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Full Length Article

Residual Effect of Cover Crops and Conservation Tillage on Soil Physical Properties and Wheat Yield Grown after Direct Seeded Rice

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Abstract

Conservation tillage (CT) in wheat offers a pragmatic option for resolving the time and edaphic conflicts in rice–wheat cropping system (RWS). This two-year study was conducted to evaluate the residual impact of cover crops and tillage methods on soil physical properties, and growth and grain yield of wheat. The cover crops, including Egyptian clover, crimson clover, hairy vetch, alfalfa, and sweet clover, were sown in the rice field at physiological maturity stage. Before wheat planting, seedbed was prepared using conventional tillage and deep tillage or wheat was sown without tillage (zero-till) into the stubbles of previous crop. Soil physical properties *i.e.*, soil bulk density, water holding capacity and soil organic matter were significantly improved by the cover crops. There was a considerable decrease in soil bulk density in both years *i.e.*, 15% in 2017 and 19% in 2018 in deep tillage using Egyptian clover as a cover crop. The soil organic matter (SOM) was increased because of the incorporation of cover crops and crop residues into the soil. The SOM in the sec year (2018) increased by 8.1% than the first year (2017). Wheat planted with conventional tillage together with cover crops, especially Egyptian clover, performed better than the other two methods. In conclusion, wheat sown using conventional tillage in combination with Egyptian clover as a cover crop seemed a viable option to improve the soil properties and crop yield.

Keywords: Cover crops; Tillage methods; Soil physical properties; Leaf area duration; Yield parameters

Introduction

Rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system (RWS) is one the major cropping systems practiced on an area of 13.5 million hectares (Mha) in South Asia (FAO 2016). In conventional RWS, rice is grown by transplanting the nursery seedling into a puddled field; however, the following wheat crop is sown in plowed and pulverized soil. However, puddling in rice deteriorates soil physical quality (Bertolino *et al.* 2010; Farooq and Nawaz 2014; Akmal *et al.* 2015), which adversely impacts root and shoot growth of the following winter crops (McDonald *et al*. 2006) by reducing nutrient and water availability (Ishaq *et al*. 2001). Indeed, puddling results in the formation of a strong crust that inhibits wheat seedling emergence (Micucci and Taboada 2006; Mohanty *et al*. 2006). This crust does not allow roots to go deep because of low porosity and too high mechanical impedance as these plow pan layers are situated shallow than the normal rooting depth (Bruand *et al*. 2004). Moreover, late maturity, and harvest of basmati rice further delay wheat planting in this system (Farooq *et al*. 2008), which drastically reduces yield and profitability (Hussain *et al*. 2012).

Due to ever-rising population and climate change, the importance of sustainable management approaches has increased to retain and amend soil quality, and to increase the crop production (Komatsuzaki and Ohta 2007; Lal 2009). To meet the challenges of the future, the idea of conservation agriculture (CA) has been recognized as an integrated management strategy (Verhulst *et al*. 2010). Conservation agriculture, which involves least soil disturbance, retains residue cover and diversified crop rotation, offers a pragmatic option to resolve the edaphic and time conflicts in the conventional RWS (Farooq and Nawaz 2014; Lal 2015). Water-saving rice production systems, including direct seeded aerobic rice (DSAR) culture, may resolve the edaphic constraints while also reducing water and energy input (Oliver *et al*. 2008; Farooq *et al*. 2009, 2011). Direct seeded aerobic rice also matures earlier than puddled flooded transplanted rice (PudTR), thus allowing the timely sowing of the following crop (Farooq *et al.* 2008). Direct seeding in the aerobic environment also improves soil physical quality for post rice winter cereals (Farooq and Nawaz 2014) by enhancing deeper root penetration and improving water and nutrients uptake. Moreover, no-tillage (NT) facilitates early wheat sowing and reduces the production cost (Farooq and Nawaz 2014). In contrast, plow tillage (PT) often degrades the soil structure (Qureshi *et al*. 2003; D'Haene *et al*. 2008), and depletes soil organic matter (SOM) content (Lal 2015).

