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Research Article

Impact of Tillage Systems Equipped with Row Cleaners on Some Selected Soil Physical Properties under Wheat Cropping

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ABSTRACT

Availability of improved tillage and herbicides during the last decades has enhanced the acceptance of conservation tillage. The main constrain to this type of tillage, particularly, zero tillage is high level of crop residue, which reduces seeding quality, soil temperature, etc. Accordingly, a study was initiated by equipping row cleaners with no-till system under wheat cultivation. For this purpose, a field experiment was laid in a split-split plot design with three types of row cleaners, three sub-treatments of travelling speed, and two sub-sub treatments of tillage depth. The results indicated that the soil temperature was highly affected by percent of residue left. Measurement of penetration resistance indicated that hard pan was not a potential limiting factor for the crop root development. The soil water was increased by 8.83%, 15.33% and 12.54% under no-till without row cleaner (M1), no-till with narrow row cleaner (M2) and no-till with wide row cleaner (M3) respectively compared to that under conventional tillage (CT). The percentage of soil loss reduction under M1, M2 and M3 were 53.11%, 59.62% and 50.51% compared to that under CT. The water losses were also reduced by 46.19%, 48.65% and 46.86% under these treatments as compared with CT.

RESEARCH ARTICLE

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- No-till,
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INTRODUCTION

Many problems arise from continuous conventional tillage practices worldwide. The severe soil disturbance under such tillage system can leave the surface soil subjected to wind and water erosion (Idowu *et al.,* 2019). Reicosky (2015) indicated that the main objectives of conservation tillage are soil protection from water and wind erosion through maintaining the surface residue cover and enhancing water infiltration into the soil. Conservation tillage like strip tillage can reduces soil erosion because most of the soil remains covered with plant residue throughout the year (NDSU, 2017). Unger *et al.* (1997) indicated that surface cover can provide more time for water infiltration into the soil and can reduce soil particle transport via retarding water flow through the mulched surface. Siemens and Wilkins (2006) reported that the employment of conservation tillage systems like no-till can maintain more than 30% of crop residue cover on the soil surface and lessen soil erosion by 90%.

Conversely, leaving the crop residue of the soil surface can reduce the sowing quality or complicating sowing operations through blockage of furrowing and seeding devices, reducing soil temperature and consequently interfere with the rate and time of seed emergence (Wang et al., 2018). Younis *et al.* (2020b) used the modification of row cleaner for zero tillage planter to clean the seeding row from the residue by adding a half-cylindrical plate to cover the stem of furrow openers. Tahir (2020) noted that the traction power increased with depth and travelling speed. It was also revealed that when the seed opener is ridden over the crop residues, the seed germination is delayed and thereby causes early plant growth depression. In light of the above findings, some degree of soil disturbance or removing plant residues is required to enhance crop production. Kaspar and Erbach (1998) revealed that use of row cleaner attachment gave rise to a higher rate of seed emergence and larger emerged corn population on account of the fact that residue removal did not interfere with planter efficiency in no–till and encouraged soil warming. Therefore, it was suggested to remove crop residues to achieve higher crop yield (Siemens *et al.*, 2004). Karuma *et al.* (2012) indicated that the success of any tillage system is directly related to the enhancement of the soil physical properties, which may affect finally crop growth and yield on account of various created soil conditions. The surface soil layers may become more compacted under zero tillage compared to that under conventional tillage (Ehlers *et al.*, 1983). Atwell (1993) reported that there is an inverse relation between root growth and penetration resistance and this relationship can be described by linear, inverse or exponential functions. Penetration resistance beyond 2000 kPa leads to a significant reduction in root growth. Younis *et al.* (2020a) demonstrated that row cleaners were introduced to push the crop residues away from the seeding rows in front of row crop planter. They observed no negative effect of zero-tillage seeder with the modification and can be effectively used under rainfed farming. Accordingly, this study was initiated to examine the performance of two types of newly designed row cleaners through using residue concentration and some selected soil physical properties under wheat cropping as indicators.

MATERIALS AND METHODS

Site Description and Experimental Setup

The experiment was conducted at the Girdarasha experimental site of the College of Agricultural Engineering Sciences/University of Salahaddin (N 360 06' 48.9", E 440 00' 45.0" and at a mean altitude of 412 m amsl), Erbil, Iraq during the growing season of 2016-2017. It was conducted on a silty clay loam (%clay =37.78; %silt =52.37, %sand=9.85, EC_e = 0.51 dSm^{-1} and pH = 7.94). A Mediterranean climate dominates in the study area, giving rise to a cold and rainy winter, hot and dry summers. Mean annual temperature amounts to about 20°C with a maximum in July (44°C) and a minimum in January (5°C). A parcel of land previously cropped with wheat was selected and divided into three blocks of 55 m x 60 m. Each block with subdivided into

18 plots (2.11 m x 60 m). The experiment was laid in a split-split plot design with three types of row cleaners, three sub-treatments of travelling speed and two sub-sub treatments of tillage depth. The factors levels were:

1) Type of row cleaner: M1= seeder without row cleaner, M2 = seeder with narrow row cleaner (diameter = 7 cm and height =15 cm) and M3 = seeder with wide row cleaner (diameter = 9 cm and height =15 cm).
2) Travelling speed: S1= 8 km h^{-1}, S2 = 9 km h^{-1} and S3 = 11 km h^{-1}
3) Seeding depth: D1 = 4-5 cm and D2 = 6-7 cm

measurements were also done on a piece of land under conventional cultivation.

