Effect of tillage method, crop residue and nutrient management on growth and yield of wheat in rice-wheat cropping system at Bhairahawa condition

■ HP Timalsina[1*], S Marahatta[2], SK Sah[2,] and AK Gautam[3]
[1]National Wheat Research Program, Bhairahawa, Rupandehi
[2]Agriculture and Forestry University, Rampur, Chitwan
[3]Nepal Agriculture Research Council, Khumaltar, Kathmandu
*Corresponding author email: himaltimalsina32@gmail.com

Abstract
Wheat (*Triticum aestivum* L), grown under traditional practices becoming less productive and less profitable in Nepal, due to ever-increasing input prices and intensive land preparation. A field experiment was conducted to find alternate practices for enhancing productivity of wheat at the National Wheat Research Program, Bhairahawa during the winter season of 2018/19 and 2019/20. The experiment plot was designed on strip-split plot design with 3 replications. Three tillage methods, surface seeding (SS), zero tillage (ZT), and conventional tillage (CT) were assigned in vertical strips with two levels of crop residue management: residue removed (R_0) and residue retention (R_{50}) in horizontal blocks, whereas three levels of nutrient management: recommended dose of NPK (F100), 25% higher dose of NPK (F125) and farmer's practice (FP) were assigned in subplots. Data regarding growth, yield attributes, and yield were recorded and analyzed by Genstat. In the first year, ZT was better in terms of number of tillers at maximum tillering stage, maximum leaf area index, effective tiller per square meter, number of grain per spike, and straw yield compared to SS and CT; whereas in the second year SS was better in terms of growth, yield attributes and yield as compared to ZT and CT. In the first year, $R_{(0)}$ produced significantly higher straw yield but significantly lower harvest index (HI) than $R_{(50)}$ whereas in second year $R_{(50)}$ produced significantly higher thousand grain weight, grain yield and HI. The application of 25% more nutrients than the recommended dose resulted significantly better most of the growth, yield attributes, and yield during both years. On the average of two years, ZT produced more yield than CT and SS by 26.6% and 3.0% respectively. The short term ZT significantly increased the bulk density as compared to SS and CT. Based on the research results, it can be suggested that the traditional practices of wheat can be replaced by ZT with retention of previous crop residues and the application of 25% more nutrients than the recommended dose.

Keywords: Conventional tillage, residue retention, surface seeding, zero tillage

Introduction
Wheat is the third most important crop after rice and maize in Nepal, covering 0.73 million hactares area with production of 1.88 million tons and productivity of 2.55 t/ha (MOAD, 2017). About 57% of the wheat area is concentrated in terai, where wheat is mostly grown after puddled transplanted rice. Traditionally wheat is grown after clean intensive tillage to create a friable seedbed that leads to a long turnround period resulting in delayed wheat planting (Tripathi *et al*., 2005), loss of nutrients (Dobermann and Fairhurst, 2002), green house gas (GHG) emission (Gupta *et al*., 2004) and environmental pollution. The major reasons for the low productivity of wheat are delay in sowing, deterioration of soil physical structure due to intensive tillage, depleted soil fertility, and imbalanced use of nutrition (Aslam *et al*., 1989). Furthermore, labour scarcity and high cost of inputs (fuel, fertilizer, and machinery) make wheat production less profitable (Tripathi *et al*., 2003). Decreasing soil productivity and profitability are the fundamental causes of unsustainable wheat production in Nepal. There are several improved management practices developed under the frameworks of conservation agriculture (CA) like, zero- or minimum-tillage in wheat, residue management that improved the water, and nutrient use efficiency, maximize the yields, increase profitability, conserve the natural resource base, and reduce risk due to both environmental and economic factors (Gathala *et al*., 2013; Ladha *et al*., 2016). However, many researchers had reported the superiority of conventional practices of wheat over conservation practices

