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Effect of Crop Establishment Method, Residue and Nutrient Management on Productivity of Rice-Wheat Cropping System at Rupandehi, Bhairahawa, Nepal

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ABSTRACT

The puddling operation and multiple tillage operations done in traditional rice-wheat system have negative impact on soil resulting into low productivity of rice - wheat system. A field experiment was conducted to find the alternate practices for enhancing the productivity of rice-wheat system at National Wheat Research Program, Bhairahawa during 2018/19. Three crop establishment methods: surface seeded wheat (SSW) followed by (fb) unpuddled transplanted rice (U-TPR), zero tilled wheat (ZTW) fb zero tilled direct seeded rice (ZT-DSR) and conventionally tilled wheat (CTW) fb puddled transplanted rice (PTR) were tested in two levels of residue management: residue removed (R_0) and residue retention (R_{50}). Three levels of nutrient management: recommended dose of NPK (F100), 25% higher dose of NPK (F125) and farmer's practice (FP) were assigned in wheat. Strip-split plot design with 3 replications was used in wheat while strip-plot design with 9 replications was used in rice. Crop establishment methods (CSM) were assigned in vertical strips; residue management in horizontal blocks and nutrient management were assigned in subplots. The number of tillers at maximum tillering stage, maximum leaf area index, effective tiller per square meter and number of grains per spike of wheat were significantly affected by CSM, where ZTW had shown better results (413.7 tillers, 2.12 LAI, 224.1 effective tiller per square meter and 34.27 grains per spike) than SSW and CTW but the CSM had no significant effect on grain yield of both rice and wheat crop. R_0 had produced significantly higher straw yield than R_{50} of both rice and wheat, whereas, R_{50} had produced significantly higher harvest index than R_0 in rice. The application of 25% more nutrients than the recommended dose resulted in the significantly better growth, yield attributes, and yield of wheat. The ZTW fb ZT-DSR had produced significantly higher system yield than SSW fb U-TPR where, CTW fb PTR was statistically at par with both systems. The recommended dose of nutrients (F100) and 25% higher than F100 (F125) had produced significantly higher system yield than farmer's practice (FP) dose. Research results revealed that ZTW fb ZT-DSR system can be suggested instead of traditional CTW fb PTR system without significant yield differences.

Keywords: Surface seeding, System yield, Un-puddled transplanting, Zero tillage

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INTRODUCTION

The rice-wheat cropping system is dominant in the terai region of Nepal, which is characterized by a wet season rice crop and a dry season wheat crop in rotation (Khatri-Chhetri et al 2017). Rice and wheat occupy 1.55 and 0.73 Million ha area (MoAD 2017) respectively, which supplies more than 75% of the country's total food demand. In 2016/17, the rice was cultivated in 1552469 ha of land with 5230327 mt production and 3.37 mt per ha yields; whereas the wheat was cultivated in 735850 ha of land with 1879191 mt production and 2.55 mt per ha yields, among which, 71% area of rice and 57% area of wheat lies in terai (MoAD 2017). The traditional method of establishing rice in the Terai region involves transplanting after puddling, and the wheat is sown after field preparation by two or three plowings followed by one or two planking. These methods require a lot of resources, such as labour, water, and energy, which are getting harder to come by and more expensive every day. However, the puddling operation used to transplant rice has a detrimental effect on the soil, resulting in a drop in the subsequent wheat yield by 8–10% and low productivity of the rice–wheat system (Kumar and Ladha

2011). Additionally, all crop residues from the previous crop—both rice and wheat—are either burned or removed for fodder before the next crop is established. This has had a number of negative effects, including nutrient loss, environmental pollution, and greenhouse gas emissions (Dobermann and Fairhurst 2002, Gupta et al 2004). Furthermore, up to this point, all nutrient management techniques have been established using traditional farming methods (conventionally tilled soil and residue removed); yet, the dynamics, balance, and efficiency of nutrient usage vary depending on the type of tillage and residue management technique used.