Measured Soil Properties

The studied soil characteristics encompassed soil temperature, penetration resistance, undrained shear strength, moisture content and soil and water losses. The obtained data were subjected to analysis of variance using SAS software ver.2009.

Soil Temperature Measurement

Soil thermometers Model Reotemp G (1 11" Dial) were also setup at a depth of about 8 cm below the soil surface to test the effect of different soil treatments on soil temperature (Wall and Stobbe, 1984) at 9:00 Am and 3:00 PM. Soil temperature was measured at three points along the seeding rows under each treatment during each day of the first month of growth, November, 2016.

Soil Penetration Resistance

The soil penetration resistance was measured at least 3 points selected at random along the seeding rows of each experimental unit with the proctor penetrometer Model 33-T0165 prior to applying the treatments (Preplaning stage) on November 4th, 2017 by following the procedure outlined by Davidson (1965). The depth of measurement was 0-60 cm. Representative soil samples were taken from the area surrounding the point of measurement for soil moisture determination. The obtained sample were kept in air tight bags and brought to the laboratory. The soil moisture was determined following gravimetric method by drying in an oven at 105-110°C for a period of 24 hours.

The penetrometer was pushed into the soil steadily until it penetrated 75 mm during 5 seconds and the maximum reading on the penetrometer was recorded in kg. The penetrometer reading at each point in kg was multiplied by the reciprocal of the end area of the penetrometer needle to obtain the soil penetration resistance in kPa. The abovementioned procedure was repeated directly after applying the treatments at a rate of five readings per each replicate of the combination treatments at planting, midseason and after harvest (Post harvest).

The Vane Shear Strength

The same procedure that has been used for measuring the penetration resistance was used for measuring the soil shear strength except that the proctor spectrometer was replaced by the vane instrument, Model G-128-26-3346. The vane shear test (ASTM D-2573-72) was performed by the test consists of forcing a vane with four orthogonal blades into the soil carefully pushing a vane with four orthogonal blades into the soil surface into a depth of 7.5 cm. A torque was then applied gradually, and the peak value was noted with the aid of a non-return type pointer retains the test reading. The dimensions of the vane were 20 mm in width by 40 mm in height. The soil shear strength was calculated by applying the following equation (Cernica, 1995):

$$\tau = \frac{\mathbf{T}}{\pi\left(\frac{\mathbf{D^2 h}}{\mathbf{2}} + \frac{\mathbf{D^3}}{\mathbf{6}}\right)} \quad (1)$$

τ = soil shear strength
T = the maximum applied torque (N m)
D = the diameter of the vane (blade) (m).
H = vane height(m).

Soil Water Content Measurement

Soil moisture condition was also monitored under the applied treatments during the growing season (measured at three dates after planting) at Girdarasha location. Soil samples were taken from 0.20 m to 0.60 m depths of the soil (0.00 - 0.20, 0.20 - 0.40, and 0.40-0.60 m) using a small manual auger with about 5 cm in diameter after the termination of each storm in a time interval of 24 hours (Tahir, 2020). The samples were kept in air-tight moisture tins after sampling and brought to the laboratory for soil moisture determination. The samples were oven-dried at 105-110°C for 24 hours. The auger holes were plugged with the same soil after each sampling. The soil moisture content was expressed on mass basis.

Measurement of Soil and Water Losses

Soil and water losses were estimated by implementing a separate experiment via establishing 8 runoff plots at Girdarasha site during the rainy season of 2016 -2017, each with dimensions of 2 m x 6 m down the slope. Each plot was bounded at the sides and top by plastic sheets of 3 m x 0.2 m, driven into the soil to a depth of around 0.1 m. At the lower end, a runoff collector system was placed, consisting of a trough to receive the eroded material from the plot, which was connected by a PVC pipe to a collection barrels located at the end of the plot, with 220 L. The barrel was covered and thus was protected against evaporation and rainfall.

The runoff plots were representing 4 treatments with two replicates in a separate experiment during the same season under wheat cropping.