For wheat sowing, zero tillage helps mitigate labor cost and use of fuel (Lal 2007; Shahzad *et al*. 2017). Minimum disturbing of soil protects soil and water reserves, limits utilization of farm energy, and raises the crop production. This technique improves soil biological and physical properties (Alvarez and Steinbach 2009). Direct tilling is used as a modality of conservation tillage and accepted as the best way of protecting the soil surface from structure deterioration and erosion (Reeves *et al*. 2005). It is found that conservation tillage increases the stability of aggregate, organic matter, K^+ ion and biotic activities (Munkholm *et al*. 2008; Schjonning *et al*. 2011; Munkholm and Hansen 2012). Reduced tillage causes stratification in the soil layer that affects chemical traits and organic matter in the soil (Franzluebbers 2002; Jones *et al*. 2007). No-tillage influences many soil traits such as porosity, pore connectivity, bulk density, infiltration rate, and water retention capability, including chemical attributes such as OM content and status of nutrients in the soil (Kribaa *et al*. 2001). In the seedbed, seed germination and plant emergence are influenced by soil temperature and soil moisture. During the growing period of crop, the high soil moisture is maintained by conservation tillage (Tan *et al*. 2002; Alletto *et al*. 2011).

The use of cover crops in rotation with the main crop provides a range of dynamic services and advantages. Winter cover exploits soil for nutrient and minimizes the losses of nutrients (Fageria *et al*. 2005; Gomez *et al*. 2009; Munkholm and Hansen 2012). It is observed that cover crops amend soil health and carbon sequestration in soil (Motta *et al*. 2007; Weil and Kremen 2007; Mutegi *et al*. 2013). Cover crops eliminate the need for intensive tilling by reducing the problem of soil compaction. Thomsen and Christensen (2004) examined that the winter legume cover alleviates the soil compaction problem in compacted sandy loam field and may be used as a replacement to intensive tillage practice due to the formation of bio-pores. Brassica cover crops have been reported for its positive effect on soil structure and health (Williams and Weil 2004; Chen and Weil 2010). Elements of conservation tillage such as no-till and shallow till produce problems for topsoil structure and cover crops alleviate this problem by increasing biological activity in the soil and producing bio-pores (Soane *et al*. 2012). Existence of crop residues on the soil surface declines the evaporation rate (Jalota *et al*. 2006), disintegration of soil particles (Rhoton *et al*. 2002) and soil temperature variations (Alletto *et al.* 2011).

Both wheat and rice are exhaustive crops and the fertility of the soil is affected. As the organic matter content of Pakistani soils is already very low and it needs to be improved. Although the effects of tillage systems on wheat performance in RWS are well reported; however, the effects of winter cover crops on soil properties and wheat performance under varying tillage systems are not reported. Therefore, this two-year field study was designed with the hypothesis that cover crops may improve the fertility status of soil and wheat performance under conventional and conservation tillage systems.

Materials and Methods

Experimental site

This two-year field experiment was conducted at Adaptive Research Farm, Gujranwala (32.18°N, 74.19°E), Punjab, Pakistan. Physico-chemical properties of the experimental soil are given in Table 1. The weather data of both years 2017–18 are 2018–19 are given in Fig. 1.

Crop husbandry

The rice crop was sown in the first week of July by the direct-seeded method. The cover crops were sown on the 5th of October at the physiological maturity of rice crop. After the harvest of rice crop by using combine harvester, the standing cover crops and the rice crop remnants were incorporated in the field by plowing and wheat was sown. The cover crops at this stage were 1.5 months old. The treatments of cover crops were control (no cover crop), crimson clover *(Trifolium incarnatum* L.), alfalfa (*Medicago sativa* L.), hairy vetch *(Vicia villosa* Roth), sweet clover (*Melilotus officinalis* (L.) Pall.) and Egyptian clover (*Trifolium alexandrinum* L.), while the tillage methods for wheat were zero-till, conventional tillage and deep tillage. The seed of cover crops was purchased from local market of seed, Dijkot road, Faisalabad, Pakistan. Cover crops were sown using a seed rate of 9 kg ha^{-1}. The experiment was conducted following a randomized complete block design with factorial arrangement having three replications. The net plot size was 5 m × 5 m for each replication. Wheat crop was sown on 26 November and 22 November and was harvested on 15 April 13 April during first and sec crop seasons, respectively. For the zero-tillage the soil after the harvesting of rice was not disturbed and the wheat was sown by direct seeding in post rice soil with a manually operated ZT drill. For the conventional sowing method of wheat, field was cultivated four times to the depth of 8–10 inches with a cultivator followed by use of rotavator levelling. The crop was sown mechanically using happy seeder drill. In deep tillage, the soil was plowed twice by the mould board plow followed by use of rotavator. The field was then cultivated four times to the depth of 15–18 inches with a cultivator followed by levelling. Crop was then sown mechanically using happy seeder drill.

