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Full Length Article

Influence of Different No-till Techniques at Varying Heights of Standing Rice Stubbles on the Wheat Performance

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Abstract

In rice-wheat cropping system of Punjab, Pakistan, seeding directly into the standing rice stubbles is gaining popularity. This study was conducted to develop the most favorable and economical no-till technique for wheat sowing in combine-harvested paddy fields with different residue conditions. The experiment was comprised of three no-till techniques *viz.* (1) turbo seeder, (2) happy seeder and (3) zone disk tiller. There were four heights of standing rice stubbles *viz.* (1) 15 cm, (2) 30 cm, (3) 45 cm, and (4) 60 cm. Different no-till techniques at various heights of standing rice stubbles significantly affected the stand establishment and yield related traits of wheat during both growing seasons. Turbo seeded plot showed 12–14% more total soil porosity in comparison with zone disk tiller sown field. Conversely, wheat plots sown by zone disk tiller exhibited 8% more soil bulk density than turbo seeder sown field. Better stand establishment and grain yield were observed in turbo seeded wheat in comparison with happy seeder and zone disk tiller sown wheat. Among the stubble heights, wheat crop sown in standing rice stubbles at 45 cm height performed the best with maximum germination, 1000 grain weight and grain yield. Furthermore, turbo seeder in standing rice stubbles at 45 cm height significantly produced 32–35% more benefit cost ratio than zone disk tiller at 15 cm stubble height during both years of experiment. In crux, direct drilling of wheat by turbo seeder in rice field combine harvested at 45 cm stubble height is the most viable technology for rice-wheat cropping system.

Keywords: No-tillage; Crop residue; Rice-wheat production system; Stubble height

Introduction

The rice-wheat system produces crop residues of about 7–10 t ha^{-1}. Generally, farmers burn residues to prepare the field for next crop, which results in the loss of nutrients i.e. nitrogen, phosphorus, potassium and sulfur (Mandal *et al*., 2004). Therefore, it is necessary to recycle these residues to meet nutrient prerequisites of field crops. Appropriate management of these crop residues maintains physical and chemical properties of soil and improves overall ecological balance of the crop production system (Mandal *et al*., 2004). Lack of appropriate technology is considered as the major constraint regarding direct drilling of wheat into heavy stubbles of rice, because direct drilling causes blockage of seeding equipment and less soil-seed contact (Erenstein *et al*., 2008; Rehman *et al.*, 2015). Happy Seeder (HS) technology in rice-wheat cropping system, gives an advantage of direct drilling of wheat into loose as well as standing stubbles of rice in a single pass of the field, giving an additional benefit of 60% against conventional sowing (Qamar *et al*., 2012). Furthermore, this technology provides an adequate substitute of burning for managing standing and fragmented residues (Gathala *et al*., 2009). No-tillage system produces equal or sometime more germination and crop yield as compared to conventional tillage system. However, coulter arrangement fitted with seed-cum-fertilizer drill work satisfactorily in manually harvested paddy fields but fail to work under heavy load of residues due to problems in cutting straw, accumulation of straw and formation of big clods (Shukla *et al*., 1984). Loose residue produced in bulk quantities as result of combine harvesting of paddy field creates hindrances to no-till seeders with frequent choking of seeding flails (Graham *et al*., 1986). On the other-hand, height of standing stubbles should also be less than seed row spacing in cereals because taller stubbles may cause clogging (Green and Poisson, 1999). No-till seeder should have an ability to micro manage the residues close to furrows for better seedling establishment (Baker and Chaudhary, 1988) and capacity of seeding with precision at different residue conditions. Otherwise, non-precised seeding causes uneven seeding depth. It may lead to scattered crop emergence that affects the crop performance badly, because early emerged plants decrease the yield of late emerged plants (Thomison and Lentz,

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2002). Loose residue not burnt/spread on the ground results in frequent choking of drill in between furrow openers and frame of the drill (Singh and Singh, 1995). However, even spreading and well chopping of loose residue reduces the straw accumulation during seeding operation of no-till seeders (Sidhu *et al*., 2015). Although a lot of work has been done to compare the performance of zero-tillage under residue based cropping system, information on how different heights of standing rice stubbles affect the performance of no-till techniques is lacking as it is the useful indices of crop yield. Therefore, this study was conducted to evaluate different no-till techniques at varying heights of standing rice stubbles for direct drilling of wheat in combine harvested rice field and to calculate the economic feasibility of different no-till techniques in rice wheat cropping system.