The "Conservation Agriculture," or CA for short, have produced a number of improved management techniques (Gathala et al 2013, Ladha et al 2016). These practices are based on three principles—minimum soil disturbance, permanent soil cover, and crop rotation—that can guarantee the sustainable productivity of a rice-wheat cropping system (Hobbs 2007). The adoption of CA technologies in Nepal is still in its early stages, and all stakeholders must work together to accelerate their growth. Though the same practices might not be relevant elsewhere, very little study utilizing CA practices has been conducted in Nepal. The majority of the studies were limited to a single crop, such as wheat or rice, in accordance with CA practices. The objective of this study was to assess the productivity of the rice-wheat system in Nepal's western terai using CA-based practices.

MATERIALS AND METHODS

Experimental site

The one-year experiment was conducted at the National Wheat Research Program (NWRP), Bhairahawa, Rupandehi, Nepal during the year 2018/19. Geographically this research station is located at 27^0 32' north latitude and $83^0$25' east longitudes with the elevation of 104 masl, which lies in the western Terai of Nepal. The climate is of sub-tropical type with three distinct seasons: summer, rainy, and winter. The soil texture of the experiment site (15cm depth) was 'Silty Clay Loam' (sand 15%, Silt 52%, clay 33%). The soil was medium in organic matter (3.47%), Total Nitrogen (0.14%), and available P_2O_5 (32.94 mg/kg) and low in available K_2O (54.48 mg/kg). The soil pH was slightly alkaline (7.73).

Weather data

In wheat season, the highest maximum temperature (40.4°C) was recorded on 30th April (2019) and the lowest minimum temperature (5.0°C) was recorded on 29th December (2018). The total rainfall during the season was 138 mm where the highest rainfall (73.2mm) was recorded on 2nd week of February (2019) (Figure 1).

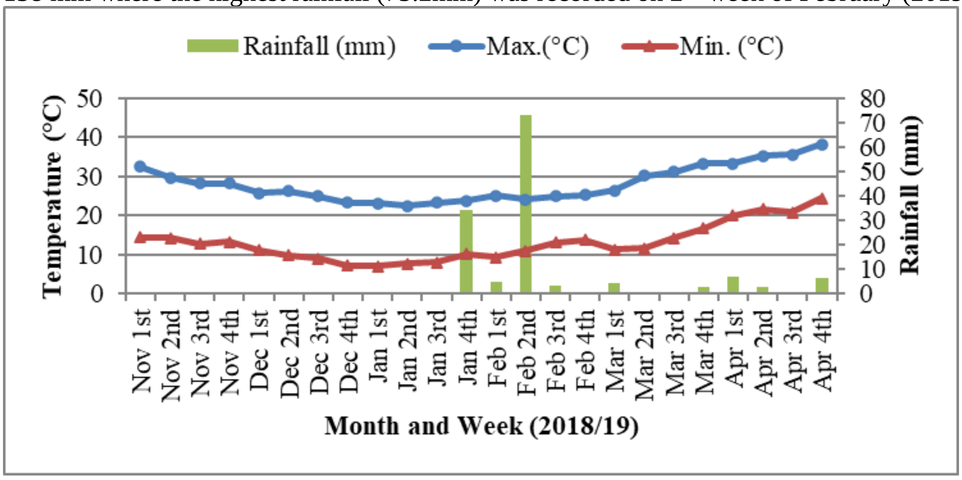

Figure. 1. Temperature and rainfall in wheat season (2018/19)

In rice season, the highest maximum temperature (43.8°C) was recorded on 17th Jun and the lowest minimum temperature (21.6°C) was recorded on 27th October (2019). The total rainfall during the season was 1265.1mm where the highest rainfall (228mm) was recorded on July 2nd week (Figure 2).