Table 1: Pre-analysis of soil in both years

Characteristics		Unit	Value	
			2017–18	2018–19
Sand		%	10	10
Silt		%	25	25
Clay		%	65	65
Textural Class		Clay		
Aggregate stability		%	21.545	22.108
Bulk density	0–15 cm	Mg m^{-3}	1.70	1.67
	15–30 cm		1.77	1.75
Porosity	0–15 cm	m^3 m^{-3}	0.360	0.365
	15–30 cm		0.342	0.344
Organic matter	0–15 cm	%	0.52	0.54
	15–30 cm		0.47	0.46
WHC	0–15 cm	m^3 m^{-3}	0.252	0.289
	15–30 cm		0.240	0.255

WHC= water holding capacity

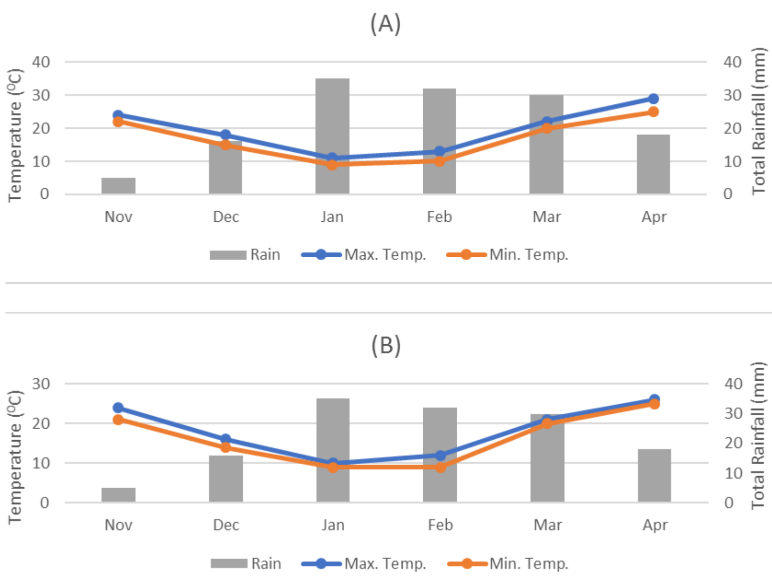

Fig. 1: Mean maximum and minimum temperature and total rainfall during the growing season of wheat at the experiment site in both years (**A**= 2017-18, **B**=2018-19)

Seed of wheat variety, procured from the Punjab Seed Corporation, was seeded at a seed rate of 125 kg ha^{-1} in all treatments. Fertilizers were applied at 85, 50 and 60 kg ha^{-1} nitrogen (N), phosphorus (P) and potassium (K) using urea (46% N), di-ammonium phosphate (DAP; 18% N, 46% N) and potassium sulphate (50% K). The total amount of P and K and half of N fertilizers were applied as basal dose at sowing while remaining half of N was applied sec irrigation. In total, three irrigations were applied to save crop from moisture stress. A selective herbicide Buctril-M (bromoxynil + MCPA) was applied for weed control (at 750 ml ha) 30 days after sowing (DAS). Wheat was harvested by using combine harvester in both years.

Data collection and soil sampling

At harvest maturity stage, tillers were counted manually from each replication from a unit area (1 m × 1 m). After tiller count, these tillers were harvested manually, and threshed. From each plot five central rows were manually harvested for grain yield and straw yield and the data were recorded by electric balance in kilograms and expressed as kg ha^{-1} after separating the grains from straw using mini thresher while the rest of crop was harvested by combine harvester. Three samples of 1000 grains were taken from each seed lot to record 1000-grain weight using electric balance. Biological yield is the sum of grain yield and straw yield.

