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Research Article

Effect of rice establishment methods and nutrient management practices on subsequent wheat crop grown under different establishment methods and nutrient management practices at Rampur, Chitwan, Nepal

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ABSTRACT

A field experiment was conducted to evaluate the effect of land management practices and residual effect of nutrient management practices of rice on the performance of subsequent wheat crop in the rice-wheat cropping system in Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal during June 2018-March 2019. The experiment was executed in a split-plot, included two establishment methods viz. (i) conventional tilled dry direct-seeded rice followed by (*fb*) zero tillage wheat (CT-DDSR *fb* ZT) (ii) puddled transplanted rice followed by conventional tillage wheat (Pu-TPR *fb* CT) as main plot treatments, and four nutrient management practices: (i) 100% recommended dose (100% RDF; 150:45:45 and 80:60:40 kg N, P_2O_5, and K_2O ha^{-1} respectively for rice and wheat), (ii) Residue retention @ 5 t ha^{-1} of wheat on rice *fb* residue of rice on wheat + 75% RDF of each crop (RR +75%RDF), (iii) Nutrient expert (NE) dose (140:56:53; 140:60:45 kg N, P_2O_5, and K_2O ha^{-1} for rice and wheat respectively), (iv) Brown/green manuring of *Sesbania* in rice *fb* rice residue @ 3.5 t ha^{-1} in wheat +75% RDF of each crop (BM/GM *fb* R+75% RDF) as subplot treatments with three replications. The variety of wheat 'Bijay' was sown @120 kg ha^{-1} with spacing 20 cm × continuous. The data on phenology, yield, yield attributes, and economics were recorded and analyzed by R studio. The study revealed that none of the yield attributes and yield of wheat were significantly influenced by the establishment methods. Significantly more effective tillers (281.94 m^{-2}) and grains per spike (44.48) and higher straw yield (5.95 t ha^{-1}) were recorded under NE dose. The grain yield of wheat was 21% and 16% more under NE dose and BM/GM *fb* R+75% RDF respectively compared to 100% RDF. CT-DDSR *fb* ZT wheat had slightly less net returns (NRs. 4523 ha^{-1}) than Pu-TPR *fb* CT-wheat. NE dose was the most profitable. Hence, rice establishment methods were indifferent but NE dose was the best nutrient management practice for better production and profitability for the wheat in the rice-wheat system.
Keywords: Nutrient Expert, residue, zero tillage wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the dominant crop of the cereal-based cropping systems, produced in 167 million ha with a yield of 3.53 t ha-1 globally and the Asian region alone contributes 43.50% to global wheat production (FAOSTAT, 2017). It is the food for more than a billion people and is crucial in ensuring food security and livelihood in Indo-Gangetic Plain (IGP) (Kumar et al., 2018). Wheat covers 1657 thousand ha of the total cultivable land of Nepal and covers 56.86% of plains of Nepal (MoALD, 2018) out of which more than 60% of the area is unirrigated (Pandey et al., 2017) Despite the higher potential yield (Amgain & Timsina, 2004) (4.4 t ha-1) of wheat in Nepal, the national average yield has been confined to 2.78 t ha-1 (MoF, 2018) which created a huge yield gap in the nation. To meet the demand, Nepalese agriculture has now been import-driven and imported wheat worth NRs. 5.07 billion during the fiscal year 2018/19 (The rising Nepal, 2019). So, the adoption of suitable agronomic management along with new technological innovation can be the only option to sustain this situation.

In the Nepalese rice-wheat cropping system, the popular crop establishment method includes the transplantation of 20-25 days old rice seedlings in the puddled field while wheat is established (in rice residue removed fields) by broadcasting/drilling seed after conventional tillage and planking operations (Bhatt, Kukal, Busari, Arora, & Yadav, 2016). The continuous practice of conventional tillage in most areas has led to degradation in soil property i.e. increase in the soil bulk density (Zamir et al., 2013), reduction in soil porosity, infiltration, and moisture retention capacity (Moraru & Rusu, 2013), and the faster decomposition of residues and quicker mineralization of the nutrients (Thomas et al. (2007) which increases the nutrient loss leaving the soil infertile in long run. In addition to the detrimental effects of traditional rice production practices on soil properties, the conventional wheat planting system involves repeated dry tillage to prepare the field which also leads to further delay in wheat seeding by almost a week compared to zero tillage planting (Kumar et al., 2014). This intensive tillage leads to a long turn round period (Tripathi et al., 2005). The hydrology of wheat is different from the rice crop and hence the rice establishment method has a great impact on its yield. The reduced or zero tillage restore the soil aeration, porosity and discard the hardpan formation making suitable field conditions for the plantation of subsequent aerobic crops i.e wheat with a 9% yield increment in the field followed after DSR than TPR (Kumar & Ladha, 2011).