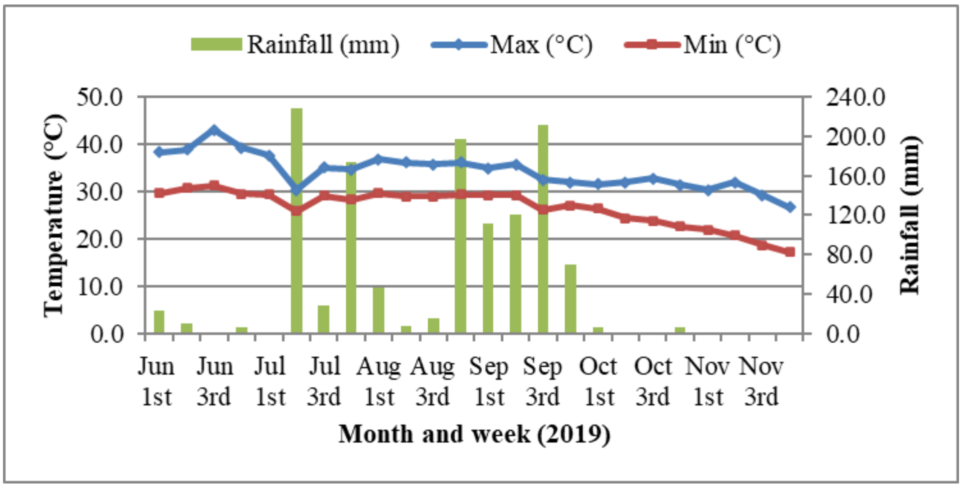

Figure. 2. Temperature and rainfall in rice season (2019)

Experimental details

The experiment was started with wheat from November, 2018. In wheat, the treatments included factorial combinations of three tillage methods, (a) surface seeding (SS), (b) zero tillage (ZT), and (c) conventional tillage (CT); and two levels of residue management (R_0: Residue removed, and R_{50}: 50% residue retention of previous rice crop), arranged in strip plots, three fertilizers levels (F100: recommended dose of fertilizer i.e. 100:50:50 kg N, P_2O_5 and K_2O ha^{-1}; F125: 25% higher than recommended dose (125:62.5:62.5 kg N, P_2O_5 and K_2O ha^{-1}) ; and FP: Farmer's practice i.e. 80:40:15 kg N, P_2O_5 and K_2O ha^{-1}) in sub-sub plots and were arranged in a strip-split plot design with three replications. To identify farmer's practice dose, a farmer's field survey was conducted in Rupandehi district, 30 farmers were randomly selected who had once adopted zero tillage in wheat. Based on their information an average NPK dose was calculated. Surface seeded wheat (SSW) was broadcasted, and zero tilled wheat (ZTW) was sown on line manually as like zero-till machine on 24th November and conventionally tilled wheat (CTW) was sown also in the line by making a narrow furrow in prepared soil by plowing and planking on 30th November. After harvesting the wheat (var. BL 4341) on April, 2019, the rice (var. Ramdhan) was grown. The treatments consist three levels of crop establishment method; a. unpuddled transplanted rice (U-TPR), b. Zero till direct seeded rice (ZT-DSR), c. puddled transplanted rice (PTR) and two levels of residue; a. residue removed, b. residue retention. Maintaining residue level in rows and crop establishment method in column, the replication was 9 under strip-plot (or criss-cross) design. The SSW was followed by (fb) U-TPR, ZTW fb ZT-DSR and CTW fb PTR. The 120:40:30 kg/ha NPK was used in rice. 50% N and full dose of P and K were applied as basal application. Rest 50% N was applied as top dressing in two equal splits at one-month interval after planting. All the other required agronomic practices were followed uniformly in all the plots throughout the growing period. Rice was harvested on 24th November, 2019.

Measurements

The data, regarding the rice-wheat systems: 1. SSW fb U-TPR, 2. ZTW fb ZT-DSR, 3. CTW fb PTR under two residue management levels was recorded. The days required for heading and maturity was recorded when 50% of plants got heading and maturity. Yield and yield attributing characteristics were recorded for the calculations of productivity of rice-wheat system. Effective tiller per meter square, number of grain per panicle, thousand grain weight, harvest index and sterility percentage were taken as yield attributing characteristics. The grain yield and straw yield was taken from the net harvested area of 8.0 m^2. Seed moisture was taken by using a seed moisture meter for yield correction at 12% moisture level. The harvest index was calculated from grain yield and biological yield at 0% moisture. Twenty spikes from each plot were randomly taken and the number of total spikelet and the number of total seed per spike were counted manually based on which sterility percentage was estimated. The rice-wheat system yield was calculated by using the formula:

Rice-wheat system yield= $$\textit{Wheat yield in kg per ha} + \frac{[\textit{Rice yield in kg per ha} * \textit{price of rice per kg}]}{\textit{price of wheat per kg}}$$

Data analysis: Data were put on a Microsoft Excel sheet and analyzed by using the computer software' Genstat' 18th edition.