For leaf area, healthy mature leaves were collected 60 DAS. Leaf area was taken by multiplying leaf length, width and correction factor. The correction factor to calculate the leaf area for wheat is 0.8. Leaf area index was calculated using the formula of Dwyer and Stewart (1986). Leaf area duration (LAD) and net assimilation rate (NAR) were recorded following to Hunt (1978) 60 DAS.

Table 2: Residual effect of cover crops and tillage methods on soil bulk density, water holding capacity and soil organic matter

Cover crops	2017–2018			2018–2019		
	ZT	CT	DT	ZT	CT	DT
Bulk density (mg m^{-3})						
Control	1.70a	1.61b	1.57c	1.65a	1.54b	1.53cd
Crimson clover	1.57cd	1.53f	1.50h	1.52de	1.48g	1.46ij
Alfalfa	1.52fg	1.49h	1.45i	1.45gh	1.43h-j	1.39kl
Hairy vetch	1.61b	1.54ef	1.53fg	1.57bc	1.46fg	1.47fg
Sweet clover	1.56c-e	1.55d-f	1.51gh	1.50de	1.50ef	1.46g-i
Egyptian clover	1.48h	1.44i	1.42j	1.40jk	1.39lm	1.38m
LSD value at $P \leq 0.05$	0.025			0.023		
Water holding capacity (m^3 m^{-3})						
Control	0.298ij	0.298ij	0.290j	0.309ij	0.308ij	0.301j
Crimson clover	0.308e-h	0.303f-i	0.300hi	0.315e-h	0.312f-i	0.311hi
Alfalfa	0.334a	0.321bc	0.322b	0.344a	0.330bc	0.330b
Hairy vetch	0.309e-g	0.312c-e	0.312c-e	0.315e-g	0.324c-e	0.321c-e
Sweet clover	0.302g-i	0.319b-d	0.299i	0.308g-i	0.327b-d	0.307i
Egyptian clover	0.320b-d	0.313b-e	0.312d-f	0.331b-d	0.325b-e	0.323d-f
LSD value at $P \leq 0.05$	8.83			8.81		
Organic matter (%)						
Control	0.51hi	0.47j	0.41k	0.55hi	0.50j	0.44k
Crimson clover	0.63b	0.56d-f	0.52hi	0.69b	0.61d-f	0.57hi
Alfalfa	0.59cd	0.54f-g	0.50i	0.66cd	0.58f-h	0.54i
Hairy vetch	0.55e-g	0.50i	0.47j	0.60e-g	0.54i	0.52j
Sweet clover	0.57de	0.52hi	0.47j	0.63de	0.57hi	0.53j
Egyptian clover	0.71a	0.61bc	0.53gh	0.74a	0.66bc	0.58gh
LSD value at $P \leq 0.05$	0.027			0.026		

Means sharing the same letters, within rows and columns for each trait during a year, don't differ significantly at $P \leq 0.05$
ZT= Zero tillage, CT= Conventional tillage, DT= Deep tillage

Statistical analysis

Experimental data were analyzed by analysis of variance (ANOVA) techniques using statistical software IBM SPSS v. 21. Before applying two-way ANOVA, data were checked for normality and were found to be normally distributed. Tukey Honestly Significant Difference (HSD) test at $P \leq 0.05$ was used for mean separation (Steel *et al.* 1997).

Results

Soil properties

The tillage methods and cover crops significantly affected the soil properties (bulk density, WHC and SOM) (Table 2). The interaction of tillage methods and cover crops was also significant. All the cover crops improved the above soil properties than the control. Tillage reduced the soil bulk density compared with zero tillage. In this regard, the most reduction in bulk density was noted in the deep tillage during the both years. Minimum soil bulk density was noted in deep tillage with Egyptian clover as a cover crop during both years that was similar to conventional tillage with Egyptian clover as a cover crop during sec growing season (Table 2). The interaction of tillage methods and cover crops on WHC was significant interaction. From the cover crops, alfalfa was the most effective in improving the WHC during both years (Table 2).

For soil organic matter, zero tillage method had strong interaction with cover crops to improve it. All the cover crops showed better results except hairy clover and sweet clover which gave non-significant results. Egyptian clover was more effective in improving the organic matter. Soil organic matter was improved significantly in both years. Zero-till was better method than conventional and deep tillage method to increase the SOM in wheat for both years (Table 2).