(Alsayim *et al*., 2018; Leghari *et al*., 2015; Surin *et al*., 2013; Shahzad *et al*., 2016; Mandal *et al*., 2018). Franchini *et al*., (2012) reported that wheat yield was not influenced by tillage systems. Also, there are so many evidences of getting better results of wheat under conservation agriculture practices over conventional practices (Mohammad *et al*., 2012; Veettil and Krishna, 2012; Aziz *et al*., 2012; Ali *et al*., 2016; Kahlon and Dhingra, 2019; Zamir *et al*., 2010; Ali *et al*., 2013). The past research results varied with ecological and agronomic management practices, although the same practices may not be applicable in all wheat growing ecologies. There is a need to develop crop-specific resource conservation production practices for each agro-ecological zone (Lafond *et al*., 1996). In Nepal, the adoption of CA is in the primary stage and its expansion requires intensive efforts to develop solid CA-based technologies with full package of practices. Thus the present study was designed to evaluate the effect of tillage methods, crop residue, and nutrient management practices on the growth and yield of wheat in the rice-wheat cropping system at Bhairahawa, Rupandehi, Nepal.

Materials and Methods

Experimental site

The two-year experiment was conducted at the National Wheat Research Program (NWRP), Bhairahawa, Rupandehi, Nepal during the winter season of 2018/19 and 2019/20. 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 (15 cm depth) was 'Silty Clay Loam' (sand 15%, Silt 52%, clay 33%). The soil was medium in organic matter (3.5%), Total Nitrogen (0.14%), and available P_2O_5 (32.9 mg/kg) and low in available K_2O (54.5 mg/kg). The soil pH was slightly alkaline (7.7).

Experimental details

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 N:P_2O_5:K_2O kg/ha F125: 25% higher than recommended dose; and FP: Farmer's practice i.e. 80:40:15 N:P_2O_5:K_2O kg/ha) 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. In 2018/19, surface seeded wheat was broadcasted and zero tilled wheat was sown on line manually as like zero-till machine on 24th November and conventionally tilled wheat was also sown in the line by making a narrow furrow in prepared soil by plowing and planking on 30th November whereas in 2019/20, SS, ZT and CT all were sown on 7th December. A newly released variety 'BL 4341' was used in this experiment and sown with a seed rate of 120 kg/ha for ZT and CT and 150 kg/ha for SS. All the other required agronomic practices were followed uniformly in all the plots throughout the growing period. [In NWRP condition, there is no significant difference in yield of wheat sown from 10th November to 10th December since last 5 years.]

Measurements

The days required for heading and maturity were recorded when 50% of plants got heading and maturity. The plant height was taken from randomly selected and marked ten plants at harvest. Similarly, the number of tillers was counted from a specific row of 4m length and converted later into the number of tillers per square meter. Destructive plant samples were taken from 25cm row length (area of 0.05 m^2) for the estimation of leaf area index and above-ground dry matter. Dry matter was determined by drying the samples at a temperature of 70 ^oC in a hot air oven for 72 hours and weighed and expressed in g/m^2. The leaf area was recorded from the automatic leaf area meter, and the leaf area index was calculated as dividing the leaf area by ground area. 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 spikelets and the number of total seed per spike were counted manually based on which sterility percentage was calculated.

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

Results and Discussions

Days to heading and days to maturity

In 2018/19, the days to 50% heading were significantly affected by tillage methods (Figure 1). The longest days to heading was found on the CT plots (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. Significantly longer days to heading (92 days) was found in residue retention (R_{50}) plots as compared to residue removed plots. But there was no significant effect of nutrient management for days to 50% heading. The days to maturity was also significantly affected by tillage methods. The longest days to maturity (106 days) was found with CT plots, followed by SS (104 days) and ZT (101 days). The residue and nutrient management had no significant effect on days to maturity. In 2019/20, days to 50% heading and physiological maturity were significantly affected by tillage methods only. The longer days to heading (94 days) was recorded in CT plots which found significantly longer than ZT (92 days) and SS plots (90 days), where, ZT plots have significantly longer days to heading than SS plots. Similarly, the longest days to maturity (123 days) was recorded in CT plots which remained significantly longer than ZT and SS plots, where, ZT and SS plots were statistically at par with each other.

