for farmers-nitrogen dose.

Conclusion

Grain, straw and total nitrogen uptake were found higher when higher amount of residue and nitrogen were applied in the soil. In establishment methods, ZT-DSR had higher straw nitrogen uptake than Pu-TPR. Different nitrogen use efficiencies values showed that there were higher efficiencies in farmers-nitrogen dose than recommended dose practices. Establishment methods had no effect on grain yield of rice but higher the amount of residue and nitrogen applied then they had significantly higher grain and straw yield.

Acknowledgments

The authors would acknowledge National Maize Research Program (NMRP), Rampur, Chitwan for providing the research plot to conduct the research trial and Agronomy Department of Agriculture and Forestry University (AFU) and all the staffs of NMRP and AFU.

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