Net assimilation rate and Leaf area duration

Net assimilation rate (NAR) and leaf area duration (LAD) were significantly improved in both the years. The interaction of tillage methods and cover crops was significant. All the tillage methods improved the NAR, but it was conventional tillage which gave better results in this regard. All the cover crops performed better than control in both the years but in the sec year sweet clover did not improve the NAR whereas alfalfa did not significantly improve the NAR during the first year in the conventional tillage compared with control (Table 3). Leaf area duration (LAD) increased significantly in both years and the highest LAD was noted in conventional tillage with Egyptian clover as a cover crop during both years that was similar to zero tillage with Egyptian clover as a cover crop during sec growing season (Table 3).

Yield and related traits

The cover crops and tillage methods significantly improved the yield parameters (tillers, grains per spike, 1000-grain

Table 3: Residual effect of cover crops and tillage methods on leaf area duration and net assimilation rate

Cover crops	2017–2018			2018–2019		
	ZT	CT	DT	ZT	CT	DT
Leaf area duration (days)						
Control	121.3j-l	120.6l	120.8kl	123.9j-l	123.4l	123.6kl
Crimson clover	123.8f-h	121.7e-g	123.7g-i	125.1f-h	125.2e-g	124.8g-i
Alfalfa	123.5cd	124.8c	122.6d-f	126.4cd	127.5c	125.8d-f
Hairy vetch	122.0i-k	124.2f-h	123.5i-k	124.3i-k	125.1f-h	124.3ijk
Sweet clover	124.7g-i	124.4de	121.7h-j	124.9g-i	126.1de	124.5h-j
Egyptian clover	125.8b	126.5a	125.3c	127.9b	129.3a	127.0c
LSD value at $P \leq 0.05$	0.79			0.84		
Net assimilation rate (g m^{-2} day^{-1})						
Control	2.59j	2.75f	2.48l	2.61j	2.78f	2.48l
Crimson clover	2.65hi	2.80e	2.54k	2.66hi	2.82e	2.56k
Alfalfa	2.86cd	3.03b	2.73fg	2.90cd	3.03b	2.75fg
Hairy vetch	2.69gh	2.87d	2.61ij	2.70gh	2.88d	2.64ij
Sweet clover	2.74fg	2.92c	2.67h	2.74fg	2.94c	2.67h
Egyptian clover	2.99b	3.22a	2.77ef	3.01b	3.25a	2.80ef
LSD value at $P \leq 0.05$	0.05			0.07		

Means sharing the same letters, within rows and columns for each trait during a year, don't differ significantly at $P \leq 0.05$
ZT= Zero tillage, CT= Conventional tillage, DT= Deep tillage

weight, grain yield and harvest index (Table 4). The interaction between cover crops and sowing methods was also significant. The conventional tillage was better to improve the yield and related parameters using Egyptian clover as cover crop in both years that was followed by the Egyptian clover (Table 4).

Economic analysis

Use of cover crops increased the total cost than control but also improved the net benefits and benefit-cost ration (BCR). The highest net benefits and BCR were recorded from wheat planted with conventional tillage using Egyptian clover as cover crop.

Discussion

Results of this two-year field study revealed that use of cover crops substantially improved the soil physical properties, SOM, soil water holding capacity and wheat yield under conventional and conservation tillage systems (Tables 2–5). Cover crops and tillage methods decreased the soil bulk density significantly. The tillage practices help to break the pan created during cropping season which increase the pore volume and ultimately reduce the soil bulk density. As the deep tillage method ploughed the soil deeply than conventional and zero tillage method so bulk density was minimum in deep tillage systems (Oquist *et al*. 2006; Jabro *et al*. 2008; Shahzad *et al.* 2016). Lowering the soil bulk density can help in water holding, deep rooting and more gaseous exchange in the soil. The soil bulk density was highest in ZT while lowest was recorded in deep tillage (Table 3). The minimum use of mechanical actions under ZT leads towards progressive densification and minimized pore volume (Du *et al*. 2010; Jemai *et al*. 2012), which improves the soil bulk density (Xu and Mermoud 2001; Thomas *et al.* 2007) due to soil compaction. Cover crops have significant interactions with all the sowing methods to reduce the soil bulk density. Alam *et al*. (2013) also claimed that adding biomass of cover crops into the soil could help to increase the available water content within soil and reduce the bulk density.