Materials and Methods

Experimental Site

The study was conducted at the Adaptive Research Farm, Department of Agriculture Extension and Adaptive Research, Gujranwala, Punjab, Pakistan during Rabi 2014–2015 and 2015–2016. Geographically, the site was situated at latitude 32° N, altitude 226 m and longitude 74° E. The texture of the soil was clay loam, sandy and Hyperthermic mixed (USDA nomenclature). Other soil chemical properties and weather data are presented in Table 1 and Table 2, respectively.

Plant Material

Seeds of wheat cultivar Punjab-2011 were collected from Punjab Seed Corporation, Gujranwala. Initial moisture and germination percentages were 9.0 and 95%, respectively.

Experimental Details

Three no-till techniques *viz.* (1) turbo seeder, (2) happy seeder, and (3) zone disk tiller were allotted to the main plots, whereas different heights of standing rice stubbles *viz.* (1) 15 cm, (2) 30 cm, (3) 45 cm and (4) 60 cm were laid out in the subplots. The experiment was conducted in randomized complete block design in split plot arrangement with three replications for each treatment combination. The net plot size of 6.75 m × 14.0 m was used. The crop was sown on 21st and 19th November 2014–2015 and 2015–2016, respectively. Wheat crop was sown in each tillage system at 22.5 cm apart rows using seeds at 125 kg ha^{-1}. Nitrogen was applied at 120 kg ha^{-1}. However, potash and phosphorus were applied at 60 and 100 kg ha^{-1}, respectively. Whole of the potash and phosphorus, while half of nitrogen were applied at sowing. Rest of the nitrogen was broadcasted at tillering with first irrigation. Both year's crop was harvested at maturity on 8th May; 2015 and 5th May; 2016, respectively.

Table 1: Some chemical characteristics of soil profile

Soil characteristics	2014–2015	2015–2016
Soil pH	7.90	7.70
ECc (dS m^{-1})	1.10	0.97
Organic matter (g kg $^{-1}$)	9.60	9.30
Nitrogen (g kg $^{-1}$)	0.59	0.63
Available phosphorus (mg kg^{-1})	5.30	5.00
Available potassium (mg kg^{-1})	141	139

Observations

Before sowing, loose and standing residue were collected separately, as standing stubbles height treatments alter the ratio of loose to standing stubbles. For this purpose, a quadrat measuring 1 m × 1 m was placed randomly on each plot at three different locations. Then the loose and standing straw contained in the quadrat were collected separately, and their dry masses were determined by oven dry method (Doan *et al*., 2005). The bulk density was measured using the core method (Blake and Hartge, 1986). After wheat harvesting, the soil bulk density was measured from 0–10 cm depth. For this purpose, soil samples were collected using soil core. Total soil porosity was also calculated from these measurements following the method of Lowery *et al*. (1996). The values of particle density (ρ_p) and soil bulk density (ρ_b) were used to determine total soil porosity (S_t) with the help of given formula:

$$S_t = (1 - \rho_b / \rho_p) \times 100$$

After completion of germination, normally at 15 days from sowing, the number of emerged seedlings was recorded in both years i.e., 2014–2015 and 2015–2016. For this purpose, four consecutive lines were selected up to one meter length from two different places randomly in each plot and germination was recorded until the constant reach. Similarly at physiological maturity, the number of productive tillers was recorded by selecting four lines up to one meter length from each treatment combination. A meter rod was used to measure the plant height at physiological maturity. Randomly, twenty plants in each treatment combination were measured separately and then averaged to determine plant height. The spikes from the same twenty plants were taken to count number of grains per spike and then averaged for individual value. For 1000-grain weight, a sub sample of 1000-grains was taken individually from each experimental unit. After that, the sample was oven dried for 24 h at 70°C and then weighed up to constant, using electric balance. When the crop attained the complete physiological maturity, manual harvesting was done in each plot with dimensions of 6.75 m × 14 m. The harvested crop was tied up and tagged. The spring balance was used to weigh the tagged bundles from each experimental unit to determine biological yield of each plot, individually. Tagged bundles from each plot were threshed individually to determine grain yield and then grain yield was converted into Mg ha^{-1}. For economic analysis, net return was determined by

Table 2: Weather data of experimental site during wheat season of 2014–2015 and 2015–2016