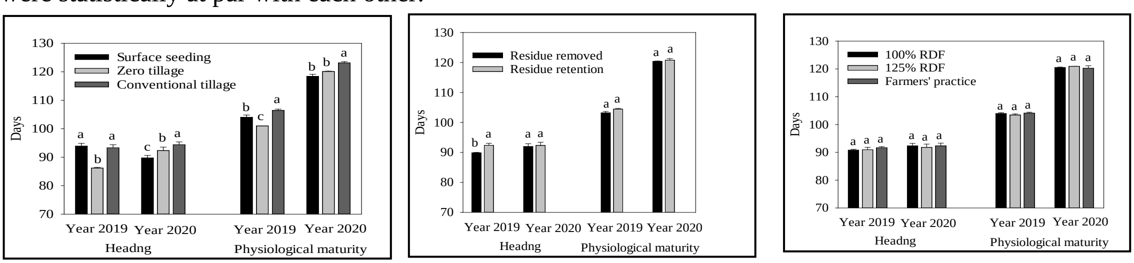

Fig. 1: Days to fifty percent heading and physiological maturity as influenced by the establishment methods, residue and nutrient management practices of wheat in the rice-wheat system at Bhairahawa, Rupendehi, 2019-2020

Biometric characteristics

Plant height

In 2019, the final plant height was significantly affected by nutrient management where the tillage method and residue management had no significant effect (Table 1). But in 2020, the tillage method and nutrient management had significant effect on the plant height, where residue management had no significant effect. The SS and ZT plots produced significantly taller plants than CT plots. F100 and F125 fertilizer levels produced significantly taller plants than FP treatment, where F100 and F125 were statistically similar. Zamir *et al.*, (2010) found significantly increased plant height in ZT than CT. This might be due to higher organic matter contents in ZT which directly affected the vegetative growth of wheat. Similar results were found by (Kahlon and Dhingra, 2019) and (Ali *et al*., 2013). Alsayim *et al*., (2018), De Vita *et al*., (2007) and Bartaula *et al*., (2019) found no significant difference in plant height due to tillage treatments. Bartaula *et al*., (2019) recorded the highest plant height at 125 N kg/ha as compared to 100, 75, and 50 N kg/ha.

Number of tillers per square meter at maximum tillering stage

The maximum number of tillers was observerd at 60 days after sowing in both years. Tillage method and nutrient management had a significant effect on the number of tillers per square meter, whereas the effect of residue management had no significant effect in both years. In 2019, 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 produced significantly fewer numbers of tillers than ZT and CT plots. But in 2020, significantly higher number of tillers per square meter was recorded in the surface seeding. The higher dose of nutrients F125 produced the maximum number of tillers per square meter, which is significantly higher than FP in 2019, and FP and F100 in 2020 (Table 1).

Leaf area index

The maximum leaf area index (LAI) was found highest at 75 days after sowing in both years. Tillage methods and nutrient management had a significant effect on maximum LAI, whereas residue management had no significant effect (Table 1). In 2019, ZT produced significantly higher LAI than CT, and CT produced significantly higher LAI than SS (Table 1). This result was in contrast with (Shahzad *et al.,* 2016), where they found low LAI in ZT wheat as compared to CT.

Table 1. Growth parameters as influenced by the establishment methods, residue and nutrient management practices of wheat in rice-wheat system at Bhairahawa, Rupendehi, 2019-2020