Soil organic matter was improved more in zero tillage method than deep and conventional methods. In ZT there is less soil disturbance, so the organic matter increases due to minimum disturbance and exposure to decomposer and environment. Zero-tilled soils with buildup of crop residues are enhanced in labile SOM at the surface, which has a pronounced influence on soil structure by modifying aggregation (Beare *et al*. 1994; Lu *et al*. 1998). In ZT, crop residues accumulation on surface as mulch effects water, energy and air exchange between the atmosphere and soil ecosystem (Lobell *et al*. 2006). It is difficult to improve the organic matter in conventional and deep tillage methods (Hobbs *et al.* 2008) because in conventional and deep tillage methods, the crop residues are in more access to decomposer and warm environment. Cover crops residues also play role as mulch to soil to restore more water. As the organic matter served as the porous agent and helpful in improving the soil structure so, the increased organic matter also increased the porosity and lowered the bulk density of the soil. The decrease in the bulk density helped in improving the pore spaces in the soil. The increase in the pore spaces helped to enhance the water retention ability of the soil. As there were more micro pores in the soil so there were more chances to hold the water and ultimately increase the water holding capacity.

As the cover crops and tillage practices improved the soil properties and enhanced the nutrients in the soil by adding the soil organic matter so, the agronomic parameters were also improved. As there were more nutrients than the control so the agronomic parameters improved significantly in all the treatments than the control. Residual effect of cover crops and conventional tillage was also clear in

Table 4: Residual effect of cover crops and tillage methods on 1000-grain weight, tiller count, yield and number of grains per spike in the heading

Cover crops	2017–2018			2018–2019		
	ZT	CT	DT	ZT	CT	DT
Tiller count (m^{-2})						
Control	568.0k	571.3h-j	555.3n	569.6k	572.6h-j	556.4n
Crimson clover	572.3g-i	574.3e-g	562.6m	573.7g-i	575.7e-g	565.7m
Alfalfa	577.3cd	579.3c	570.3ij	578.5cd	581.3c	572.2ij
Hairy vetch	575.0ef	575.6de	565.2l	576.6ef	577.3de	567.3l
Sweet clover	573.3f-h	574.6ef	569.3jk	575.2f-h	545.8d-f	570.8jk
Egyptian clover	581.6b	586.6a	573.6e-g	583.7b	588.7a	575.7e-g
LSD value at $P \leq 0.05$	2.25			2.26		
Number of grains per spike						
Control	43.6k	47.0h-j	31.0n	44.3j	48.0g-i	32.6l
Crimson clover	48.0g-i	50.0e-g	38.3m	49.0f-h	49.3e-g	40.3k
Alfalfa	53.0cd	55.0c	46.0ij	53.3c	56.0b	47.0hi
Hairy vetch	50.6ef	51.3ed	41.0l	51.6cd	51.3c-e	41.3k
Sweet clover	49.0f-h	50.3ef	45.0jk	50.0d-g	51.3c-e	46.0ij
Egyptian clover	57.3b	62.3a	49.3e-g	57.5b	64.0a	50.3d-f
LSD value at $P \leq 0.05$	2.25			2.27		
1000-grain weight (g)						
Control	40.7ij	42.4h	39.6j	41.5ij	43.0h	40.0j
Crimson clover	44.6fg	46.7c-e	41.9hi	45.1fg	47.6c-e	42.6hi
Alfalfa	48.2c	49.9b	45.0f	48.9c	50.5b	45.9f
Hairy vetch	41.9hi	45.4ef	43.2gh	42.6hi	46.1ef	44.0gh
Sweet clover	46.5de	47.4cd	45.3ef	47.4de	48.1cd	45.9ef
Egyptian clover	50.1b	52.3a	47.1cd	50.7b	53.2a	47.8cd
LSD value at $P \leq 0.05$	1.50			1.55		
Grain yield (kg ha^{-1})						
Control	4080.4ij	4248.4h	3968.5	4208.9ij	4376.8h	4096.9j
Crimson clover	4465.8fg	4673.2c-e	4195.7hi	4594.2fg	4801.7c-e	4324.1hi
Alfalfa	4814.9c	4982.8b	4498.7f	4943.3c	5111.3b	4627.1f
Hairy vetch	4195.7hi	4538.2ef	4327.5gh	4324.1hi	4666.7ef	4455.9gh
Sweet clover	4650.2de	4739.1cd	4534.9ef	4778.6de	4867.5cd	4663.4ef
Egyptian clover	5009.2b	5219.9a	4706.2cd	5137.6b	5348.4a	4834.6cd
LSD value at $P \leq 0.05$	148.76			148.84		