RESULTS AND DISCUSSIONS

Days to Heading and Days to Maturity of Wheat and Rice

In wheat, the days to 50% heading were significantly affected by tillage methods. The longest days to heading were found on the CT plot (93 days) which was statistically at par with SS plots, where ZT had significantly shorter days to heading (86) than both CT and SS plots. But there was no significant effect of residue and nutrient management for days to 50% heading. The days to maturity was also significantly affected by tillage methods. The longest days to maturity (120 days) were found with CT plots, followed by SS (116 days) and ZT (115 days). The residue and nutrient management had no significant effect on days to maturity. In rice, the days to 50% heading (GM=112.35) was significantly affected by crop establishment method, while residue management did not affect the phenology of rice. The zero-till direct seeded rice (ZTDSR) had significantly shorter heading (109.78) and maturity (131.78) days than unpuddled (113.72HD & 135.72MD) and puddled transplanting rice (113.56HD & 135.56MD).

Growth Parameters of Wheat

The final plant height was significantly affected by nutrient management where the crop establishment method and residue management had no significant effect (Table 1). F100 and F125 fertilizer dose had produced significantly taller plants than FP dose, where F100 and F125 were statistically at par with each other. Bartaula et al (2019) also recorded the highest plant height at 125 kg N ha^{-1}as compared to 100, 75, and 50 kg N ha^{-1} and no significant effect of tillage method on plant height.

Table 1: Growth parameters of wheat as influenced by the establishment methods, residue and nutrient management practices in rice-wheat cropping system at Bhairahawa, Rupandehi, 2018/19

Treatments	Final Plant Height (cm)	Maximum No. of tiller per m^2	Max. Leaf Area Index	Dry matter at heading (g m^{-2})
Establishment methods				
Surface seeding	76.03	374.10^{b}	1.38^{b}	464.80
Zero tillage	88.10	413.70^{a}	2.12^{a}	657.10
Conventional tillage	84.19	406.40^{a}	1.64^{b}	555.90
p-value	0.17	0.04	0.02	0.09
SEm (±)	3.61	7.70	0.11	44.21
LSD (=0.05)	14.16	30.24	0.44	173.59
CV, %	7.50	3.40	11.30	13.70
Residue management practices				
Residue removed	82.76	408.40	1.84	572.80
Residue retention	82.79	387.80	1.59	545.80
p-value	0.98	0.25	0.07	0.19
SEm (±)	0.62	9.09	0.05	9.63
LSD (=0.05)	3.78	55.31	0.30	58.60
CV, %	1.30	4.00	5.00	3.00
Nutrient management practices				
F100	83.88^{a}	396.80^{ab}	1.47^{ab}	529.3^{b}
F125	84.25^{a}	421.60^{a}	2.01^{a}	633.8^{a}
Farmer's practice	80.19^{b}	375.90^{b}	1.66^{b}	514.8^{b}
p-value	<.001	0.01	<.001	<.001
SEm (±)	0.68	9.72	0.08	13.84
LSD (=0.05)	1.99	28.36	0.23	40.40
CV, %	3.50	10.40	19.70	10.50
Grand mean	82.77	398.10	1.71	559.30

Note: F100 = 100:50:50 N, P_2O_5, K_2O ha^{-1}; F125 =125:62.5:62.5 N, P_2O_5, K_2O ha^{-1}; Farmer's practice=80:40:15 N, P_2O_5, K_2O ha^{-1}; same letter in the column indicates no difference.

The maximum number of tillers was produced at 60 days after sowing. Tillage method and nutrient management had significant effect on the number of tillers per square meter whereas the residue management had no significant effect. The highest number of tillers per square meter was produced by ZT plots followed by CT and

SS, where ZT and CT were statistically at par with each other and the SS plots had produced significantly fewer numbers of tillers than ZT and CT plots. The higher dose of nutrients F125 had produced the maximum number of tillers per square meter, which is significantly higher than FP but statistically at par with F100.

The maximum leaf area index (LAI) was found at 75 days after sowing. Tillage method and nutrient management had significant effect on maximum LAI, whereas residue management had no significant effect (Table 1). ZT had produced significantly higher LAI than CT, and SS, where CT and SS were statistically at par. This result was in contrast with Shahzad et al (2016), where they found low LAI in ZT wheat as compared to CT. Similarly, F125 nutrient dose had produced significantly higher LAI than F100 and FP dose, where, F100 was statistically at par with both F125 and FP dose. Ghadikolayi et al (2015) also reported that increased Nitrogen rates significantly increased LAI. Similar results were also reported by Potter et al (1995) and Sinclair and Horie (1989) who found that LAI and crop growth were affected by Nitrogen rates.