The height of water in the tanks were measured and converted to liters by means of a calibration curve between height and volume of suspension in the tanks (Al-Banna *et al.*, 1986). Following runoff volume measurement, the volume of collected runoff water was reduced by siphoning the relatively clear water. Thereafter, the remaining suspension (runoff and sediments) were transferred to metal containers and oven dried to determine the weight of sediment load.

RESULTS AND DISCUSSION

Soil Temperature

The measurement of soil temperature at a depth of about 8 cm below the soil surface signified that the average soil temperatures along the seed row during the first month of plant growth ranged from a minimum of 8.60°C for the treatment combination of M1S2D2 to a maximum of 11.42°C for the treatment combination of M2S3D1 (Table 1).

Table 1. Some selected variables as influenced by different treatments at Girdarasha site during the growing season of 2016-2017.

Row cleaner type	Travelling speed	Tillage depth	Response variables		
			Residue cover ($g\ m^{-1}$)	Soil temperature (°C)	Yield ($t\ ha^{-1}$)
M1	S1	D1	30.37	10.65	1243.66
	S1	D2	19.43	11.16	2018.30
	S2	D1	48.53	8.90	2237.46
	S2	D2	60.73	8.60	1293.77
	S3	D1	46.67	9.90	1477.57
	S3	D2	57.26	8.82	1412.14
M2	S1	D1	23.23	10.98	1958.41
	S1	D2	19.33	10.82	1284.87
	S2	D1	19.27	11.16	1235.24
	S2	D2	20.00	11.13	1122.54
	S3	D1	16.67	11.42	2422.38
	S3	D2	21.83	11.24	2406.61
M3	S1	D1	25.70	11.13	1616.19
	S1	D2	25.90	10.86	1353.44
	S2	D1	20.70	11.10	1549.86
	S2	D2	23.89	10.95	1542.54
	S3	D1	29.67	9.82	969.80
	S3	D2	22.56	11.01	2569.21

The no-till system equipped with (M2) offered the highest soil temperature during the first month of growth followed by the no-till system equipped (M3). The order of effectiveness of the applied treatment on increasing the soil temperature was:
M2 > M3 > M1

The soil temperature under M2 was 1.46°C higher than the no-till system with M1, while that under the M3 was 1.14°C higher than that under M1. These findings support the work of Shen *et al.* (2018), who observed that tillage had significant effects on soil temperature in 10 of 15 weekly periods. Weekly average no-till soil temperature was 0–1.5°C lower than moldboard plowing. By contrast, (Siemens *et al.*, 2007) reported that a soil temperature difference of 0.5°C did not cause a difference in the emergence rates of corn seedling.

The warmer soil temperature during the first month after planting may explain more vigorous plant growth and greater crop yield under no-till with row cleaner attachment. As can be seen in Figure 1, there is a positive relationship between soil temperature during the early stage of growth and wheat yield. The variation in soil temperature explained only 6% of variation in wheat yield. It appears from these findings that the crop yield was affected by a host of factors besides the effect of soil temperature on the rate of seed emergence during the early stage of growth.

Higher soil temperature differences are expected under these two treatments at a depth of less than 8 cm due to a decreased dumping effect with a decrease in soil depth.

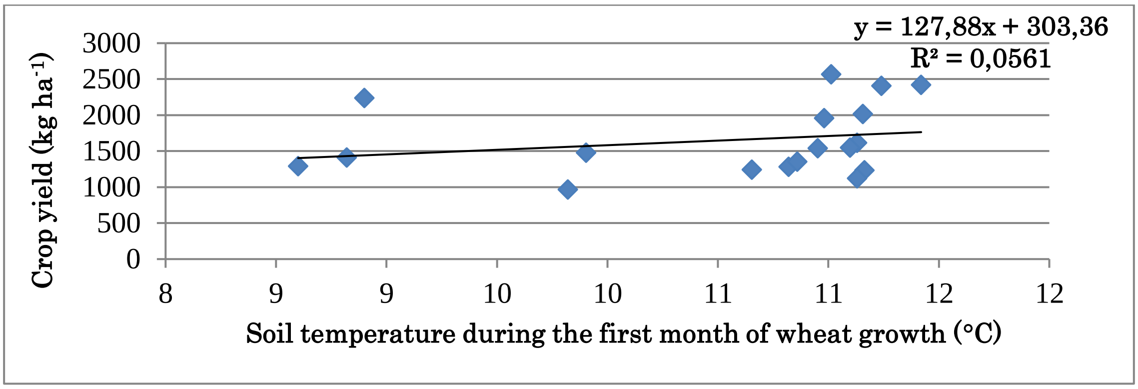

Figure 1. Wheat yield as influenced by the average soil temperature measured during the first month of wheat growth.