Crop residue is the above-ground part of the plants that remained after the grain is harvested and is the important plant nutrient source that can replenish the extensively mined nutrients due to intensive cropping. Typical amounts of nutrients in rice straw at harvest are 5-8 kg N, 0.7-1.2 kg P_2O_5, 12-17 kg K_2O, 0.5-1 kg S, 3-4 kg Ca, 1-3 kg Mg, and 40-70 kg Si per ton on a dry weight basis. South Dakota State University data shows that wheat stover contains approximately 4.54 kg N, 3 1.36kg P_2O_5, 14.06 kg K_2O, and 0.91 kg S per ton (iGrow, 2014) and hence, the decomposition of such applied crop residues in the field can reduce the amount of fertilizers to be applied. Green manuring and brown manuring also have a positive impact on soil organic matter. In addition, it acts as surface mulch thereby conserving the soil moisture and improving the soil physicochemical properties, and reduce the problems of soil crusting resulting in faster germination of succeeding wheat crop (Samant, 2017). Nutrient Expert (NE) is computer-based nutrient decision support software based on site-specific nutrient management (SSNM) principles and enables farm advisors to develop fertilizer recommendations tailored to a specific field or growing environment (IPNI, 2017). It is being popular among the farm managers for supplying the nutrient to the crop through the right source and in the right dose in line with the crop demand.

The yield stability of wheat grown after the rice has been a popular issue and the appropriate agronomic management practices including the methods of crop establishment and suitable nutrient management practices have always been the focal area of global research but a solid conclusion is yet to be derived. Hence, the current study was carried out.

MATERIALS AND METHODS

Site description

The experiment was conducted at the research block of Agronomy Farm of Agriculture and Forestry University (AFU), Rampur, Chitwan district of Bagamati Province of Nepal (27˚40' N and 84˚23' E and 256 masl) from June 2018 to May 2019. The soil in the experimental field was sandy loam with pH with slightly acidic to neutral with medium to low OM and nitrogen content, high phosphorus and medium potassium content according to the standard rating of Directorate of Soil Management, Ministry of Agriculture Development, Government of Nepal, Kathmandu, Nepal (Table 1).

Table 1. Physico-chemical properties of soil of the experimental site during 2018-19

Properties	Average Content	Rating			Methods and References (Estefan, Sommer & Ryan,2014)
Physical properties					
Sand (%)	63.10	Sandy loam			Hydrometer
Silt (%)	28.00				
Clay (%)	8.90				
Chemical properties					
	0-15 cm	Rating	15-30 cm	Rating	Methods and References
Soil pH	6.40	Acidic	6.5	Neutral	Beckman Glass Electrode pH meter
Soil organic matter (%)	3.20	Medium	1.79	Low	Walkey and Black
Total nitrogen (%)	0.16	Medium	0.09	Low	Micro Kjeldhal Distillation
Available phosphorus (kg ha^{-1})	85.03	High	130.97	High	Modified Olsen's method
Available potassium (kg ha^{-1})	214.61	Medium	138.65	Medium	Ammonium Acetate method

The experimental site lies in the subtropical humid climate belt of Nepal. The area has sub-humid type of weather condition with cool winter, hot summer, and distinct rainy season with annual rainfall of about 2000 mm. The weather data during the cropping seasons was recorded from the metrological station of the National Maize Research Program (NMRP), Rampur, Chitwan (Figure 1).

Experimental design and treatments

The experiment was done by using a split-plot design, with two factors i.e. two establishment methods as main plot and four nutrient management practices as sub plot factors. The two establishment methods comprised of (i) conventionally tilled dry direct seeded rice (CT-

DDSR) followed by zero tillage (ZT) wheat (CT-DDSR fb ZT) (ii) puddled transplanted rice (Pu-TPR) followed by conventionally tilled (CT) wheat (Pu-TPR fb CT). The four nutrient management practices included: (i) 100% recommended dose (100% RDF; 150:45:45 and 80:60:40 kg N, P_2O_5, and K_2O ha^{-1} respectively for rice and wheat), (ii) Residue retention @ 5 t ha^{-1} of wheat on rice *fb* residue of rice on wheat + 75% RDF of each crop (RR +75%RDF), (iii) Nutrient expert (NE) dose (140:56:53; 140:60:45 kg N, P_2O_5, and K_2O ha^{-1} for rice and wheat respectively), (iv) Brown/green manuring of *Sesbania* in rice *fb* rice residue @ 3.5 t ha^{-1} in wheat +75% RDF of each crop (BM/GM *fb* R+75% RDF) and the treatments were replicated thrice. The variety of wheat 'Bijay' was sown @120 kg ha^{-1} with spacing 20 cm × continuous in the experimental units of size 14.4 m^2 (4.8m×3 m).

