

Full Length Research Paper

Growth, phenology, yield and yield attributes of rice as influenced by tillage, residue and nitrogen management practice in Chitwan, Nepal

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A field experiment was conducted in three factorial strip-split-plot design to evaluate the effect of two establishment methods (EM) [transplanted in puddled soil (PuTPR) and direct seeded in zero tillage (ZT-DSR)], two residue levels [residue kept at 3 t ha⁻¹ (RK) and residue removed (RR)] with two nitrogen doses [recommended dose (100 kg N ha⁻¹) (RD) and farmers' dose (50 kg N ha⁻¹) (FD)] with six replications on rice variety "Ramdhan" during the year 2016. PuTPR, RK, and RD of nitrogen had taller plant height in almost all the days of observation. Similarly, the number of tillers per square meter and leaf area index was significantly higher in ZT-DSR and RD of nitrogen in all the days of observation. Number of effective tillers (ET) and sterility percentage were significantly higher in ZT-DSR but thousand grain weight (TGW), grain per panicle and panicle weight were significantly higher in Pu-TPR. Residue incorporation produced more number of ET. ET, TGW, panicle length and weight were significantly higher in RD. Days to heading and physiological maturity was significantly lower in PuTPR than ZT-DSR. Grain yield was significantly higher in residue kept treatment and recommended nitrogen dose.

Key words: Conservation agriculture, direct seeded rice, leaf area, nitrogen, sterility, tiller.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important major food crop in the world and is eaten by more than 50% of the world's total population. Food security and rice security is considered equal in the Asian region. In Nepal, rice is cultivated in an area that spans 1,491,744 ha from where grain yield of 5,610,110 tons was obtained with average productivity of 3.76 t ha⁻¹ (MoALD, 2020). In Nepal, rice is the most important staple food and of the total calorie

requirement, rice alone supplied about 40%; economically, it shares about 20 and 7% of agricultural gross domestic product and total domestic product respectively of Nepal (CDD, 2015). Transplanting in puddled soil and direct seeding are two methods of rice cultivation. However, puddling had the negative impact on physical properties of soil, by which porosity of lower layer is reduced (Sharma et al., 2003), creating hard-

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pans which impede the development of roots of subsequent crops grown in rice based crop rotation and more methane gas emission in the atmosphere (Tripathi et al., 2005). Thus, with these drawbacks in transplanted rice (TPR), direct seeded rice (DSR) is considered suitable among the farmers because of its less labor, water requirement and higher efficiencies in energy use (Kumar and Ladha, 2011). DSR reduce the water (12-35%) and labor demand (up to 40%); also, fuel and energy requirement will ultimately decrease the cost of production (Mann et al., 2007). Residues incorporation in the soil improved moisture retention in the soil by reducing evaporation and thus increased water availability for crop growth and production. The determinants of soil productivity and quality (chemical, physical and biological conditions of soil) are improved by incorporation of the residue (Doran and Parkin, 1994). Since residue removal is the major reason for marginal land degradation, incorporation of residue in the soil have been attributed to increasing the soil organic carbon and producing the higher crop yield (Sehgal and Abrol, 1994). Nitrogen (N) is the highly required nutrient for the growth and yield of the crops, hence, for economically sustaining the cropping system, efficient use of nitrogen is very important. The soil available nitrogen generally does not meet the crop demand for growth; therefore, application of nitrogen through fertilizer is essential (Yoshida, 1981). Most of Nepalese farmers are poor in economy and availability of fertilizers in the market is also less due to which nitrogenous fertilizers are applied less than the recommended dose for rice. Nitrogen recommendation in DSR is 22.5-30 kg ha⁻¹ which is more than TPR because in DSR more aerobic condition is present, leaving the phosphorus and potassium constant in either methods (Kumar and Ladha, 2011). So, to access the influence of establishment methods, residue and nitrogen on the growth, phenology, yield and yield attributing traits of rice, this research was designed.