The results also revealed that the soil temperature was slightly and insignificantly affected by depth of seeding and travelling speed at $p \leq 0.05$). By contrast, it was noticed that the soil temperature was highly affected by percent of residue left on the soil surface. The lower the percent of residue left; the higher will be the soil temperature (Figure 2). More than 91% of variation in soil temperature at a depth of 8 cm below the soil surface can be explained on the basis of variation in percent of residue left on the soil surface after seeding. Additionally, the linear regression analysis pinpointed that the linear model slightly under predicted the soil temperature (Mean biased error, MBE = 0.008). The mean absolute percentage error of the linear model was 6.93%. On the other hand, the RMSE was 0.263. Judging from these performance indicators, it can be concluded that the soil temperature can be predicted with a reasonable accuracy from percent of residues left.

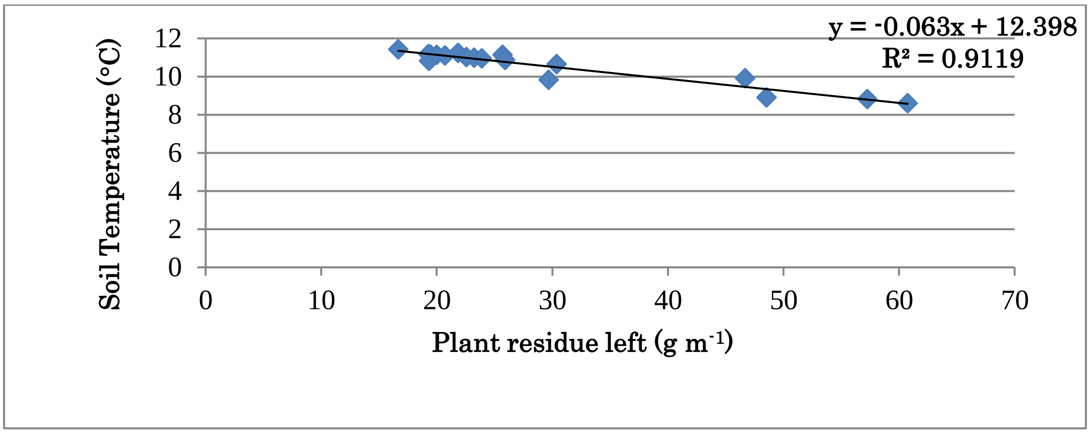

Figure 2. Soil temperature measured at a depth of 8 cm as influenced by quantity of residue left.

Soil Penetration Resistance (SPR)

Table 2 displays the soil penetration resistance measured at different depths under various treatments during the growing season of 2016/2017. The results indicated that it varied from as low as 895 kPa under the treatment combination of M2S2D1 at a depth increment of 0.0-0.1 m immediately after planting to a maximum of 22331 kPa under the treatment combination of M1S3D1 during the mid-growing season at a depth increment of 0.20-0.30 m. Overall this parameter was characterized by a high coefficient of variation ranging from about 26 to about 47%.

Table 2. Penetration resistance at different depths under different treatments measured immediately after seeding and at mid-season of in 2016/2017.

Main treatment	Sub treatment	Sub sub treatment	Penetration Resistance (kPa)					
			After seeding immediately			Mid-season		
			0-10 cm	10 -20 cm	20 -30 cm	0-10 cm	10 -20 cm	20 -30 cm
M1	S1	D1	1202	1550	1665	1450	1950	2015
	S1	D2	1288	1648	1778	1494	2028	2087
	S2	D1	1059	1391	1551	1229	1751	1806
	S2	D2	1269	1608	1762	1530	2008	2078
	S3	D1	1401	1761	1940	1690	2173	2231
	S3	D2	1257	1578	1734	1490	2001	2046
M2	S1	D1	1212	1545	1666	1421	1924	1990
	S1	D2	976	1296	1441	1263	1741	1802
	S2	D1	895	1175	1362	1109	1565	1632
	S2	D2	1013	1283	1405	1192	1679	1753
	S3	D1	988	1248	1449	1144	1659	1739
	S3	D2	1186	1488	1655	1332	1864	1913
M3	S1	D1	1166	1475	1660	1423	1920	1985
	S1	D2	1147	1467	1616	1422	1890	1976
	S2	D1	1005	1302	1514	1184	1706	1755
	S2	D2	933	1231	1400	1112	1626	1682
	S3	D1	1095	1398	1543	1308	1795	1868
	S3	D2	1254	1590	1804	1489	1996	2045

Overall, the average values of this parameter were 1680, 1445, 1522 kPa under M1, M2 and M3 respectively. It is apparent from the presented results that the no-till with a narrow row cleaner attachment (M2) resulted in a less compacted or soft soil, followed by M3 and M1 (Figure 3). The percents of the reduction under M2 and M3 were about 14.01% and 9.43% respectively compared to that under M1. It is commendable to refer that these differences were significant at ($p \leq 0.05$). The immediately after planting and midseason SPR measured in 2017 showed that the no-till treatment had significantly ($p \leq 0.05$). higher SPR compared to conventional tillage at all depths of measurement (1680 versus 1351 kPa). One can infer that no-till adversely affected the mean soil penetration resistance. This effect was not evident by the greater crop yield under no-till compared to that under conventional tillage.