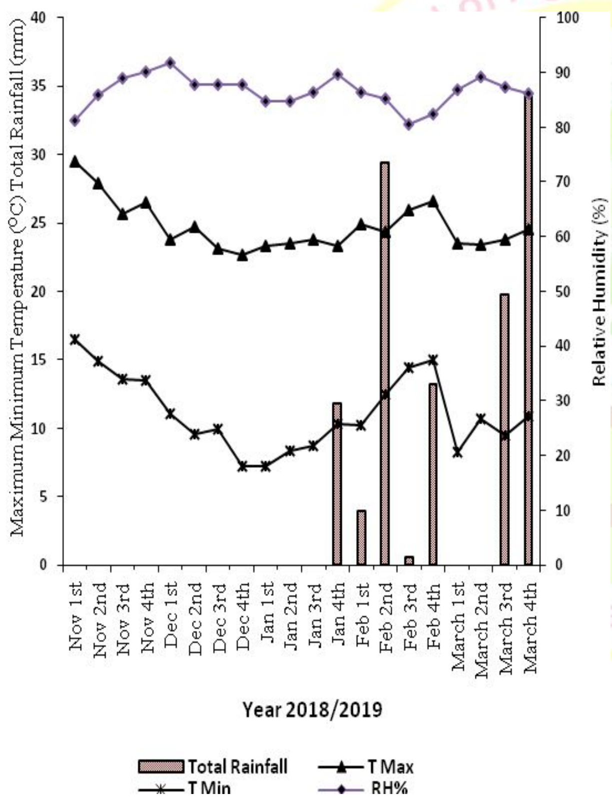

Figure 1. Minimum and maximum daily temperature (°C), daily rainfall (mm) and daily relative humidity during the experimental period at Rampur, Chitwan, Nepal, 2019 (Source: NMRP, 2019).

Crop management

During rice season, the field was tilled twice, planked and leveled and rice crop was established using two methods: dry seeds directly sown in rows (DDSR) and transplanted in puddled field (Pu-TPR). The wheat residue on rice crop @ 5 t ha^{-1} was applied as mulch in DDSR and incorporated in soil for Pu-TPR. For ZT wheat after DDSR, the plots were sprayed glyphosate-47L with 5ml L^{-1} was applied in the field a week prior to sowing and wheat was directly sown in lines. For CT, after Pu-TPR, the field was ploughed twice, pulverized and leveled and wheat was sown. For both establishment methods, seed was sown on 5th November 2018 in continuous manner in the rows spaced 20 cm apart.

The RDF used for rice and wheat was 150: 45:45; 80:60:40kg N, P_2O_5 and K_2O ha^{-1} respectively. The nutrient expert dose i.e.140:56:53; 140:60:45 kg N, P_2O_5, and K_2O ha^{-1} for rice and wheat respectively were calculated using Nutrient Expert Model of each crops developed by International Plant Nutrient Institute (IPNI). The residue amount varied with treatments and was used as surface mulch. Full dose of K_2O and P_2O_5 was applied through MOP and DAP as basal dose whereas N in each treatment was divided three equal splits and each split was applied at 0 DAS (basal dose), 30 days after sowing (DAS) and 60 DAS respectively. No irrigation and weed management practice was carried out.