Months	Rain fall (mm)		Relative humidity (%)		Temperature (°C)					
					Daily maximum		Daily minimum		Daily mean	
	2014–2015	2015–2016	2014–2015	2015–2016	2014–2015	2015–2016	2014–2015	2015–2016	2014–2015	2015–2016
November	0.0	10.0	62.0	61.0	25.0	26.3	10.0	12.1	17.5	19.2
December	0.0	0.0	78.0	64.0	17.0	20.8	5.3	6.9	11.2	13.9
January	20.5	17.7	78.5	75.6	15.3	17.0	5.0	7.1	10.2	12.1
February	55.0	15.6	69.9	60.3	18.0	22.6	9.7	9.2	13.8	16.0
March	83.7	50.0	64.0	59.9	23.7	26.5	12.9	15.2	18.3	20.8
April	90.9	0.0	50.7	36.7	30.5	32.4	17.3	18.6	23.9	25.5

Source: Punjab meteorological department, adaptive research farm, Gujranwala

subtracting the total cost of production from the gross income of each treatment (Byerlee, 1988). While, benefit cost ratio was calculated by dividing the gross income to the total cost of production.

Statistical Analysis

Data collected from both experiments were statistically analyzed by STATISTIX 8.1 and the differences among the treatment means were compared for significance by using the HSD Tukey's Test at 5% level of probability.

Results

Crop Residue Cover

In both years, the maximum loose, while the minimum standing residue in plots were recorded when rice crop was combine harvested at 15 cm height (Table 4). Conversely, the least loose and the maximum standing residue were recorded when rice crop was combine harvested at 60 cm height. However, rice combine harvesting at 30 cm height showed the loose to standing residue ratio of 54–46 and 53–47 during first and second year, respectively (Table 4), which was followed by rice combine harvesting at 45 cm height.

Soil Physical Properties

Different no-till techniques significantly affected the soil physical properties i.e. soil bulk density and total soil porosity in both years (Table 3). The maximum soil bulk density in both years was observed in plot sown with zone disk tiller while the minimum in turbo seeded wheat (Table 3). On the other-hand, total soil porosity was higher in turbo seeded wheat and the lowest in zone disk tiller sown wheat during both experimental years (Table 3). However, the effect of different stubble heights on soil physical properties was not significant.

Crop Establishment

Wheat stand establishment was also affected significantly by different no-till techniques and standing stubble heights in both years. During 2014–2015, statistically similar number of emerged seedlings was obtained in turbo and happy seeded wheat, while zone disk tiller sown wheat

Table 3: Effect of different no-till techniques on soil physical properties

No-till techniques	Soil bulk density (g cm^{-3})		Total porosity (cm^3 cm^{-3})	
	2014–2015	2015–2016	2014–2015	2015–2016
Turbo seeder	1.54 b	1.55 c	0.42 a	0.41 a
Happy seeder	1.62 ab	1.63 b	0.39 b	0.39 b
Zone disk tiller	1.68 a	1.69 a	0.36 c	0.36 c

Figures sharing the same letter in a column do not differ significantly at $p \leq 0.05$

showed the less number of emerged seedlings (Table 5). However during 2015–2016, turbo seeded wheat exhibited the higher number of emerged seedlings than happy seeder and zone disk tiller (Table 5). Moreover, in case of stubble height, wheat crop sown in rice field combine harvested at 45 cm height showed more germination as compared to other heights of rice stubble due to different residue loads (Table 5).

Wheat crop sown by turbo seeder had significantly taller plants followed by happy seeder, while the less plant height was recorded with zone disk tiller sown wheat in both years of study (Table 5). On the other-hand, statistically similar plant height was observed in wheat crop sown in stubbles of rice crop combine harvested at 45 and 60 cm heights, respectively during 2014–2015 (Table 5). However during 2015–2016, the maximum plant height was observed in wheat crop sown in stubbles of rice crop combine harvested at 45 cm height followed by 60 cm stubble height while the wheat crop sown into standing rice stubbles at 15 cm height significantly reduced the plant height (Table 5).

The interactive effect of no-till techniques and stubble heights was significant for the number of productive tillers (Table 5). The significant improvement in productive tillers was observed with wheat crop sown by turbo seeder in standing stubbles of rice crop combine harvested at 45 cm height, while the minimum number of productive tillers was exhibited by wheat crop sown with zone disk tiller in standing stubbles of rice crop combine harvested at 15 cm height over both years (Table 5).