Means sharing the same letters, within rows and columns for each trait during a year, don't differ significantly at $P \leq 0.05$
ZT= Zero tillage, CT= Conventional tillage, DT= Deep tillage

Table 5: Economic analysis of wheat production by using cover crops

Treatments	Total cost (US$ ha^{-1})			Gross income (US$ ha^{-1})			Net benefits (US$ ha^{-1})			Benefit-cost ratio		
	ZT	CT	DT	ZT	CT	DT	ZT	CT	DT	ZT	CT	DT
2017–18												
Control	308.7	310.4	310.4	834.5	840.1	825.5	525.8	529.7	515.1	2.70	2.70	2.65
Crimson clover	310.5	311.9	311.9	928.1	935.7	923.3	617.6	623.8	611.4	2.98	3.00	2.96
Alfalfa	311.9	313.6	313.6	955.8	965.4	948.4	643.9	651.8	634.8	3.06	3.07	3.02
Hairy vetch	311.6	312.3	312.3	912.3	920.6	904.7	600.7	608.3	592.4	2.92	2.94	2.89
Sweet clover	310.1	311.7	311.7	916.7	925.3	910.2	606.6	613.6	598.5	2.95	2.96	2.92
Egyptian clover	311.4	313.3	313.3	974.6	980.6	967.9	663.2	667.3	654.6	3.12	3.12	3.08
2018–19												
Control	308.2	310.4	310.4	835.9	840.3	828.6	527.7	529.9	518.2	2.71	2.70	2.66
Crimson clover	309.6	311.7	311.3	931.7	937.2	928.1	622.1	625.5	616.8	3.00	3.01	2.98
Alfalfa	311.2	313.5	312.9	960.2	970.6	957.4	649.0	657.1	644.5	3.08	3.09	3.05
Hairy vetch	311.1	312.3	312.1	919.3	918.2	907.6	608.2	605.9	595.5	2.95	2.94	2.90
Sweet clover	309.3	311.7	311.4	914.8	922.4	911.8	605.5	610.7	600.4	2.95	2.95	2.92
Egyptian clover	310.8	313.0	312.7	977.2	984.3	975.7	666.4	671.3	663.0	3.14	3.14	3.12

ZT= Zero tillage, CT= Conventional tillage, DT= Deep tillage, 1 US$= 160.6 PKR

improving the LAD, LAI, NAR and wheat yield (Vazin *et al*. 2010; Haider *et al.* 2016). The residual effect of cover crops helped to increase the LAD and NAR for the crop so there was increase in the growth of main crop than the weed (Uchino *et al*. 2012). The cover crops and tillage methods also improved the grain weight and yield (Table 5). The cover crops residues served as mulch and helped in water retention and to increase the yield because mulching is a viable management practice for improving crop yield and water (Jabran *et al.* 2016).

Profitability principally depends upon the input cost involved and the economic yield. Increase in the profitability is the single most important factor, which may attract the growers to adopt the conservation tillage systems.

The maximum net benefits, benefit–cost ratio and highest method productivity were obtained in conventional tillage using Egyptian clover as cover crop followed by alfalfa as cover crop in conventional tillage. The improved profitability in wheat may be due to better grain yield (Table 5) and less input cost, which resulted in more profit margins (Farooq and Nawaz 2014).

Conclusion

Tillage systems and cover crops had significant effect on wheat productivity due to their noteworthy impact on soil physical properties and organic matter. Conventional tillage along with Egyptian clover as cover crop help to improve the organic matter, moisture level and to reduce the crust pan which ultimately help wheat crop to grow well leading to its higher productivity and net returns.

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