Sampling and measurements

The effective tillers at harvest were counted from an entire row in the net plot area and expressed in per sq. meter. For the computation of sterility, 20 average spikes from each treatment were selected, the unfertilized and fertilized florets were counted and sterility was computed and expressed in percentage using the formula:

$$\text{Sterility (\%)} = \frac{\text{unfertilized florets}}{\text{total floret}} \times 100$$

The average grains per spike was also calculated form the same 20 selected average spikes. The crop was harvested at physiological maturity stage from the net plot area of 9.6 m^2 for determination of yield. The thousand grain weight (TGW) was also calculated from the grain lot by counting 1000 grains. The harvest index (HI) was determined by calculating the ratio of grain yield and biological yield and expressed in percentage. The B:C ratio was calculated by dividing the gross returns (based on the local market price of Chitwan) by total cost of cultivation

Statistical analysis

The recorded data were subjected to analysis of variance, and Duncan's multiple range test at α level 0.05 (DMRT) for mean separations (Gomez & Gomez, 1984). Dependent variables were subjected to analysis of variance using the R Studio for split plot design. Sigma Plot v. 12 was used for the graphical representation.

RESULTS AND DISCUSSION

The yield attributing characters, yield and economics of subsequent wheat as influenced by establishment methods and nutrient management practices of it and preceding rice crop is discussed below:

The average number of effective tillers per square meter at the time of harvest was 234.10. In response to establishment methods, Pu-TPR fb CT showed higher number of effective tillers per square meter than CT-DDSR fb ZT. Regarding the nutrient management practices, NE dose had shown significantly higher number of effective tillers (281.94 m^{-2}) (Table 2).

Significant interaction was seen between establishment methods and nutrient management practices for no. of effective tillers per sq. meter of wheat as shown in Figure 2.

Table 2. Number of effective tillers per square meter, number of grains per spike, thousand grain weight (g), sterility (%) of wheat as influenced by the establishment methods and nutrient management practices at Rampur, Chitwan, 2018-2019

Treatments	Number of effective tillers (m^{-2})	Number of grains per spike	Thousand grain weight (g)	Sterility (%)
Establishment methods				
CT-DDSR fb ZT	233.33	41.38	66.41	46.92
Pu-TPR fb CT	234.86	38.28	67.60	47.19
SEm (±)	6.76	0.78	0.24	0.27
LSD (=0.05)	ns	ns	ns	ns
CV, %	10.00	6.80	1.40	1.80
Nutrient management practices				
100% RDF	219.44[b]	38.55[b]	66.99	47.90
RR+75% RDF	214.72[b]	38.77[b]	66.70	47.32
NE dose	281.94[a]	44.48[a]	67.64	45.46
BM/GM fb R+75% RDF	220.28[b]	37.53[b]	66.69	47.54
SEm (±)	4.19	1.09	0.73	0.86
LSD (=0.05)	12.90	3.35	ns	ns
CV, %	4.40	6.70	3.20	3.80
Grand mean	234.10	39.81	67.01	47.07

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fb, followed by; CT, conventional tillage; ZT, zero tillage; Residue[#], Residue retention (5 t ha^{-1}); Residue[@], Residue retention (3.5 t ha^{-1}); RDF, recommended dose of fertilizer (80:60:40 kg N, P_2O_5, K_2O ha^{-1}); NE, nutrient expert (140:60:45 kg N, P_2O_5, K_2O ha^{-1}); DAS, days after sowing**.** Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

The interaction showed that, under both establishment methods, the no. of effective tillers per sq. meter was statistically higher for NE dose treated plots and was even significantly higher for Pu-TPR fb CT than CT-DDSR fb ZT. The residue applied treatments were similar in terms of effective tillers per sq. meter but superior than 100% RDF under CT. In contrast to which, 100% RDF under ZT had higher effective tillers than residue applied treatments

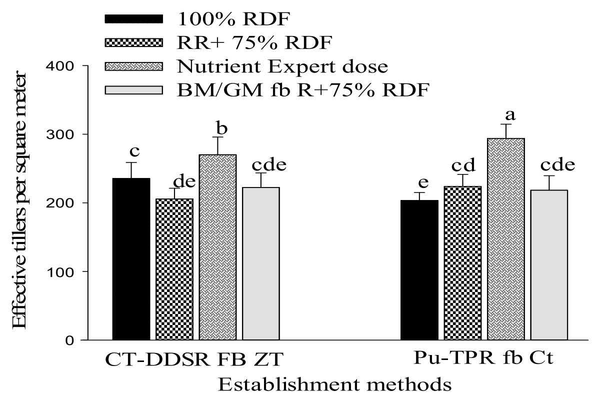

Figure 2. Number of effective tillers (m^{-2}) meter at the time harvest of wheat as influenced by the interaction of establishment methods and nutrient management at Rampur, Chitwan, 2018-19