Yield and Yield Related Traits

The interactive effect of different no-till techniques and stubble heights was significant for the number of grains per

Table 4: Crop residue cover (Mg ha^{-1}) measured before seeding trial

Stubble height	2014–2015				2015–2016			
	Loose	Standing	Total	Loose-standing Ratio	Loose	Standing	Total	Loose-standing Ratio
S_1	5.71	1.75	7.45	77–23	5.8	2.23	8.03	72–28
S_2	4.29	3.71	8.0	54–46	4.13	3.68	7.81	53–47
S_3	2.95	4.78	7.73	38–62	3.17	4.93	8.10	39–61
S_4	1.87	5.93	7.80	24–76	2.01	6.46	8.47	24–76

S_1 = 15-cm, S_2 = 30-cm, S_3 = 45-cm and S_4 = 60-cm

Table 5: Crop establishment, yield and yield related traits of wheat as influenced by sowing with different no-till techniques in various heights of standing rice stubbles under rice-based cropping system

	2014–2015					2015–2016				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
Germination count										
Turbo seeder	143	152	166	159	155A	149	158	175	163	161 A
Happy seeder	140	148	162	156	152 A	148	155	167	164	159 B
Zone disk tiller	125	127	136	132	130 B	129	132	144	138	136 C
Mean	136 D	142 C	155 A	149 B		142 C	148 BC	162 A	155 AB	
Plant height (cm)										
Turbo seeder	96.8	97.0	98.0	97.3	97.3A	97.1	97.2	98.3	97.8	97.6 A
Happy seeder	96.1	96.3	96.8	96.7	96.5 B	96.2	96.5	97.2	96.8	96.7 B
Zone disk tiller	95.7	95.9	96.1	96.3	96.0 C	95.8	96.0	96.3	96.1	96.1 C
Mean	96.2 B	96.4 B	97.0 A	96.8 A		96.4 D	96.6 C	97.3 A	96.9 B	
Productive tillers (m^{-2})										
Turbo seeder	249 c	250 c	265 a	258 b	255 A	267 d	271 c	284 a	278 b	275 A
Happy seeder	227 g	235 e	251 c	244 d	239 B	262 e	267 d	278 b	273 c	270 B
Zone disk tiller	215 i	220 h	232 f	225 g	223 C	239 i	246 h	259 f	252 g	249 C
Mean	231 D	235 C	249 A	242 B		256 D	261 C	274 A	268 B	
Grains per spike										
Turbo seeder	45.9 ef	46.0 ef	46.7 a	46.3 b-e	46.2 AB	45.9	46.9	48.0	47.3	47.0 A
Happy seeder	46.0 f	46.1 def	46.6 ab	46.4 bc	46.3 A	45.2	47.1	46.9	46.2	46.3 A
Zone disk tiller	45.9 f	46.1 def	46.4 bcd	46.2 cde	46.1 B	44.7	45.0	46.1	45.0	45.2 B
Mean	45.9 D	46.1 C	46.5 A	46.3 B		45.3 C	46.3 AB	47.0 A	46.2 B	
1000-grain weight (g)										
Turbo seeder	45.0	45.2	45.6	45.4	45.3 A	46.4	46.4	47.6	46.8	46.8 A
Happy seeder	44.8	45.3	45.5	45.3	45.2 A	45.9	46.0	46.9	46.4	46.3 B
Zone disk tiller	44.0	44.2	44.7	44.2	44.3 B	45.7	45.8	46.3	46.0	45.9 C
Mean	44.6 C	44.9 B	45.3 A	45.0 B		46.0 B	46.1 B	46.9 A	46.4 AB	
Grain yield (Mg ha^{-1})										
Turbo seeder	4.0 ef	4.2 cd	4.7 a	4.5 ab	4.4 A	4.5	5.3	5.9	5.4	5.3 A
Happy seeder	3.9 fg	4.1 de	4.5 ab	4.4 bc	4.2 A	3.8	4.7	5.2	4.9	4.6 B
Zone disk tiller	2.9 i	3.1 h	3.7 g	3.3 h	3.2 B	3.0	3.7	4.3	3.8	3.7 C
Mean	3.6 D	3.8 C	4.3 A	4.1 B		3.8 C	4.6 B	5.1 A	4.7 AB	
Biological yield (Mg ha^{-1})										
Turbo seeder	10.3	10.8	11.8	11.3	11.0 A	11.6	13.5	15.3	13.7	13.5 A
Happy seeder	9.7	10.4	11.3	10.9	10.6 B	9.8	11.9	13.3	12.2	11.8 B
Zone disk tiller	7.2	7.7	8.9	8.2	8.0 C	7.4	9.5	11.2	9.8	9.5 C
Mean	9.1 D	9.6 C	10.7 A	10.2 B		8.6 C	11.6 B	13.3 A	11.9 B	
Straw yield (Mg ha^{-1})										
Turbo seeder	6.3	6.6	7.1	6.8	6.7 A	7.1	8.2	9.4	8.3	8.3 A
Happy seeder	6.1	6.2	6.8	6.5	6.4 B	6.0	7.2	8.1	7.3	7.1 B
Zone disk tiller	4.4	4.6	5.3	5.0	4.8 C	4.4	5.8	6.9	6.0	5.8 C
Mean	5.6 D	5.8 C	6.4 A	6.1 B		5.8 C	7.1 B	8.1 A	7.2 B	