Treatments	Final plant height (cm)		No. of tillers per m^2 at max. tillering stage		Maximum leaf area index		Dry matter at heading (g/m^2)	
	2019	2020	2019	2020	2019	2020	2019	2020
Establishment methods								
Surface seeding	76.0	73.7^{a}	374.1^{b}	345.8^{a}	1.4^{b}	1.2^{a}	464.8	391.5^{a}
Zero tillage	88.1	70.6^{a}	413.7^{a}	272.4^{b}	2.1^{a}	1.0^{b}	657.1	317.8^{b}
Conventional tillage	84.2	59.1^{b}	406.4^{a}	218.1^{c}	1.6^{b}	0.9^{c}	555.9	216.1^{c}
p-value	0.17	0.00	0.04	0.01	0.02	0.00	0.09	<.001
SEm (±)	3.61	1.10	7.70	13.01	0.11	0.03	44.21	7.73
LSD (P<0.05)	14.17	4.30	30.24	51.07	0.44	0.12	173.59	30.36
CV, %	7.50	2.80	3.40	8.10	11.30	5.30	13.70	4.30
Residue management practices								
Residue removed	82.7	66.7	408.4	280.9	1.8	1.0	572.8	321
Residue retention	82.8	68.9	387.8	276.7	1.6	1.1	545.8	295
p-value	0.98	0.40	0.25	0.26	0.07	0.07	0.19	0.07
SEm (±)	0.62	1.40	9.09	1.88	0.05	0.02	9.63	4.89
LSD (P<0.05)	3.78	8.51	55.31	11.46	0.30	0.11	58.60	29.73
CV, %	1.30	3.60	4.00	1.20	5.00	3.00	3.00	2.70
Nutrient management practices								
F100	83.9^{a}	67.7^{b}	396.8^{ab}	275.9^{b}	1.48^{b}	1.05^{b}	529.3^{b}	320.4^{b}
F125	84.3^{a}	71.1^{a}	421.6^{a}	305.0^{a}	2.01^{a}	1.14^{a}	633.8^{a}	363.7^{a}
Farmer's practice (FP)	80.2^{b}	64.6^{c}	375.9^{b}	255.3^{c}	1.66^{b}	0.90^{c}	514.8^{b}	241.3^{c}
p-value	<.001	<.001	0.01	<.001	<.001	<.001	<.001	<.001
SEm (±)	0.68	0.50	9.72	3.46	0.08	0.02	13.84	4.24
LSD (P<0.05)	1.99	1.46	28.36	10.10	0.23	0.05	40.40	12.39
CV, %	3.50	3.10	10.40	5.30	19.70	6.90	10.50	5.80
Grand mean	82.77	67.80	398.10	278.80	1.71	1.03	559.30	308.50

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

Whereas in 2020, SS plots had significantly higher LAI than ZT and CT plots and ZT had significantly higher LAI than CT plots. In both years, F125 nutrient dose produced significantly higher LAI than F100 and FP dose but in the first year F100 and FP were statistically at par to each other. Ghadikolayi *et al*., (2015) reported that increased nitrogen rates significantly increased LAI. Similar results were reported by Potter *et al*., (1995) and Sinclair and Horie (1989), who found that LAI and crop growth were affected by nitrogen rates.

Dry matter production

In 2019, only nutrient management had significant effect on dry matter production at heading whereas in 2020 tillage methods and nutrient management had significant effect (Table 1). The SS plots produced significantly higher dry matter than ZT and CT plots, where ZT plots also produced significantly higher dry matter than CT plots in 2020. During both the years, dry matter at F125 nutrient dose had significantly higher than dry matter of F100 and FP dose.

Yield attributing characteristics

Effective tiller per square meter

Tillage method and nutrient management significantly affected the effective tiller per square meter, but residue management had no significant effect in both the years. In 2019, the ZT and CT plots produced significantly higher number of effective tiller 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). In the second year, the SS plots produced significantly higher effective tiller than ZT and CT, where ZT and CT were statistically similar. Fertilizer levels of F125 produced significantly higher number of effective tiller than FP dose, but statistically at par with F100 in 2019 and significantly higher than the number of effective tillers produced at F100 in 2020. 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 highest at 125 kg N per hectare followed by 100 kg N per hectare, where 50 kg N per hectare recorded the lowest values.

Number of grain per spike

In 2019, the number of grain per spike was significantly affected by tillage method and nutrient management, but residue management had no significant effect (Table 2). The ZT plots produced significantly higher number of grains per spike than SS and CT plots, where SS and CT plots were statistically at par. Similar results were reported by (Zamir *et al*., 2010). Whereas, in contrast, Leghari *et al*., (2015) noted maximum number of grain per spike under CT, while this number declined under reduced tillage and no-tillage. In 2020, only nutrient management had significant effect on the number of grains per spike. F125 nutrient dose produced significantly higher number of grains per spike than F100 and FP doses during both the years. Similar results were reported by Bartaula *et al*., (2019).

Thousand grain weight

Nutrient management had a significant effect on thousand grain weight (TGW) in both years while the effect of residue management was significant only in 2020 (Table 2). Similar results were obtained by Alsayim *et al*., (2018). In 2019, F100 nutrient dose produced significantly higher TGW than F125 and FP doses, whereas in 2020, significantly higher TGW was recorded in the treatment F125. Meena *et al*. (2020) reported that residue retention did not affect TGW statistically as compared to residue removal. Residue retention plots produced significantly higher TGW than residue removed plots in 2020.