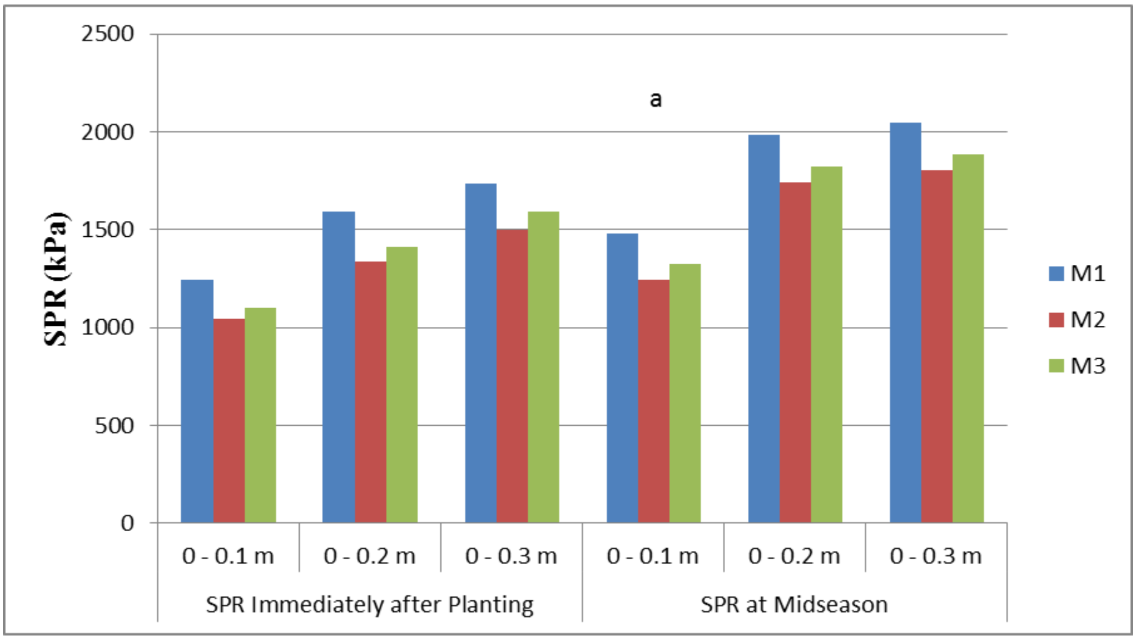

Figure 3. Soil penetration resistance as affected by different treatments during the growing season.of.2016/2017.

It is also interesting to note that no considerable differences were found between different treatments under no till system including travel speed and tillage depth in terms of soil strength (Figures 4 and 5).

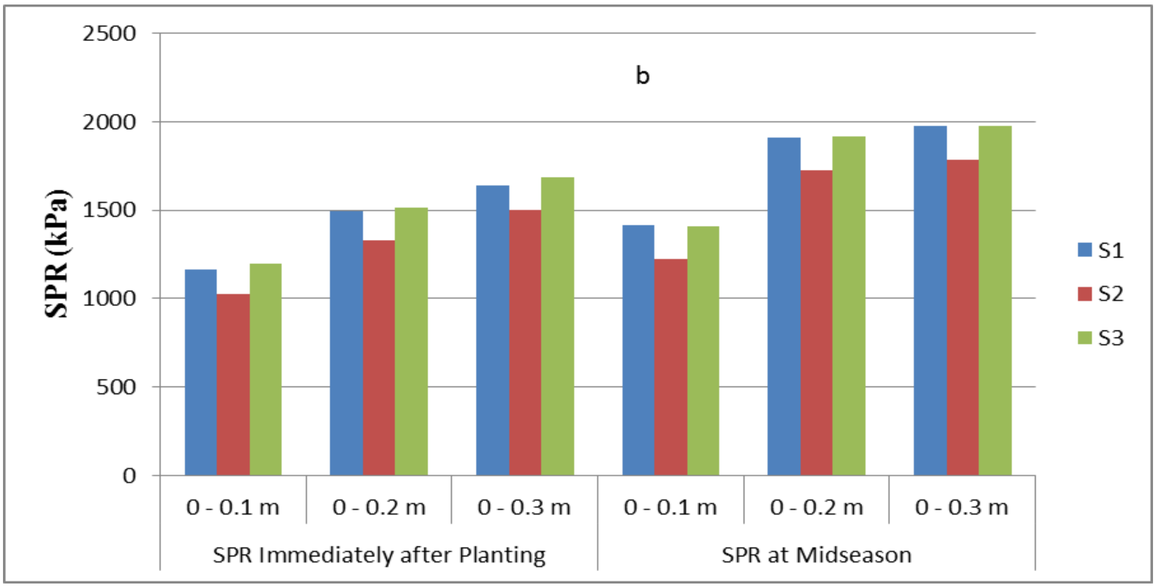

Figure 4. Soil penetration resistance as affected by different treatment during the growing season of 2016/2017.