Figures sharing the same case letter, for a parameter, in a year do not differ significantly at $p = 0.05$

S_1= 15-cm, S_2= 30-cm, S_3= 45-cm and S_4= 60-cm

spike during 2014–2015 (Table 5). Wheat crop sown with turbo seeder in standing stubbles of rice crop combine harvested at 45 cm height produced the maximum number of grains per spike, and that was statistically similar to happy seeded wheat under same stubble height treatment. Conversely, the minimum number of grains per spike was observed in wheat crop sown by zone disk tiller in standing stubbles of rice crop combine harvested at 15 cm height that was statistically similar to turbo and happy seeded wheat under same stubble height treatment (Table 5). However, during 2015–2016, statistically similar number of grains per spike was observed in turbo and happy seeded wheat, while wheat crop sown with zone disk tiller showed the less number of grains per spike (Table 5). Moreover, wheat crop sown in standing stubbles of paddy crop combine harvested at 45 cm height produced more number of grains per spike in comparison with other stubble heights. Nonetheless, the minimum number of grains per spike was observed by

Table 6: Total cost, net return and benefit cost ratio as influenced by sowing of wheat with different no-till techniques in combine harvested rice field with various stubble heights

Treatments	Grain yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})	Gross income (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit cost ratio
			2014-2015			
Turbo seeder						
S_1 (15 cm)	4.0	6.3	181106	100744	80362	1.80
S_2 (30 cm)	4.2	6.6	189719	100139	89580	1.89
S_3 (45 cm)	4.7	7.1	210031	100340	109691	2.09
S_4 (60 cm)	4.5	6.8	202917	98540	104377	2.06
Happy seeder						
S_1 (15 cm)	3.9	6.1	176367	102889	73478	1.71
S_2 (30 cm)	4.1	6.2	185151	102458	82692	1.81
S_3 (45 cm)	4.5	6.8	202538	102304	100234	1.98
S_4 (60 cm)	4.4	6.5	196147	100577	95569	1.95
Zone disk tiller						
S_1 (15 cm)	2.9	4.3	128050	93850	34200	1.36
S_2 (30 cm)	3.1	4.6	138378	95350	43028	1.45
S_3 (45 cm)	3.7	5.3	161958	95253	66706	1.70
S_4 (60 cm)	3.3	5.0	146376	93364	53013	1.57
	2015-2016					
Turbo seeder						
S_1 (15 cm)	4.7	7.4	214338	103127	111210	2.08
S_2 (30 cm)	4.9	7.6	219917	102306	117611	2.15
S_3 (45 cm)	5.5	8.5	248571	103016	145555	2.41
S_4 (60 cm)	5.2	8.0	233188	100563	132625	2.32
Happy seeder						
S_1 (15 cm)	4.4	7.2	202556	104622	97934	1.94
S_2 (30 cm)	4.7	7.5	213281	104264	109017	2.05
S_3 (45 cm)	5.2	8.1	234000	104327	129673	2.24
S_4 (60 cm)	5.1	7.9	228448	102708	125740	2.22
Zone disk tiller						
S_1 (15 cm)	3.5	5.4	157408	95897	61511	1.64
S_2 (30 cm)	3.7	5.8	168296	97362	70934	1.73
S_3 (45 cm)	4.3	6.6	193131	97300	95831	1.98
S_4 (60 cm)	4.1	6.2	183490	96097	87392	1.91

Wheat grain price = Rs. 1300 per 40 kg, Wheat straw price = Rs. 325 per 40 kg

wheat crop sown in combine harvested paddy crop with 15 cm stubble height (Table 5).