Nutrient management had a significant effect on dry matter production at heading, but tillage method and residue management had no significant effect. F125 nutrient dose had produced significantly higher dry matter above ground level than produced by F100 and FP dose, where F100 and FP were statistically at par with each other.

Yield Attributing Characteristics of Wheat and Rice

Effective tiller per square meter

In wheat, the ZT and CT plots had produced significantly higher number of effective tillers than SS plots, where ZT and CT plots were statistically at par with each other (Table 2). The result agreed with the result of Ali et al (2013). The F125 nutrient dose had produced significantly higher number of effective tillers than FP dose, but F125 was statistically at par with F100. This result is in line with the findings of Bartaula et al (2019) who reported that the maximum number of effective tiller per meter square was recorded at 125 kg N per hectare followed by 100 kg N per hectare, where 50 kg N per hectare recorded the lowest values. In rice, crop establishment methods had significant effect on effective tillers per meter square, but residue management had no significant effect (Table 3). ZT-DSR had produced significantly higher number of effective tiller than PTR, where U-TPR was statistically at par with both ZT- DSR and PTR.

Number of grain per spike

In wheat, the number of grain per spike was significantly affected by nutrient management but crop establishment method and residue management had no significant effect (Table 2). Whereas, Leghari et al (2015) noted maximum number of grain per spike under CT, while this number declined under reduced tillage and no-tillage. The F125 nutrient dose had produced significantly higher number of grains per spike than both F100 and FP dose. Similar results were also reported by Bartaula et al (2019). In rice, residue management and crop establishment methods had no significant effect on number of grain per panicle.

Thousand grain weight

Tillage method and residue management had no significant effect on thousand grain weight (TGW). Meena et al (2020) also reported the similar results. But nutrient management had significant effect on TGW. The F100 nutrient dose had produced significantly higher TGW than F125 and FP dose. In case of rice, the thousand grain weight was not significantly affected by residue management and crop establishment methods. Although, U-TPR had produced higher TGW (23.48g) than ZT- DSR (23.05g) and TPR (23.17g). The range of TGW in wheat was 36.70 to 42.50 whereas in rice was 22.02 to 24.63 g.

Table 2: Yield attributes of wheat as influenced by the establishment methods, residue and nutrient management practices in rice-wheat system at Bhairahawa, Rupandehi, 2018/19

Treatments	Effective Tiller per m^{-2}	No. of grain per spike	Thousand grain weight (g)	Sterility (%)
Establishment methods				
Surface seeding	181.2^{b}	30.52	40.51	36.24
Zero tillage	224.1^{a}	34.27	38.91	35.96
Conventional tillage	211.9^{a}	29.82	39.43	36.44
p-value	0.03	0.20	0.07	0.89
SEm (±)	6.99	1.52	0.34	0.70
LSD (=0.05)	27.46	5.96	1.32	2.74
CV, %	14.42	8.30	3.60	8.17

Treatments	Effective Tiller per m^{-2}	No. of grain per spike	Thousand grain weight (g)	Sterility (%)
Residue management practices				
Treatments	213.60	31.51	39.38	36.00
Residue retention	197.90	31.57	39.85	36.43
p-value	0.13	0.94	0.34	0.69
SEm (±)	4.45	0.50	0.27	0.66
LSD (=0.05)	27.09	2.99	1.66	4.03
CV, %	11.25	2.70	2.73	9.51
Nutrient management practices				
F100	204.9^{ab}	30.05^{b}	40.38^{a}	36.81^{a}
F125	215.6^{a}	33.10^{a}	39.35^{b}	34.36^{b}
Farmer's practice	196.8^{b}	31.46^{ab}	39.11^{b}	37.47^{a}
p-value	0.01	0.01	<0.01	0.001
SEm (±)	4.06	0.66	0.22	0.55
LSD (=0.05)	11.84	1.91	0.65	1.61
CV, %	8.40	8.80	2.40	6.48
Grand mean	205.70	31.54	39.61	36.21

Note: F100 = 100:50:50 N, P_2O_5, K_2O ha^{-1}; F125 =125:62.5:62.5 N, P_2O_5, K_2O ha^{-1}; Farmer's practice=80:40:15 N, P_2O_5, K_2O ha^{-1}; same letter in the column indicates no difference.