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fb, followed by; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 t ha^{-1}); BM, brown manuring; GM, green manuring , R, residue retention (@3.5 t ha^{-1}); RDF, recommended dose of fertilizer (80:60:40 kg N, P_2O_5, K_2O ha^{-1}); NE, nutrient expert (140:60:45 kg N, P_2O_5, K_2O ha^{-1}); DAS, days after sowing**.** Same letter(s) represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

The average number of grains per spike was 39.81 which was about 8% higher for CT-DDSR fb ZT than that for Pu-TPR fb CT and regarding the nutrient management practices, NE assisted nutrient management was significantly higher 44.48 grins per spike. The average thousand grain weight (TGW) was 67.01g and sterility was 47.07% respectively but none of them were found significantly different among the various nutrient management practices and crop establishment methods. However, CT-DDSR fb ZT had relatively lesser TGW and sterility. Among the nutrient management practices, Ne dose had relatively higher TGW and lesser sterility.

The higher number of tillers in 100% RDF under ZT might be due to the better soil moisture conservation (Moraru & Rusu, 2013); better nutrient mobility and higher N availability due to lesser loss due to rapid mineralization (Thomas et al., 2007) than the conventional tillage and favorable environment created due to absence of puddling in DSR. In addition to this, the tillage operation also hastened the decomposition and mineralization process thereby increasing the nutrient availability in residue applied treatments (Halvorson, Wienhold, & Black, 2002) and hence relatively higher tillers were observed in residue applied plots under CT compared to 100% RDF which lacked residue. Under ZT, conserved soil moisture increased the nutrient availability and uptake by the plants, resulted in better nutrient use efficiency (Hulugalle & Lal, 1986; Halvorson et al., 2002). Hence, the grains per panicle increased under CT-DDSR fb ZT. Since, the grains per spike has inverse relationship with TGW and sterility, the increased grains per spike resulted in lower TGW and lower sterility than Pu-TPR fb Ct. In addition to this, increased pollen viability and hence higher grains per panicle and lower sterility was recorded under CT-DDSR fb ZT.

Grain and straw yield and harvest index (HI)

The average grain yield of wheat under ZT planted after DSR was 11.44% lower than under CT after TPR. But the difference was not significant and same case was pragmatic with straw yield and HI; the average straw yield and HI were 4.41 t ha^{-1} and 38.41% respectively. The grain yield was 15.5% more under NE dose assisted nutrient management practices and significantly higher straw was obtained under NE dose as shown in Table 3.

Table 3. Grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%) of wheat as influenced by the establishment methods and nutrient management practices at Rampur, Chitwan, 2018-2019

Treatment	Grain yield (t h^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
Establishment methods			
CT-DDSR fb ZT	2.97	4.73	36.19
Pu-TPR fb CT	3.31	4.25	40.62
SEm (±)	0.11	0.33	2.47
LSD (=0.05)	ns	ns	ns
CV, %	12.40	25.60	22.30
Nutrient management practices			
100% RDF	2.84	3.83^{b}	40.09
RR+75% RDF	3.02	4.38^{b}	37.18
NE dose	3.43	5.95^{a}	33.60
BM/GM fb R+ 75% RDF	3.28	3.80^{b}	42.76
SEm (±)	0.20	0.37	2.42
LSD (=0.05)	ns	1.14	ns
CV, %	15.20	20.20	15.50
Grand mean	3.14	4.41	38.41

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fb, followed by; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 t ha^{-1}); BM, brown manuring; GM, green manuring , R, residue retention (@3.5 t ha^{-1}); RDF, recommended dose of fertilizer (80:60:40 kg N, P_2O_5, K_2O ha^{-1}); NE, nutrient expert (140:60:45 kg N, P_2O_5, K_2O ha^{-1}); DAS, days after sowing**.** Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

The higher yield of wheat under conventional system might primarily be due proper seed bed and cropping which resulted in the the destruction of weed seeds, soil pathogens, lack of interference by residues and similar explanation was given by Bahrani, Kheradnam, Emam, Ghadiri, & Assad (2002). Sainju, Lenssen, Caesar-Tonthat, & Waddell (2006) and Busscher, Bauer, & Frederick (2006) harvested higher yields under conventional tillage as compared to no tillage or reduced tillage and explained that greater inorganic N and N uptake can be optimized and potentials for soil erosion and N leaching can be reduced by this treatment.