Wheat crop sown through turbo and happy seeder treatments showed the statistically similar 1000-grain weight, while the lowest 1000-grain weight was recorded in zone disk tiller sown wheat during the first year study (Table 5). On the other-hand, the maximum 1000-grain weight was observed with wheat crop sown in standing stubbles of rice crop combine harvested at 45 cm height followed by wheat crop with 60 cm stubble height that was statistically similar to wheat crop with 30 cm stubble height. Conversely, the less 1000-grain weight was observed in wheat crop sown in combine harvested rice field with 15 cm stubble height (Table 5). However, the 1000-grain weight was improved in the order of turbo seeder > happy seeder > zone disk tiller during the second year study (Table 5). In case of stubble heights, statistically similar 1000-grain weight was observed in wheat crop sown in standing stubbles of rice crop with 45 and 60 cm stubble heights, respectively (Table 5).

Different no-till techniques and their interaction with stubble heights significantly affected the grain yield in 2014–2015. The maximum grain yield was recorded in wheat crop sown with turbo seeder in standing stubbles of rice crop combine harvested at 45 cm height followed by 60 cm stubble height under same no-till treatment, and happy seeded wheat under same stubble height treatment. Nonetheless, wheat crop sown with zone disk tiller in standing stubbles of rice crop combine harvested at 15 cm height showed the less grain yield (Table 5). However, during 2015–2016, the highest grain yield was observed in the order of turbo seeder > happy seeder > zone disk tiller, among no-till techniques. On the other-hand, wheat crop sown in standing stubbles of rice crop combine harvested at 45 cm height showed more grain yield than other stubble heights (Table 5). Similarly, the significant effect was reported by different no-till techniques and stubble heights for biological yield and straw yield in both years (Table 5). Turbo seeded wheat significantly improved the biological and straw yield than other no-till seeders (Table 5). Moreover, wheat crop sown in standing stubbles of rice crop combine harvested at 45 cm height produced the maximum biological and straw yield, while the wheat crop sown in 15 cm rice stubble height plots showed the less biological and straw yield during both years of experiment (Table 5).

Economic Analysis

The data presented indicated that wheat crop sown with turbo seeder in standing stubbles of rice crop combine harvested at 45 cm height showed the maximum benefit-cost ratio followed by 60 cm stubble height under same no-till technique. Conversely, the wheat crop sown with zone disk tiller in rice field combine harvested at 15 cm height showed the less benefit cost ratio over both years (Table 6).

Discussion

The results indicated that leaving the stubble height of 15 cm in rice after combine harvesting, followed by sowing of wheat with zone disk tiller adversely affected the stand establishment and productvity of wheat. This poor performance of wheat sown with zone disk tiller might be attributed to the poor soil physical status i.e. the highest bulk density and the lowest total soil porosity values. Indeed, poor soil physical status adversely affects the wheat performance in rice-wheat system (Nawaz *et al*., 2017), by affecting the root penetration. On the other hand, the poor soil physical status of wheat crop in zone disk tilled wheat might be the function of clogging due to uprooting of standing stubbles by seeding coulters of zone disk tiller which enhanced the soil bulk density (Green and Poisson, 1999).

However, combine harvesting of rice crop at 45 cm height and sowing of wheat through turbo seeder substantially improved the germination, tillering and grain yield in wheat. This better performance of wheat might be attributed to the highest soil porosity and the lowest soil bulk density in the plots sown through turbo seeder (Kumar *et al*., 2014). Indeed, turbo seeder performs efficient seeding operation and it has ability to micro manages the residues to the seeding zone.