MATERIALS AND METHODS

A trial was setup at Agronomy Research Farm of National Maize Research Program, Chitwan, Nepal from June to November, 2016. The site was geographically located at 27.655095 North latitude and 84.357383 East longitudes having altitude of 183 m above sea-level. Strip-split plot design was used with establishment methods as horizontal factor, residue as vertical factor and nitrogen levels as sub-plot factor with two levels in each treatment which was replicated six times. Establishment methods involved (i) zero till-direct seeded rice (ZT-DSR) and (ii) puddled transplanting rice (Pu-TPR). Residue involved (i) residue kept and (ii) residue removed whereas sub plot factor included 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 experimental site falls in the subtropical humid climate belt of Nepal. The total rainfall during research was 1646.20 mm. Average maximum and minimum temperature during the cropping period were 32.32°C (ranging from 27.48-34.70°C) and 22.98°C (ranging from 11.84-26.0°C) respectively. The average relative humidity was 84.58% and average sunshine hour was 5.12 h per day during the cropping

time. The soil of experiment locations had organic matter 0.09-2.04%, available phosphorus 19.73-32.3 kg ha⁻¹ and potassium 67-134 kg ha⁻¹ in different depths of soil. Seeds of "Ramdhan" variety with a rate of 50 kg ha⁻¹ were sown on 22nd of June, 2016 for direct seeding by maintaining the space of 0.2 m between the rows and on the same day nursery bed preparation was done and 30 days old seedlings were transplanted for puddled-TPR. Phosphorus and potassium at the rate of 30: 30 kg ha⁻¹ and 1/3rd N were incorporated in soil at the time of field preparation and the remaining 2/3rd N was top-dressed in two equal split dose at active tillering and panicle initiation stage. Weeding by hand was done at 20 and 40 days after sowing (DAS) for weed management. Crop was irrigated on continuous basis by maintaining the water level of 2 cm for the first one month after planting; thereafter 5 cm water level was maintained during the entire crop duration and it was stopped 10 days before crop harvest. Crop was cultivated as per package of practice for rice during the entire crop duration. At maturity, crop was harvested and threshed manually; grain moisture was recorded plot-wise and yield was computed at 14% moisture content. Data on height of plant, tillers number, leaf area, count on effective tillers, thousand grain weight, grain per panicle, panicle length and weight, sterility, days to heading, physiological maturity and grain yield were recorded during the entire crop duration. Excel 2010 was used for processing of collected experimental data; data analysis was done using Genstat 13.2 software and significant treatments was subjected to Duncan's Multiple Range Test (DMRT) at 5% level for mean separation with references to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant height

Establishment methods, residue and nitrogen doses had significant influence on height of rice plant in different days of observation (Table 1). Across the time series, plant height was taller for Pu-TPR; however, it was significant at 70, 85 and 115 DAS. Aslam et al. (2008) and Ehsanullah et al. (2000) also recorded that height of plant was significantly more in conventional planting than in direct seeding of rice. It may be due to lower competition in space, sunlight and nutrients in transplanted crop than direct seeding which increase the plant height in transplanted crop. Similarly, plant height was significantly influenced by the nitrogen dose in all the dates of observation. Plant height was recorded taller in recommended nitrogen dose than farmers' nitrogen dose across all the dates of observation. Taller plant height with increased nitrogen dose might be due to vigorous vegetative growth with enough nitrogen available for absorption by plant. Nitrogen contributes to accumulation of carbohydrates in leaf sheaths and culms during pre-flowering stage and in the grain during grain filling stage (Swain and Jagtap, 2010). Haque et al. (2012) reported that with increase in the nitrogen from 0-150 kg, height of plant also increased; subsequently, and at maturity the height of plant was significantly higher at 100 kg N ha⁻¹ than 50 kg N ha⁻¹. At 75 DAS, Haque et al. (2012) observed significant difference in plant height between recommended dose and 50% of recommended dose but at 90 and 105 DAS, there was no significant difference of

Table 1. Plant height in rice as influenced by establishment methods, residue and nitrogen dose in Chitwan, Nepal.