It is obvious from the presented results that there was a substantial increase in SPR with time during the growing season. The immediately after planting readings had 18% lower than the measured values during the midseason (1395 vs. 1703 kPa). It is noteworthy that the SPR reading was not obtained at harvest on account of the very high resistance offered by the soil to the penetrating probe. The relatively high SPR during the midseason and very high resistance at harvest may mainly be due to lower soil moisture content compared to that during the early stage of plant growth.

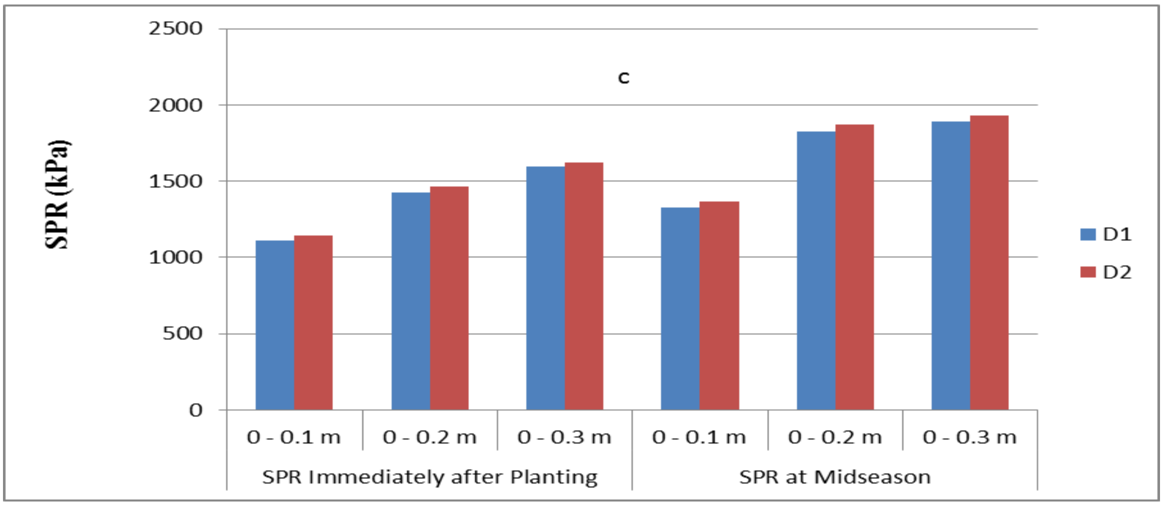

Figure 5. Soil penetration resistance as affected by different treatment during the growing season of 2016/2017.

Close examination of the results also revealed that the SPR tended to increase with an increase in depth of measurement. The results also indicated that 76% of the observation values were below 1800 kPa. This value of soil penetration resistance is considered an agronomical threshold value (Ehlers *et al.*, 1983). Hence, hard pan was not a potential limiting factor for the crop root development under the prevailing soil conditions during the growing season. The hard pan becomes a potential limiting factor as the soil dries (Francis *et al.*, 1987). This critical value can be different depending on the soil type and can be lower or higher than the 2500 kPa (Simmons, 1992). Further assessment, over a longer period of time, will be needed to confirm the long term of the study treatments on the values of this parameter.

Vane Shear Strength

Table 3 displays the measured undrained soil shear strength at depth of about 8 cm below the soil surface under different treatment combinations after planting using a vane shear test. It can be noticed that the treatment combination M2S1D1 offered the lowest value of nine kPa (Table 3). By contrast, the treatment combination M3S3D2 offered the highest un-drained soil shear strength of 12.67 kPa and those of the remaining treatments fell between these two extremes (Table 3). Similar to penetration resistance, the vane shear strength exhibited relatively a high coefficient of variation. The coefficient of variation ranged from as low as 24.39% under MSD to as high as 52.48% under MSD. As a whole, the measured shear strength was lower compared to those found in the literature. For instance, Stavi *et al.* (2011) observed that the vane shear strength under no-tillage and occasional tillages were 173.6 and 171.0 kPa respectively.

Table 3. Soil shear strength as influenced by different treatments at Girdarasha site during the growing season of 2016-2017.