Better germination was observed in the wheat crop sown at 45 cm stubble height in combine harvested rice field. This better germination at 45 cm stubble height might be attributed to high moisture retention in these plots, and proper seed to soil contact, which enhanced the germination (Dixit *et al*., 2002). On the other hand, the concentrated loose residue in swathes left by combine harvester may be the cause of less germination count in wheat crop sown at 15 cm stubble height, which affected proper seed depth and the soil moisture properties. On the other hand, more germination count in the wheat crop sown through turbo seeder might be the function of penetration accuracy without leaving the seeds on residues. However, the seeding operation that leaves seeding zone uncovered may be a cause of the minimum germination in wheat crop sown through zone disk tiller (Tessier *et al*., 1991), as was observed in this study. It is well documented that seed germination in zero tillage depends upon efficient working of zero tillage drills. The drilling efficiency greatly depends upon material (residue) left in the field after the harvesting of previous crop.

In rice fields, two types of residues *viz.* loose and standing, are left in the field after combine harvesting of rice. The ratio of standing to loose stubbles is very much important regarding working of zero tillage drills in combine harvested rice field. The paddy straw present in the field often builds up in front of the tines of the drill and eventually blocks the tine and frame, causing unwanted interruptions, uneven seeding rate and depth and a patchy stand of plants (Graham *et al*., 1986). These factors attributed towards the differences in seed germination in the wheat sown with different no till machines at variable stubble height of rice.

The maximum plant height in wheat crop sown through turbo seeder was the function of high moisture availability, greater nutrient concentrations and more rooting depth due to the placement of seed at proper depth (Hemmat and Eskandari, 2006; Lupwayi *et al*., 2006). However, the less plant height in wheat crop sown with zone disk tiller may be due to poor soil physical structure which affected the growth of wheat. Wheat crop sown in 45 cm stubble height exhibited the maximum plant height over other stubble heights, which might be due to the better soil physical environment. More number of productive tillers in wheat crop sown through turbo seeder in standing stubbles of rice crop combine harvested at 45 cm height might be due to more germination count (Dixit *et al*., 2002). Whereas, the minimum number of fertile tillers in wheat crop sown by zone disk tiller in standing stubbles of paddy crop harvested at 15 cm height was because of the less germination and poor soil physical environment.

Turbo seeder and 45 cm stubble height substantially improved the number of grains per spike, 1000-grain weight, biological, grain and straw yield over other no-till techniques and stubble heights. This better wheat performance in this treatment might be due to better soil moisture and optimum temperature. The highest grain yield in wheat crop sown in 45 cm stubble height might be the function of better yield attributing characters (Table 5; Dixit *et al*., 2002). The maximum benefit cost ratio in wheat crop sown with turbo seeder in standing stubbles of rice crop combine harvested at 45 cm height may be a function of high net return and the less cost of production. On the other hand, the minimum benefit cost ratio in crop sown by zone disk tiller in standing stubbles of paddy crop combine harvested at 15 cm height could be due to the less net return and high cost of production.

Significant difference in wheat grain yields between growing seasons was also apparent. More grain yield during 2015–2016 was due to the favorable temperature and effective rainfall (Table 2). However during 2014–2015, excessive rainfall (Table 2) and crop lodging in the months of March and April from flowering stage till maturity badly affected the wheat crop that lowered the grain yield.

Conclusion

Wheat crop sown with zone disk tiller had substantially low grain yield owing to more bulk density and less total porosity; conversely, turbo seeded wheat exhibited more grain yield and greater economic returns due to better soil physical environment. Wheat grain yield was substantially low when was sown in 15 cm stubbles of rice crop after combine harvesting; nonetheless, leaving 45 cm stubbles of rice crop after combine harvesting favored the grain yield and economic return. Therefore, combine harvesting of rice crop at 45 cm stubble height and the use of turbo seeder for wheat sowing should widely be adopted in rice-based cropping system.

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References

Baker, C.J. and A.S. Chaudhry, 1988. Barley seedling establishment by direct drilling in a wet soil. *Soil Till. Res.,* 11: 167–181

Blake, G.R. and K.H. Hartge, 1986. Bulk Density, *In*: *Methods of Soil Analysis*, 2nd edition, Part I Physical and Mineralogical Methods, pp: 363–375. A. Klute, (ed.). Agronomy Monograph no. 9, , American Society of Agronomy–Soil Science Society of America, Madison, Wisconsin, USA

Byerlee, D., 1988. *From Agronomic Data to Farmers Recommendations*, pp: 31–33. Academic training manual CIMMYT, Mexico

Dixit, J., R.S.R. Gupta, V.P. Behl and R.S. Rinwa, 2002. Effect of sowing depth, seed coverage and stubble height on the yield and yield attributes of wheat crop in no-tillage system under paddy-wheat crop rotation. *Agric. Sci. Digest.,* 22: 1–5