Treatments	Plant height (cm)					
	40 DAS	55 DAS	70 DAS	85 DAS	100 DAS	115 DAS
Establishment methods						
ZT-DSR	32.22	48.14	53.28 ^b	60.26 ^b	80.65	91.13 ^b
Pu-TPR	32.93	50.88	55.23 ^a	66.80 ^a	81.07	99.08 ^a
SEm (±)	0.37	0.78	0.54	0.65	0.88	0.44
LSD (=0.05)	NS	NS	1.94	2.39	NS	1.61
CV, %	2.7	3.9	2.4	2.5	2.7	1.1
Residues						
With residue	33.55	50.8	55.27	64.71 ^a	83.35 ^a	96.83 ^a
Without residue	31.6	48.23	53.24	62.35 ^b	78.38 ^b	93.38 ^b
SEm (±)	0.59	0.71	0.89	0.63	1.35	0.92
LSD (=0.05)	NS	NS	NS	2.29	4.92	3.36
CV, %	4.4	3.5	4.0	2.4	4.1	2.4
Nitrogen dose						
RD	36.33 ^a	53.06 ^a	59.04 ^a	67.56 ^a	86.95 ^a	100.35 ^a
FD	28.82 ^b	45.96 ^b	49.46 ^b	59.50 ^b	74.78 ^b	89.86 ^b
SEm (±)	0.44	0.47	0.48	0.53	0.83	0.57
LSD (=0.05)	1.3	1.38	1.41	1.57	2.44	1.7
CV, %	6.6	4.6	4.3	4.1	5.0	3.0
Grand Mean	32.58	49.51	54.25	63.53	80.86	95.1

ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; NS, non-significance; DAS, Days after sowing. Different letter following the treatments means are significantly different among each other.

nitrogen dose on plant height.

Tillers number per square meter

Tiller number in the rice was found to be influenced significantly by the establishment methods and nitrogen dose in all the dates of observation but residue management practice did not show any significant influence in the tiller number in all the dates of observation (Table 2). In both crop establishment methods, tillers number goes on increasing from 40 to 70 DAS, but afterwards decreased. In DSR, rice seeds were sown regularly in the rows resulting in higher plants number per unit area, but in case of TPR, 30 days seedlings were transplanted at 20 cm × 20 cm spacing. Moreover, the differences in the number of tillers were less between DSR and TPR during later stage because TPR starts producing tillers after 55 days and tiller mortality becomes higher due to higher intra plant competition in DSR. Gill et al. (2014) reported that numbers of tillers per square meter was higher under DSR than puddled TPR. Residue management practices had no any significant differences on tillers number per square meter in all the dates of observation, but residue incorporation practice showed higher tillers number as

compared to without residue practice in all dates. Nitrogen dose significantly influenced the tiller number at all the dates of observation. Recommended nitrogen dose produced significantly more tillers number than farmers' dose of nitrogen in all the dates of observation. At 75, 90 and 105 DAS, Haque et al. (2012) observed similar results at between recommended dose and 50% of recommended dose. Manzoor et al. (2006) reported that numbers of effective tillers were seen as highest in 225 kg N ha⁻¹ while minimum tillers were seen in control.

Leaf area index

Leaf area index was found to be significantly influenced by establishment methods in all days of observation except at 100 DAS, and was found higher in ZT-DSR than puddled TPR (Table 3). Higher LAI in ZT-DSR is observed due to higher tillers number per square meter in all the dates of observation by which there were higher number of leaves which would ultimately result in higher leaf area as compared to puddled TPR. Ginigaddara and Ranamukhaarachchi (2009) also reported that DSR produced higher LAI than puddled transplanted rice. Also, leaf area index was found to be significantly influenced by the nitrogen dose in all the dates of observation and was

Table 2. Tillers number per meter square in rice as influenced by establishment methods, residue and nitrogen dose in Chitwan, Nepal.