Table 2. Yield attributes as influenced by the establishment methods, crop residue and nutrient management practices of wheat in the rice-wheat system at Bhairahawa, Rupendehi, 2019-2020

Treatments	Effective tillers per m^2		No. of grains per spike		Thousand grain weight (g)		Sterility (%)	
	2019	2020	2019	2020	2019	2020	2019	2020
Establishment methods								
Surface seeding	181.2^b	275.4^a	28.2^b	27.8	40.5	38.85	36.2	50.6
Zero tillage	224.1^a	205.7^b	35.1^a	26.6	38.9	37.46	36.0	51.8
Conventional tillage	211.9^a	173.8^b	29.8^b	22.9	39.4	39.08	36.4	54.7
p-value	0.03	0.02	0.05	0.17	0.07	0.26	0.89	0.18
SEm (±)	6.99	14.31	1.31	1.51	0.34	0.63	0.698	1.124
LSD (P<0.05)	27.46	56.17	5.12	5.92	1.32	2.48	2.739	4.413
CV, %	5.9	11.4	7.3	10.1	1.5	2.8	3.3	3.7
Residue management practices								
Residue removed	213.6	218.1	31.5	23.8	39.4	37.8^b	36.0	53.6
Residue retention	197.9	218.5	30.6	27.8	39.9	39.2^a	36.4	51.1
p-value	0.13	0.95	0.32	0.07	0.34	0.03	0.69	0.16
SEm (±)	4.45	4.80	0.51	0.81	0.27	0.18	0.662	0.786
LSD (P<0.05)	27.09	29.21	3.07	4.90	1.66	1.07	4.031	4.78
CV, %	3.7	3.8	2.8	5.4	1.2	0.8	3.2	2.6
Nutrient management practices								
F100	204.9^{ab}	218.3^b	29.5^b	26.3^b	40.4^a	38.4^b	36.8^a	52.2^b
F125	215.6^a	239.3^a	33.3^a	28.1^a	39.4^b	39.4^a	34.4^b	49.3^c
Farmer's practice (FP)	196.8^b	197.3^c	30.4^b	22.9^c	39.1^b	37.6^c	37.5^a	55.6^a
p-value	0.01	<.001	<.001	<.001	0.00	<.001	0.001	<.001
SEm (±)	4.06	3.39	0.55	0.40	0.22	0.14	0.553	0.512
LSD (P<0.05)	11.84	9.88	1.61	1.16	0.65	0.41	1.614	1.494
CV, %	8.40	6.60	7.50	6.50	2.40	1.60	6.5	4.1
Grand mean	205.70	218.30	31.04	25.78	39.61	38.46	36.21	52.35

Note: *F100 = 100:50:50 N, P_2O_5, K_2O kg/ha; F125 = 125:62.5:62.5 N, P_2O_5, K_2O kg/ha; Farmer's practice=80:40:15 N, P_2O_5, K_2O kg/ha; same letter in the column indicates no difference.*

Sterility percentage

The tillage method and residue management had no significant effect on sterility percentage in both years. In 2019, FP and F100 nutrient dose had significantly higher sterility percentage than F125 dose, where FP and F100 were statistically similar (Table 2). In 2020, FP dose had significantly higher sterility percentage than F100 and F125 doses, where F100 also had significantly higher sterility percentage than F125 dose.