The better yield attributing parameters under nutrient expert model dose might be due to higher doses of fertilizer i.e. 75% more N and 12.25% more K_2O than for 100% RDF. The increased N dose had resulted in significant increase in number of grain per spike, number of spikes per square meter and hence had lowered sterility. Similar explanations were also given by Woyema (2012); Abedi, Alemzadeh, & Kazemeini, (2011); Maqsood, Ali, Aslam, Saeed, & Ahmad, (2002)and Ali et al. (2002). In the same manner, nutrient expert follows the principle of SSNM which provides the nutrient based on the crop demand and at the right time. Improved timing and/or splitting of fertilizers increased nutrient use efficiency under nutrient expert model assisted nutrition management (Khurana et al., 2005)and aided in yield improvement. BM/GM fb R+75% RDF yielded 15.49% more yield compared to 100% RDF (Table 3). The plots under this treatment had residual effects of *Sesbania* crop grown in the previous rice season and the finding was in accordance with (Hoque et al., 2017) who found yield advantage of 38% in wheat crop planted after the green manuring practices in rice field. The favorable soil environment due to the addition of OM and conservation of beneficial microbes due to the green and brown manuring practices in rice field might be responsible for the improved yield under BM/GM fb R+75% RDF (Hoque, Akter, & Islam, 2017).

Economic analysis

The average total cost of production, gross return, net return (NRs. ha^{-1}) and B:C ratio of wheat were NRs.60793.54, NRs.98721.12 and NRs.37927.58 ha^{-1} respectively as shown in Table 4. and were not significantly different among the establishment methods. The net return under NE dose was 49% more than 100% RDF and hence had significantly higher B:C ratio.

The significantly lower net returns and B:C ratio under RR+75% RDF was due to the added cost of rice residue as it is a valueable byproduct and main source of roughage feed for livestock. Despite having about NRs. 6000 ha $^{-1}$ more gross return and reduction of cost of 25% fertilizers compared to 100% RDF, the net return from RR+75% RDF was about NRs. 7000 ha^{-1} lesser than 100% RDF due to cost incurred for residue. The higher cost of production under Pu-TPR fb CT was due to the added cost for the tillage operations. The significantly higher B:C ratio under NE was due to significantly higher yield which fetched higher benefits over added cost of fertilizers. These findings were also in accordance with the results of by Kumar & Batra (2017), Khan et al. (2017), Kumar et al. (2015), Tripathi (2010), and Lales et al. (2008).

Table 4. Total cost of production gross returns, net returns (NRs. ha^{-1}) and B:C ratio of wheat as influenced by the cropping systems, establishment methods and nutrient management practices at Rampur, Chitwan, 2018-2019

Treatments	Total cost of production (NRs. ha^{-1})	Gross return (NRs. ha^{-1}),	Net return (NRs. ha^{-1})	BC ratio
Establishment methods				
CT-DDSR fb ZT	58143.54	93809.62	35666.08	1.63
Pu-TPR fb CT	63443.54	103632.62	40189.08	1.64
SEm (±)		4911.50	2261.497	0.004
LSD (=0.05)		ns	ns	ns
CV, %		10.70	27.90	9.10
Nutrient management practices				
100% RDF	54525.44	88933.44	34408.00	1.64[ab]
RR+75% RDF	67951.58	94979.58	27028.00	1.39[b]
NE dose	57620.56	108772.31	51151.75	1.89[a]
BM/GM fb R+ 75% RDF	63076.58	102199.16	39122.58	1.62[ab]
SEm (±)		2823.68	5062.07	0.10
LSD (=0.05)		ns	ns	0.30
CV, %		14.80	38.50	14.70
Grand mean	60793.54	98721.12	37927.58	1.63

Note: CT-DDSR, conventional tillage dry direct seeded rice; Pu-TPR, puddled transplanted rice; fb, followed by; CT, conventional tillage; ZT, zero tillage; RR, Residue retention (5 t ha^{-1}); BM, brown manuring; GM, green manuring , R, residue retention (@3.5 t ha^{-1}); RDF, recommended dose of fertilizer (80:60:40 kg N, P_2O_5, K_2O ha^{-1}); NE, nutrient expert (140:60:45 kg N, P_2O_5, K_2O ha^{-1}); DAS, days after sowing. Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test.

CONCLUSION

The wheat crop was not much affected by the establishment methods of preceding rice crop and itself however, it was much more productive and profitable under Nutrient expert model dose. The residue application in the field was beneficial under the conventional tillage practice but the residue application also reduced the profitability of the crop whereas the practice of brown manuring and green manuring in rice also improved the yield of subsequent wheat crop with the improvement of soil health and saving of 25% RDF.

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