Treatments	Tiller number per square meter					
	40 DAS	55 DAS	70 DAS	85 DAS	100 DAS	115 DAS
Establishment methods						
ZT-DSR	276.1 ^a	378.4 ^a	437.5 ^a	374.1 ^a	331.5 ^a	305.9 ^a
Pu-TPR	132.7 ^b	297.8 ^b	360.9 ^b	322.4 ^b	258.6 ^b	247.4 ^b
SEm (±)	11.4	13.4	10.8	9.9	12.4	8.5
LSD (=0.05)	41.3	48.9	39.4	35.9	45.2	31.0
CV, %	13.6	9.7	6.6	6.9	10.3	7.5
Residues						
With residue	220.9	359.3	404.8	365.6	296.9	289.2
Without residue	187.9	317.0	393.6	330.8	293.2	264.2
SEm (±)	11.2	16.4	19.8	14.4	10.7	8.5
LSD (=0.05)	NS	NS	NS	NS	NS	NS
CV, %	13.4	11.9	12.1	10.1	8.9	7.5
Nitrogen dose						
RD	239.4 ^a	391.0 ^a	450.2 ^a	364.9 ^a	312.6 ^a	293.5 ^a
FD	169.5 ^b	285.2 ^b	348.2 ^b	331.6 ^b	277.5 ^b	259.8 ^b
SEm (±)	9.0	14.7	9.3	7.5	9.9	8.1
LSD (=0.05)	26.6	43.5	27.3	22.0	29.3	23.9
CV, %	21.6	21.4	11.4	10.5	16.5	14.4
Grand mean	204.4	338.1	399.2	348.2	295.1	276.7

ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; NS, non-significance; DAS, Days after sowing. Different letter following the treatments means are significantly different among each other.

Table 3. Leaf area index in rice as influenced by establishment methods, residue and nitrogen dose in Chitwan, Nepal.

Treatment	Leaf Area Index					
	40 DAS	55 DAS	70 DAS	85 DAS	100 DAS	115 DAS
Establishment methods						
ZT-DSR	0.52 ^a	1.03 ^a	1.52 ^a	1.69 ^a	2.18	2.16 ^a
Pu-TPR	0.14 ^b	0.43 ^b	1.03 ^b	1.21 ^b	1.66	1.45 ^b
SEm (±)	0.02	0.03	0.09	0.05	0.20	0.06
LSD (=0.05)	0.08	0.09	0.32	0.19	NS	0.24
CV, %	16.9	8.70	17.10	8.80	25.80	8.00
Residues						
With residue	0.38 ^a	0.79	1.37	1.66	2.00	1.90
Without residue	0.28 ^b	0.66	1.19	1.25	1.84	1.70
SEm (±)	0.02	0.04	0.05	0.14	0.08	0.02
LSD (=0.05)	0.09	NS	NS	NS	NS	NS
CV, %	18.5	14.40	9.90	23.90	10.00	9.80
Nitrogen dose						
RD	0.46 ^a	1.07 ^a	1.73 ^a	1.93 ^a	2.44 ^a	2.20 ^a
FD	0.19 ^b	0.39 ^b	0.82 ^b	0.98 ^b	1.40 ^b	1.40 ^b
SEm (±)	0.04	0.05	0.07	0.09	0.79	0.07
LSD (=0.05)	0.11	0.14	0.22	0.25	0.23	0.20
CV, %	55.9	31.80	28.70	28.80	20.10	18.40
Grand mean	0.33	0.73	1.28	1.45	1.92	1.80

ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; NS, non-significance; DAS, Days after sowing. Different letter following the treatments means are significantly different among each other.

Table 4. Yield attributing characteristics of rice as influenced by establishment methods, residue and nitrogen dose in Chitwan, Nepal.

Treatments	Yield attributing characteristics					
	Effective tillers	TGW	Grain per panicle	Panicle length	Panicle weight	Sterility (%)
Establishment methods						
ZT-DSR	253.02 ^a	20.98 ^b	103.27 ^b	24.44	2.44 ^b	9.64(3.15) ^a
Pu-TPR	237.35 ^b	21.91 ^a	116.80 ^a	24.93	2.91 ^a	7.04(2.73) ^b
SEm (±)	2.92	0.14	2.07	0.19	0.07	0.07
LSD (=0.05)	10.61	0.52	7.53	NS	0.26	0.26
CV, %	2.9	1.6	4.6	1.9	6.5	6.0
Residues						
With Residue	261.64 ^a	21.58	108.38	24.61	2.64	8.71(3.00)
Without Residue	228.73 ^b	21.31	111.68	24.76	2.7	7.98(2.88)
SEm (±)	4.81	0.11	2.13	0.17	0.04	0.08
LSD (=0.05)	17.49	NS	NS	NS	NS	NS
CV, %	4.8	1.3	4.7	1.6	3.7	6.3
Nitrogen dose						
RD	273.06 ^a	22.18 ^a	110.68	25.19 ^a	2.75 ^a	8.32(2.94)
FD	217.31 ^b	20.72 ^b	109.39	24.18 ^b	2.59 ^b	8.36(2.94)
SEm (±)	7.76	0.11	1.57	0.16	0.05	0.09
LSD (=0.05)	22.89	0.33	NS	0.48	0.15	NS
CV, %	15.5	2.5	7	3.2	9	15.70
Grand mean	245.18	21.45	110.03	24.69	2.67	8.34(2.94)

ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; TGW, Thousand grain weight; NS, non-significance. Different letter following the treatments means are significantly different among each other and sterility data were subjected to square root $\sqrt{(x+0.5)}$ transformation before analysis and figures in parenthesis are transformed value.

seen as higher in recommended nitrogen dose than farmers' nitrogen dose. Higher leaf area in recommended nitrogen might be due to the better vegetative growth due to the higher nitrogen dose which results in the increase in the number of leaf and leaf area. LAI was found higher in more nitrogen level due to expansion of individual leaves and increased number of tillers. Swain and Jagpat (2010) reported that nitrogen contributes to more vegetative growth before flowering due to which LAI increased up to 90 DAS, but after that, LAI reduced because almost all the nitrogen translocated from leaf to grains after heading. Haque et al. (2016) also observed higher leaf area index in 100 kg/ha N dose which was seen 45 days after transplanting but lowest LAI was seen in control plots.

Yield attributing characteristics

Effective tillers per meter square were significantly greater in ZT-DSR than in puddled-TPR (Table 4). Aslam et al. (2008) had higher number of productive tillers per square meter in direct seeding of rice as compared to

that of conventional planting. Hobbs et al. (2002) also recorded 150% higher number of effective panicles per unit area in DSR than puddled TPR. Residue application gave significantly higher number of effective tillers than without residue application. Arshadullah et al. (2012) observed significantly higher number of tillers in residue applied treatments than control treatments. Nitrogen application produced significantly higher number of effective tillers in recommended nitrogen dose than farmers' nitrogen dose. Further, panicles per hill were found significantly higher in 60 kg N ha⁻¹ and lowest were seen under control plots (Haque et al., 2016). Thousand grain weight was also significantly higher in puddled-TPR than ZT-DST in our experiment. Aslam et al. (2008) and Ehsanullah et al. (2000) reported significantly more TGW in conventional planting than in direct seeding of rice; also, Sharma et al. (2005) had reported that establishment methods had no significant effect on the thousand grains weight. Thousand grain weight was also significantly higher in recommended nitrogen than farmers' nitrogen. Oo et al. (2007) reported significantly higher TGW in 150 kg N ha⁻¹ which was significantly same with 100 kg N ha⁻¹; TGW at 50 and 100 kg N ha⁻¹