Grain yield

In 2019, tillage methods and residue management had no significant effect on grain yield but nutrient management showed significant effect (Table 3). Ali *et al*., (2013) reported non significant difference in grain yield of winter wheat among tillage practices. The F125 nutrient dose produced significantly higher grain yield than F100 and FP doses, where F100 dose produced significantly higher grain yield than FP dose. A similar result was 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 better yield attributes of wheat (Kumar and Yadav, 2005). In 2020, the grain yield was significantly affected by tillage methods, residues, and nutrient management. The SS plots produced significantly higher grain yield than ZT and CT plots, whereas ZT plots produced significantly higher grain yield than CT plots. Due to the heavy rainfall in the early growth stage, CT wheat was more prone to excess water stress which might have resulted in growth retardation and hence the poor yield. Chaosu *et al*., (2019) found a negative effect of CT on wheat production. Furthermore, in silty clay loam soil, the zero tillage did not favor the roots to proliferate down into the deeper layers of the soil profile to extract nutrients that led to lower growth and yield of wheat, which might be the reason for the low yield of ZT wheat in the experiment. Shahzad *et al*., (2016) recorded minimum wheat grain yield under zero tillage condition.The residue retention plot produced significantly higher grain yield than residue removed plots. Similar result was found by Meena *et al*., (2020). It might be due to the addition of nutrients to the soil after decomposition of rice residue leading to enhancement in soil organic carbon (Lollato *et al*., 2019). Similarly, F125 nutrient dose produced significantly higher grain yield than F100 and FP doses, where F100 dose also produced significantly higher grain yield than FP dose. The different fertilizer doses produced grain yields differently, the higher dose produced higher grain yield. Similar results were reported by Ghadikolayi *et al*., (2015), Alijani *et al*., (2012) and Hejazi *et al*., (2010). Analysis of average grain yield of two years experiment showed that residues and nutrient management had no significant effect on mean grain yield, where tillage method had significant effect (Table 3). The ZT and SS plots produced significantly higher grain yield than CT, where ZT and SS were statistically similar. The ZT produced 26.6% higher grain yield than CT and 3% higher than SS, where SS also produced 23% higher grain yield than CT.

Straw yield

In 2019, the straw yield was significantly affected by the tillage method, residue, and nutrient management but in 2020 residue management practices had no significant effect. The ZT plots produced significantly higher straw yield than SS plots, where CT plots were statistically at par with ZT and SS plots in 2019 but in 2020, significantly higher straw yield was produced from SS plots followed by ZT and CT plots. The ZT plots also produced significantly higher straw yield than CT plots (Table 3). The residue removed plots produced significantly higher straw yield than residue retention plots in 2019. F125 nutrient dose produced significantly higher straw yield than F100 and FP doses.

Table 3. Grain yield, straw yield, and harvest index as influenced by the establishment methods, residue and nutrient management practices of wheat in the rice-wheat system at Bhairahawa, Rupendehi, 2019-2020

Treatments	Grain yield (kg/ha)		2years Mean	Straw yield (kg/ha)		Harvest index (%)	
	2019	2020	(kg/ha)	2019	2020	2019	2020
Establishment methods							
Surface seeding	1825	2887[a]	2356[a]	2802[b]	3253[a]	0.40	0.47[a]
Zero tillage	2855	1997[b]	2426[a]	4065[a]	2568[b]	0.41	0.43[b]
Conventional tillage	2263	1570[c]	1916[b]	3463[ab]	2180[c]	0.39	0.41[b]
p-value	0.07	<0.001	0.018	0.03	0.003	0.37	0.01
SEm (±)	217.20	69.30	76.5	200.4	89.2	0.01	0.01
LSD (P<0.05)	852.90	272.20	300.4	786.7	350.1	0.04	0.03
CV, %	16.3	5.6	5.9	10.1	5.8	4.2	2.5
Residue management practices							
Residue removed	2427	1968[b]	2198	3865[a]	2522	0.39	0.43[b]
Residue retention	2201	2335[a]	2268	3022[b]	2813	0.42	0.45[a]
p-value	0.10	0.00	0.252	0.02	0.054	0.06	0.04
SEm (±)	55.50	10.3	31.2	87.1	49.70	0.01	0.003
LSD (P<0.05)	337.70	62.6	189.8	529.9	302.50	0.03	0.02
CV, %	4.2	0.8	2.4	4.4	3.2	2.3	1.0

Treatments	Grain yield (kg/ha)		2years Mean	Straw yield (kg/ha)		Harvest index (%)	
	2019	2020	(kg/ha)	2019	2020	2019	2020
Nutrient management practices							
F100	2312[b]	2165[b]	2239	3477[b]	2654[b]	0.40	0.44
F125	2482[a]	2423[a]	2453	3760[a]	2941[a]	0.40	0.45
Farmer's practice (FP)	2148[c]	1866[c]	2007	3092[c]	2406[c]	0.41	0.43
p-value	<.001	<.001	<.001	<.001	<.001	0.19	0.17
SEm (±)	47.9	38.7	27.3	66.3	59.3	0.00	0.01
LSD (P<0.05)	139.8	113.1	79.6	193.6	173.1	0.01	0.02
CV, %	8.80	7.60	5.2	8.20	9.40	4.80	5.90
Grand mean	2314	2151	2233	3443	2667	0.40	0.44