Sterility percentage

The tillage method and residue management had no significant effect on sterility percentage of wheat, whereas, nutrient management had significant effect. The FP and F100 nutrient dose had sown significantly higher sterility percentage than F125 dose, where FP and F100 were statistically at par with each other. Similarly, in rice, the residue and crop establishment methods had no significant effect on sterility percentage. The range of sterility percentage was 28.25 to 43.91 in wheat and 8.53 to 26.67 in rice.

Table 3. Effect of crop establishment methods and residue management on effective tiller per meter square, number of grain per spike, thousands grain weight (TGW) and sterility percentage of rice at Bhairahawa, 2019.

Treatments	Effective Tiller m^{-2}	Grain $spike^{-1}$	TGW (g)	Sterility%
Crop Establishment methods				
Unpuddled Transplanted Rice (U-TPR)	211.00^{ab}	97.10	23.48	16.57^{a}
Zero till Direct Seeded Rice (ZT-DSR)	220.00^{a}	95.70	23.05	14.14^{ab}
Puddled Transplanted Rice (PTR)	198.60^{b}	103.10	23.17	13.60^{b}
p-value	0.03	0.36	0.25	0.01
SEm (±)	5.01	3.77	0.18	0.96
LSD (=0.05)	15.03	11.30	0.54	2.87
CV, %	7.20	11.50	2.30	19.40
Residue Management				
Residue removed	212.90	97.90	23.12	14.47
Residue retention	206.80	99.30	23.34	15.07
p-value	0.31	0.62	0.25	0.40
Sem(±)	3.95	1.88	0.13	0.48
LSD (=0.05)	12.88	6.13	0.42	1.57
CV, %	5.60	6.13	1.70	9.70
Grand mean	209.90	98.60	23.23	14.77

Grain Yield, Straw Yield and Harvest Index of Wheat and Rice

Grain yield

In wheat, tillage methods and residue management had no significant effect on grain yield (Table 4). Ali et al (2013) also reported that there was no significant difference in grain yield of winter wheat among tillage practices. Ali et al (2013) also reported that there was no significant difference in grain yield of winter wheat among tillage practices.

Table 4. Effect of tillage method, crop residue and nutrient management on grain yield, straw yield and harvest index of wheat at Bhairahawa, 2018/19

Treatments	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index (%)
Establishment methods			
Surface seeding	1825.00	2724.00	39.00
Zero tillage	2855.00	4045.00	41.00
Conventional tillage	2263.00	3463.00	39.00
p-value	0.07	0.06	0.38
SEm (±)	217.20	262.90	0.01
LSD (=0.05)	852.90	1032.30	0.04
CV, %	16.30	13.40	4.20
Residue management practices			
Residue removed	2427.00	3871.00^{a}	38.00
Residue retention	2201.00	3005.00^{b}	42.00
p-value	0.10	0.05	0.06
SEm (±)	55.50	129.80	0.01
LSD (=0.05)	337.70	789.60	0.03
CV, %	4.20	6.60	2.50
Nutrient management practices			
F100	2312.00^{b}	3138.00^{b}	40.00
F125	2482.00^{a}	3553.00^{a}	40.00
Farmer's practice	2148.00^{c}	3541.00^{a}	41.00
p-value	<.001	<.001	0.20
SEm (±)	47.90	75.80	<0.01
LSD (=0.05)	139.80	221.40	0.01
CV, %	8.80	9.40	4.50
Grand mean	2314.00	3411.00	40.00

Note: F100 = 100:50:50 N, P_2O_5, K_2O ha^{-1}; F125 =125:62.5:62.5 N, P_2O_5, K_2O ha^{-1}; Farmer's practice=80:40:15 N, P_2O_5, K_2O ha^{-1}; same letter in the column indicates no difference.