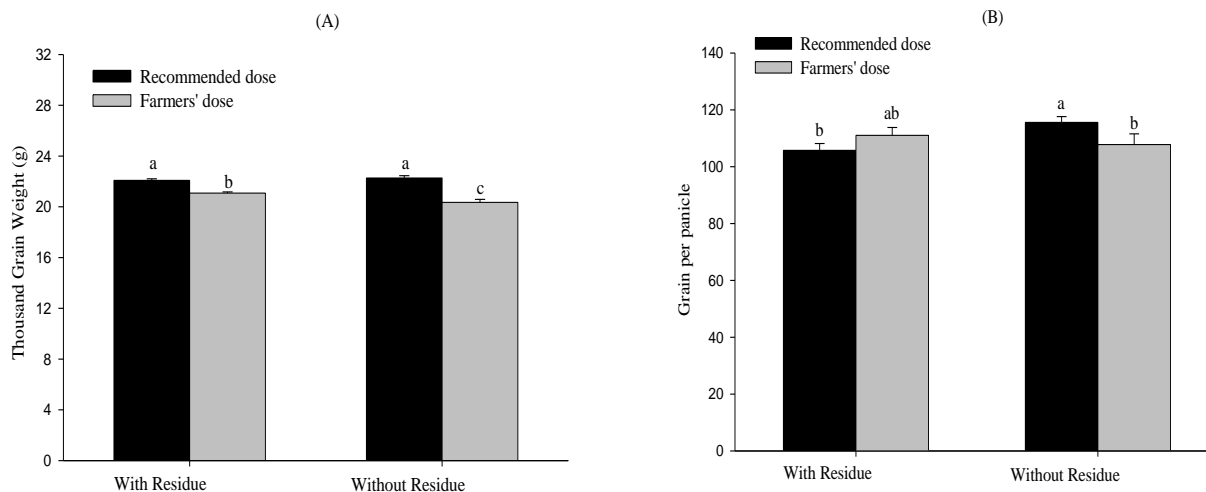


Figure 1. Influence of interaction between residue and nitrogen dose on (A) TGW and (B) grain per panicle in Chitwan, Nepal.

were statistically at par; significantly lower TGW was seen at control but contrasting results were reported by Tayefe et al. (2014) and Patil et al. (2001) where they found that nitrogen levels had no significant effect on thousand grain weight of rice.

Grain per panicle was also significantly higher in puddled-TPR than ZT-DSR (Table 4). Aslam et al. (2008) reported significantly higher grain per panicle in conventional planting than in direct seeding of rice. Gathala et al. (2011) also reported lower GPP in DSR as compared to puddled TPR. Significant interaction between residue and nitrogen dose was seen in thousand grain weight (Figure 1A) of rice. Residue and without residue with recommended dose were statistically at par with TGW, but in farmers' dose, without residue had significantly lower TGW than with residue. Interaction between the residue and nitrogen dose significantly influenced the grain per panicle of rice (Figure 1B). In without residue, recommended dose had significantly higher grain per panicle than farmers' dose, but in residue, recommended dose had lower but statistically at par grain per panicle to farmers' dose.

Non-significant effect of establishment methods was seen on panicle length (Table 4). Gill et al. (2014) also had similar findings in his experiment, but recommended nitrogen produced panicle with longer length than farmers' nitrogen. Significantly longer panicle length was recorded in 150 kg N ha^{-1} and length were also significantly different at 100 kg and 50 kg N ha^{-1} and lower length was obtained in control plots (Oo et al., 2007). Panicle weight was significantly higher in puddled-TPR than ZT-DSR in our trial. Less number of effective tillers under ZT-DSR favors more supply of produced assimilates, which increase the panicle weight as compared to puddled TPR. Sharma et al. (2005) also observed significantly higher panicle weight in

transplanted rice as compared to unpuddled direct seeding of rice in the lines 20 cm apart. Also, recommended nitrogen dose produced panicle of higher weight than farmers' field practice nitrogen application. Sterility percentage was significantly higher in ZT-DSR than Pu-TPR. More number of tillers and effective tillers under ZT-DSR caused intra plant competition for assimilates formed which results to higher sterility percentage in direct seeded rice. Gathala et al. (2011) also reported higher count of sterile spikelets in DSR as compared to Pu-TPR.

Phenological observation and grain yield

Nitrogen dose had significant influence on days to heading, but establishment methods and residue did not have any significant influence on the heading of rice (Table 5). Establishment methods and nitrogen dose had significant effect on days to physiological maturity. Root development in ZT-DSR was found to be better from the day of germination and also lack of transplanting shock in ZT-DSR, with the physiological maturity occurring earlier than Pu-TPR. Sharma et al. (2005) and Gill (2008) reported early maturity and shorter crop duration in direct seeding of rice in comparison with transplanted rice. Recommended nitrogen application results in early heading and physiological maturity by 4.84 and 3.54 days than farmers who practice nitrogen application. Yesuf and Balcha (2014) observed similar findings in days to maturity, but contrasting result was seen in days to flowering where flowering was faster in lower nitrogen dose than higher nitrogen dose.

There was also significant interaction between establishment methods and residue on days to heading (Figure 2A) of rice plant. In ZT-DSR, residue removed

Table 5. Days to heading, physiological maturity and grain yield of rice as influenced by establishment methods, residue and nitrogen dose in Chitwan, Nepal.