Note: *F100 = 100:50:50 N, P_2O_5, K_2O kg/ha; F125 = 125:62.5:62.5 N, P_2O_5, K_2O kg/ha; Farmer's practice=80:40:15 N, P_2O_5, K_2O kg/ha; same letter in the column indicates no difference.*

Harvest index

In 2019, the harvest index was not significantly affected by the tillage method, residue, and nutrient management. In 2020, tillage method and residue management had a significant effect on HI (Table 3). The SS plots produced significantly higher HI than ZT and CT plots, where ZT and CT were statistically at par. Similarly, residue retention plots produced significantly higher HI than residue removed plots. Ali *et al*., (2013) and Bartaula *et al*., (2019) reported the non-significant effect of tillage on harvest index

Bulk density and soil moisture

After the first year experiment of wheat and rice, the tillage method and residue management had shown a significant effect on soil bulk density. Significantly higher bulk density was found in ZT plots as compared to CT plots, where bulk density of SS plots was statistically at par with both ZT and CT plots (Fig. 2). Higher bulk density in ZT might be due to the lack of mechanical operations resulting into reduced pore volume and soil compaction (Shahzad *et al*., 2016; Du *et al*., 2010; Jemai *et al*., 2012; Xu and Mermoud, 2001; Thomas *et al*., 2007). ZT induces more soil compaction in the upper layer than CT (Thomas *et al*., 2007). In contrast, frequent cultivation under CT tends to disturb the soil structure by breaking clods and reducing bulk density and mechanical impedance (Chatterjee and Lal, 2009), with simultaneous improvement in soil porosity (Meek *et al*., 1992; Rashidi and Keshavarzpour, 2011), as was observed in this study. Similarly, residue retention plots had significantly lower bulk density than residue removed plots. There were no significant effects of any treatment on soil moisture level after one year of experiment.

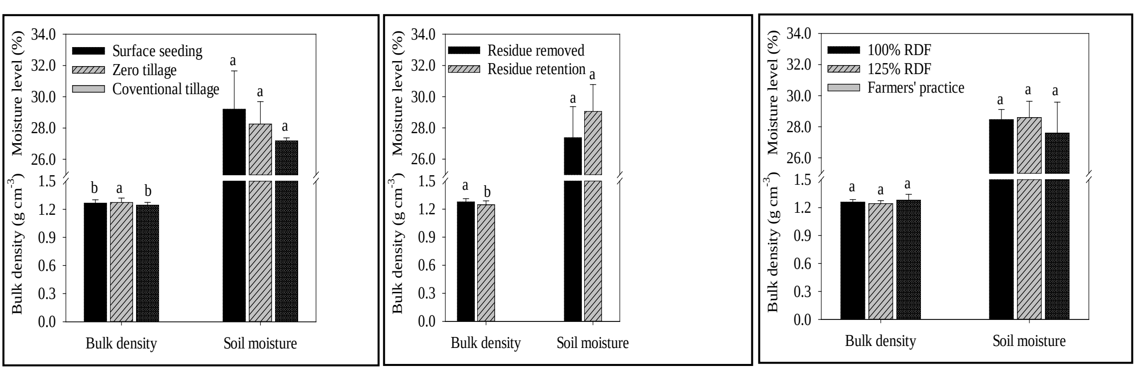

Fig. 2: Soil bulk density (g/cm^3) and soil moisture status (%) after the first-year wheat and rice harvest as influenced by the establishment methods, residue and nutrient management practices in rice-wheat system at Bhairahawa, Rupendehi, 2018-2019

Conclusion

Based on the results of two years experiment, it can be concluded that wheat can be grown under a zero tillage system with previous crop (rice) residues retention and application of 25% higher NPK fertilizer than the recommended dose in the Terai region of Nepal. Surface seeding of wheat can also be a better option especially in the year when the winter rain is high or in the well irrigated conditions.

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