The F125 nutrient dose had produced significantly higher grain yield than both F100 and FP doses, where F100 dose had also produced significantly higher grain yield than FP dose. A similar result was also found by Mandal et al (2018). The increase in grain yield may be due to the availability of NPK at various critical crop growth stages in an optimal amount which might have accelerated photosynthetic activities, resulting in yield attributes of wheat thus resulting in the increased grain yield (Kumar and Yadav 2005). In rice, both crop establishment methods and residue management had no significant effect on grain yield (Table 5). Bhattacharaya et al (2006) had also found similar results, where the rice yield was statistically at par in case of zero tillage when compared with conventional tillage system in direct seeding rice. Zheng et al (2014) also reported that CA practices had no significant effect on rice yield.

Straw yield

In wheat, the straw yield was significantly affected by the tillage method and residue management. The ZT plots had produced significantly higher straw yield than SS plots, where CT plots were statistically at par with both ZT and SS plots. The residue removed plots had produced significantly higher straw yield than residue retention plots. Also in rice, residue management and crop establishment methods had significantly affected straw yield. The residue removed plots had produced significantly higher straw yield than residue retention plots. The PTR had produced significantly higher straw yield than ZT- DSR, where UTPR and ZT- DSR were statistically at par with each other.

Table 5. Effect of crop establishment methods and residue management on grain yield (GY), straw yield (SY) and harvest index (HI) of rice at Bhairahawa, Rupandehi.

Treatments	**GY (kg ha^{-1})**	**SY (kg ha^{-1})**	**HI (%)**
Crop Establishment methods			
Unpuddled Transplanted Rice (U-TPR)	4286.00	8386.00^{b}	36.00
Zero till Direct Seeded Rice (ZT-DSR)	4766.00	7700.00^{b}	40.00
Puddled Transplanted Rice (PTR)	4893.00	9587.00^{a}	36.00
p-value	0.12	<0.01	0.15
SEm (±)	205.60	362.70	0.02
LSD (=0.05)	616.40	1087.30	0.05
CV, %	13.30	12.70	13.80
Residue Management			
Residue removed	4619.00	9084.00^{a}	36.00^{b}
Residue retention	4677.00	8031.00^{b}	39.00^{a}
p-value	**0.32**	**<0.01**	**0.01**
Sem(±)	39.30	191.30	0.01
LSD (=0.05)	128.30	624.00	0.02
CV, %	2.50	6.70	4.10
Grand mean	4648.00	8558.00	37.00

Harvest index

In wheat, the harvest index was not significantly affected by the tillage method, residue and nutrient management. In rice, residue retention plot had produced significantly higher harvest index than residue removed plots, but establishment methods had no significant effect on harvest index.

Rice-wheat system yield

The tillage method and nutrient management had significant effect on system yield, where residue management had no significant effect. ZTW fb ZT-DSR had produced significantly higher grain yield (6727.00 kg ha^{-1}) than SSW fb U-TPR (5330.00 kg ha^{-1}), where CTW fb PTR produced yield (6005.00 kg ha^{-1}) was statistically at par with both ZTW fb ZT-DSR and SSW fb U-TPR. Sah et al (2014) also reported higher rice-wheat system yield under ZT condition than CT condition. Similarly, F100 wheat fb 100 RDF rice (6172.00 kg ha^{-1}) and F125 wheat fb 100 RDF rice (6274.00 kg ha^{-1}) had produced significantly higher system yield than FP wheat fb 100 RDF rice (5816.00 kg ha^{-1}), where F100 wheat fb 100 RDF rice and F125 wheat fb 100 RDF rice were statistically at par with each other. Sah et al (2014) also reported increased productivity of rice-wheat system yield with increased N level up to 120 kg ha^{-1}.

CONCLUSION

Wheat and rice crop can be grown under a zero tillage system with previous crop residues retention without significant yield loss. Based on the research results, it can be concluded that traditional rice-wheat system (i.e. puddled transplanted rice followed by conventionally tilled wheat) can be replaced with conservation agriculture based practices (i.e. zero till direct seeded rice followed by zero till wheat).

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AUTHOR’S CONTRIBUTION

H. P. T., methodology, investigation, data collection, analysis, writing original manuscript; S. M., conceptualization, supervision, data validation, data analysis, editing final manuscript; S. K. S., methodology, supervision, data validation, editing final manuscript; A. K, G., conceptualization, supervision, data validation, editing final manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The author declares that they have no competing financial interests or personal relationships that could influence the work reported in this study.

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