Treatments	Days to heading (DAS)	Days to physiological maturity (DAS)	Grain Yield (t ha ⁻¹)
Establishment methods			
ZT-DSR	108.58	138.79 ^b	4.30
Pu-TPR	107.83	141.08 ^a	4.80
SEm (±)	0.45	0.37	0.2
LSD (=0.05)	NS	1.33	NS
CV, %	1.0	0.6	8.4
Residues			
With Residue	107.38	139.42	4.81 ^a
Without Residue	109.04	140.46	4.27 ^b
SEm (±)	0.54	0.41	0.1
LSD (=0.05)	NS	NS	0.2
CV, %	1.2	0.7	3.5
Nitrogen dose			
RD	105.79 ^b	138.17 ^b	5.24 ^a
FD	110.63 ^a	141.71 ^a	3.85 ^b
SEm (±)	0.47	0.33	0.1
LSD (=0.05)	1.40	0.98	0.2
CV, %	2.10	1.20	7.3
Grand Mean	108.21	139.94	4.5

ZT-DSR, Zero tilled direct seeded rice; Pu-TPR, Puddled transplanted rice; RD, Recommended dose; FD, Farmers practice dose; NS, non-significance; DAS, Days after sowing. Different letter following the treatments means are significantly different among each other.

treatment took significantly higher number of days for heading than residue retained, but in Pu-TPR there was no significant difference on heading by the residue application. There was also significant interaction between establishment methods and dose of nitrogen on days to heading (Figure 2B). In ZT-DSR, farmers' dose took statistically more days for heading than recommended dose, but in Pu-TPR, both recommended and farmers' doses were statistically at par. On days to physiological maturity, there was significant interaction of establishment methods and nitrogen dose (Figure 2C). ZT-DSR with recommended dose had statistically early physiological maturity than farmers' dose, but in Pu-TPR, both recommended and farmers' doses were statistically at par.

There was non-significant effect of establishment methods on grain yield of rice (Table 5). Sah et al. (2014) in their trial during 2010/2011 also observed similar findings. Sharma et al. (1988) recorded that DSR can produce grain yield comparable to TPR. Contrasting results were observed by Cabangon et al. (2002), Hayashi et al. (2007) and Bhushan et al. (2007) where they observed either similar or even higher grain yield in direct seeding than conventional methods of rice planting.

Residue incorporation gave significantly higher grain yield than residue removed. Similar finding was observed in year 2011/2012 by Sah et al. (2014). The higher yield in the residue kept plot was due to positive effect of residue by directly conserving the soil moisture from evaporation which makes more water available for the absorption, and controlling the weed growth by acting as the surface mulch as well as in the later days by the slow decomposition of the residue makes more nutrients available for the growth and which ultimately gives higher yield. Similarly, higher yield was obtained in residue incorporated treatment by Hobbs et al. (2002). Significantly higher grain yield was obtained in recommended dose of nitrogen than farmers' nitrogen dose (Table 4). Similar finding was also recorded by Sah et al. (2014). Increase in the nitrogen content of rice plant is closely related with numbers of tillers, spikelets and leaf area index which in turn increases the yield. Nitrogen increases the aggregation of the carbohydrate in the leaf sheaths and culms before heading stage; and during the ripening stage, carbohydrate pile-up in the grain of rice (Swain and Jagtap, 2010). By the application of nitrogen, different yield attributing traits like more number of panicle, lower grain sterility, higher thousand grain