Doan, V., Y. Chen and B. Irvine, 2005. Effect of residue type on performance of no-till seeder openers. *Can. J. Biol. Eng.,* 47: 29–35

Erenstein, O., K. Sayre, P. Wall, J. Dixon and J. Hellin, 2008. Adapting no-tillage agriculture to the conditions of smallholder maize and wheat farmers in the tropics and sub-tropics. *No-till Farm. Syst.*, pp: 253–278

Gathala, M.K., H. Pathak, J.K. Ladha, V. Kumar, D. Mishra, J. Blackwell, C. Roth, V. Kumar, V. Kumar and S. Sharma, 2009. Happy seeder technology provides an alternate to burning for managing rice loose straw after combine harvest. *4th World Congress on Conservation Agriculture*, pp: 4–7. New Delhi, India

Graham, J.P., F.B. Ellis, D.G. Cristian and R.Q. Cannel, 1986. Effects of straw residues on the establishment, growth and yield of autumn sown cereals. *J. Agric. Engg. Res.*, 33: 39–49

Green, M. and D. Poisson, 1999. *Residue Management for Successful Direct Seeding.* Agdex 570-4. Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada

Hemmat, A. and I. Eskandari, 2006. Dryland winter wheat response to conservation tillage in a continuous cropping system in northwestern Iran. *Soil Till. Res*., 86: 99–109

Kumar, S., Shivani, U. Kumar and Manibhushan, 2014. Productivity and economics of rice-wheat cropping system as affected by methods of sowing and tillage practices in the eastern plains. *J. AgriSearch*, 1: 145–150

Lowery, B., W.J. Hickey, M.A. Arshad and R. Lal, 1996. *Soil Water Parameters and Soil Quality*, pp: 143–155. Methods for Assessing Soil Quality, oil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, Wisconsin, USA

Lupwayi, N.Z., G.W. Clayton, J.T.O. Donovan, K.N. Harker, T.K. Turkington and Y.K. Soon, 2006. Nitrogen release during decomposition of crop residues under conventional and zero tillage. *Can. J. Soil Sci*., 86: 11–19

Mandal, K.G., A.K. Misra, K.M. Hati, K.K. Bandyopadhyay, P.K. Ghosh and M. Mohanty, 2004. Rice residue management options and effects on soil properties and crop productivity. *Food Agric. Environ.,* 2: 224–231

Nawaz, A., M. Farooq, R. Lal, A. Rehman, T. Hussain and A. Nadeem, 2017. Influence of Sesbania brown manuring and rice residue mulch on soil health, weeds and system productivity of conservation rice–wheat systems. *Land Degrad. Dev*., 28: 1078–1090

Qamar, R., Ehsanullah, R. Ahmad and M. Iqbal, 2012. Response of wheat to tillage and nitrogen fertilization in rice-wheat system. *Pak. J. Agric. Sci*., 49: 243–254

Rehman, H., A. Nawaz, A. Wakeel, Y.S. Saharawat and M. Farooq, 2015. Conservation Agriculture in South Asia. *In: Conservation Agriculture,* pp: 249–282. Farooq, M. and K.H.M. Siddique (eds.). Springer International Publishing, Switzerland

Shukla, L.N., S.K. Tandon and S.R. Verma, 1984. Development and field evaluation of coulter arrangement for direct drilling. *Agric. Mech. Asia Africa Latin Amer*., 27: 15–18

Sidhu, H.S., M. Singh, Y. Singh, J. Blackwell, S.K. Lohan, E. Humphreys and S. Singh, 2015. Development and evaluation of the Turbo Happy Seeder for sowing wheat into heavy rice residues in NW India. *Field Crops Res.,* 184: 201–212

Singh, B. and T.P. Singh, 1995. Development and performance evaluation of zero till fertilizer cum seed drill. *J. Agric. Eng.*, 32: 13–23

Tessier, S., K.E. Saxton, R.I. Papendick and G.M. Hyde, 1991. Zero-tillage furrow opener effects on seed environment and wheat emergence. *Soil Till. Res.*, 21: 347–360

Thomison, P.R. and E. Lentz, 2002. *Corn Planter Maintenance and Stand Establishment Profit Tips*. In Agronomy Notes. College of Agricultural Sciences, Pennsylvania State University, University Park, Philadelphia, USA

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