Main treatments	Sub treatments	Sub sub treatments	Shear Strength (kPa)	
			Average value	Coefficient of variation (%)
M1	S1	D1	9.67	30.45
	S1	D2	11.83	44.85
	S2	D1	9.33	32.97
	S2	D2	11.17	35.56
	S3	D1	10.33	41.81
	S3	D2	10.33	46.48
M2	S1	D1	9.00	39.75
	S1	D2	10.83	52.68
	S2	D1	11.00	34.50
	S2	D2	11.00	24.39
	S3	D1	11.33	31.40
	S3	D2	10.83	42.27
M3	S1	D1	10.67	32.30
	S1	D2	12.00	35.36
	S2	D1	10.50	30.57
	S2	D2	10.17	30.10
	S3	D1	10.33	34.98
	S3	D2	12.67	24.80

Soil Moisture Conservation

Calculation of soil moisture to a depth of 60 cm showed that the no-till treatment irrespective of the attached row cleaner type offered higher soil moisture content compared with that under conventional tillage (Figure 6). The use of no-till resulted in maintaining most of the residues on the soil surface. Maintaining crop residues on the soil surface shades the soil, decreases soil evaporation, slow surface runoff and increases water infiltration. Thus, it simultaneously converses with soil water (Hedhbi *et al.*, 2005). The benefits of no-tillage with respect to improved soil water content have been well documented by (Ritchie and Nesmith, 1991).

The trend of the effect of tillage system on conserving soil moisture was:

No-till with a narrow row cleaner attachment (M2) > No-till with a wide row cleaner attachment (M3) > No-till without a row cleaner attachment (M1) > Conventional tillage (CT).

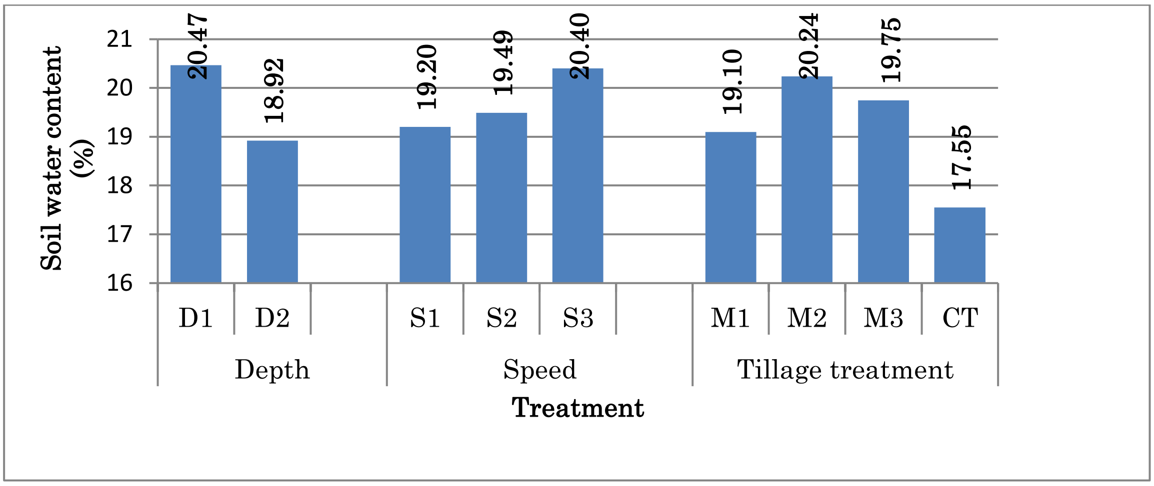

Figure 6. Soil water content of the upper 60 cm of the soil as influenced by different treatments at Girdarasha site during the growing season of 2016-2017.

The conserved soil water was increased by 8.83%, 15.33% and 12.54% under M1, M2 and M3 respectively as compared to that under CT. These differences were significant at the 5% probability level. It is worthy to note that the percent of increase in wheat yield was in concord with the percent of yield under these treatments. The results indicated that the percents of increase in yield were 34.48%, 44.86%, and 33.35% under M1, M2 and M3 respectively as compared to that under CT. The profound effect of no-till on the crop yield can be attributed to limited precipitation in the area, particularly during the year of the experiment. The benefits of using no–tillage generally were greatest in years where precipitation was limited (Unger *et al.*, 1997).

The results presented in Table 4 indicate the treatment combination (M3S3D1 offered the highest soil moisture content followed by the treatment M2S3D1. Conversely, the treatment combination M1S1D2 offered the lowest soil moisture content for the upper 60 cm stratum.

Table 4. Soil water content at different depth increments as influenced by different treatments at site during the growing of 2016-2017.