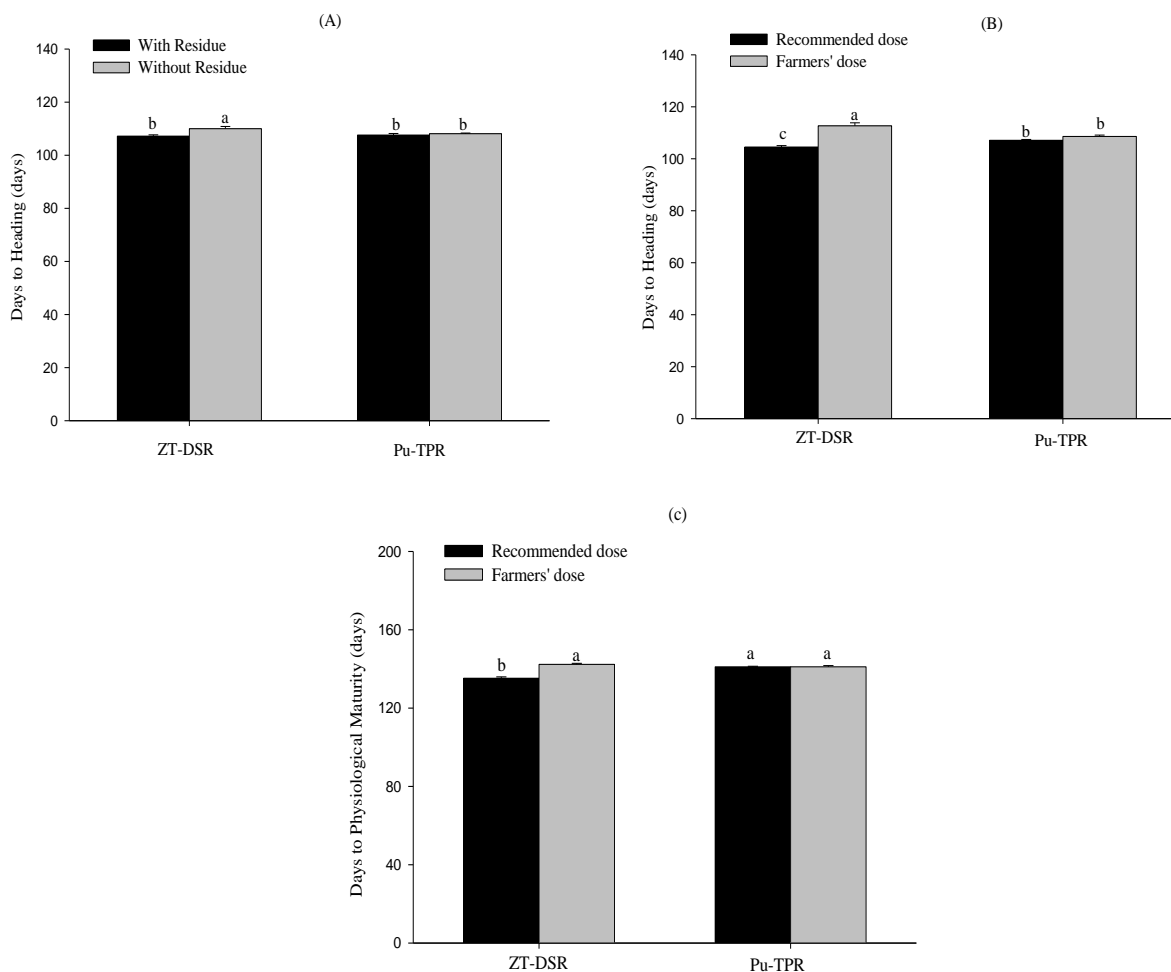


Figure 2. Days to heading as influenced by interaction between establishment methods and residue (A) and establishment methods and nitrogen dose (B) and days to physiological maturity as influenced by interaction between establishment methods and nitrogen (C) in Chitwan, Nepal.

weight, etc and increased height of plant, size of leaf and number of tillers and grain yield were improved (Walker et al., 2008).

Conclusion

The present study which evaluates the effect of tillage, residue and nitrogen management practices on growth, phenology and yield of rice suggested direct seeding methods of rice cultivation with residue to be incorporated in the soil, and nitrogen must be applied at recommended dose for better growth and yield. Although puddled transplanting had higher yield, it has statistically similar yield with direct seeded rice. Because of many advantages of direct seeding, it is good in terms of better water, labor and cost efficiencies. Residue incorporation increases the organic matter content and conserves soil moisture; also, recommended nitrogen dose had better growth and yield of rice than farmers' practice dose of

nitrogen.

The study which was conducted only one year in Chitwan, Nepal, may not be generalized over large agricultural domain, hence it is the major limitation of the research. For larger recommendation, multi-located domains and multi-year research could be conducted. This research was conducted in research stations where DSR was found to be good, but farmers are reluctant to practice it; therefore, in order to scale it up, off-farm research needs to be strengthened.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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