Main treatments	Sub treatments	Sub sub treatments	Soil water content (%) at depth increment			Overall soil profile water content (%)
			0.0-0.2 m	0.2 -0.4 m	0.4-0.6 m	
M1	S1	D1	23.20	16.30	15.90	18.47
		D2	18.14	15.12	14.51	15.92
	S2	D1	21.50	20.30	19.60	20.47
		D2	19.97	19.58	18.69	19.41
	S3	D1	22.75	20.68	19.50	20.98
		D2	20.30	19.10	18.70	19.37
M2	S1	D1	22.80	20.70	18.50	20.67
		D2	20.90	20.50	17.80	19.73
	S2	D1	23.15	20.65	18.90	20.90
		D2	20.30	19.10	17.94	19.11
	S3	D1	23.40	21.39	19.50	21.43
		D2	22.11	19.50	17.16	19.59
M3	S1	D1	21.70	20.20	19.30	20.40
		D2	21.10	19.90	19.10	20.03
	S2	D1	21.05	18.99	18.30	19.45
		D2	19.56	17.26	15.90	17.57
	S3	D1	23.30	21.20	20.00	21.50
		D2	21.10	19.50	18.00	19.53

The finding of the current study also revealed that the first depth D1 offered a higher soil water content compared with the second depth D2. Additionally, it was noticed that there was a continuous increase in soil water content with increasing travelling speed.

Soil and Water Losses

Although the soil and water losses were not significantly affected by the type of row cleaners, the no-till with a narrow row cleaner attachment (M2) produced the least amount of soil and water losses, followed by the no-till with without row cleaner attachment (M1) and the no-till with a wide row cleaner attachment (M3) (Figure 7). Compared with the conventional tillage, the soil and water losses under all the row cleaner types were significantly lower than those under conventional tillage. The percentages of reduction in soil loss under M1, M2 and M3 were 53.11%, 59.62% and 50.51% compared to that under the conventional tillage. Higher reduction in soil occurred under no-till system compared with those reported in the literature. For instance, Unger *et al.* (1997) observed that soil losses by erosion to wind or water are reduced to about 0.25 to 0.30 of the losses from the surface without residue. On the other hand, the water losses via runoff were reduced by 46.19%, 48.65%, and 46.86% under M1, M2 and M3 respectively compared to that under the conventional tillage. No-till practice is an effective technique for maintaining ground cover and crop residues on the soil surface is one of the most effective means of controlling soil erosion (Hargrove, 1990). This implies that reduced crop productivity due to soil erosion, frequent tillage and residue removal can be eliminated by conservation agriculture (Avci, 2011).

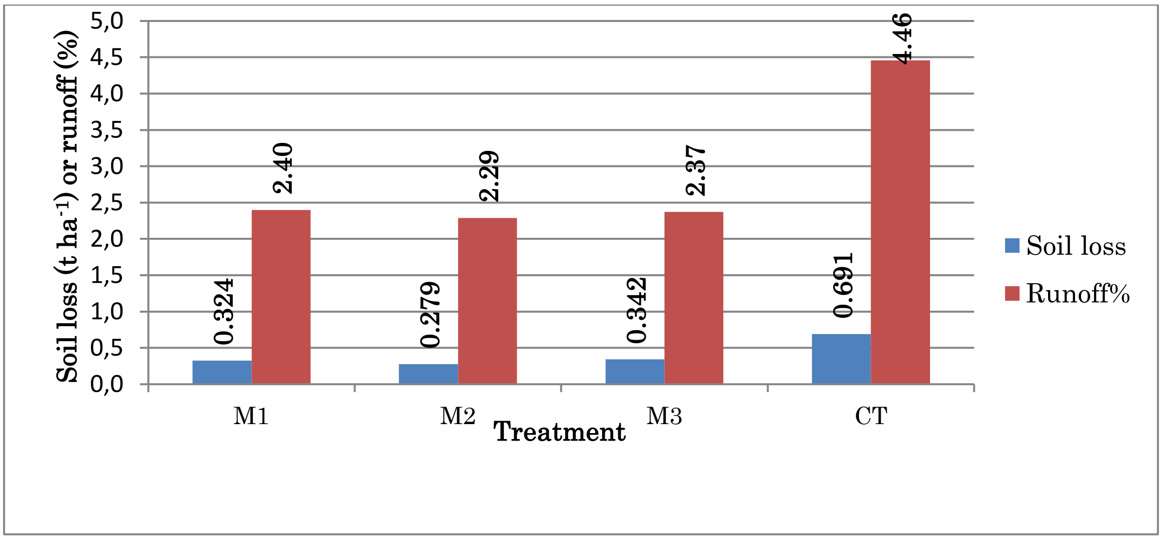

Figure 7. Annual soil loss and water loss due to runoff as influenced by different treatments during the growing season of 2016-2017.

These results are in conjunction with those reported in literature suggested maintaining residues on the soil surface under no-till are one of the simplest and surest methods of soil and water conservation. It is interesting to note that obtained results during this study reflect the combined effects of row cleaning, depth of tillage and operation speed all together. It is recommended to implement such type of experiments under different rainfall conditions for testing the performance of proposed row cleaners under plant residues with different densities.

CONCLUSION

1. The performance of each of narrow and wide row cleaners for reducing residue concentration was diminished with an increase in working speed and seeding depth.
2. The warmer soil temperature during the first month after planting under row cleaner attachment enhanced plant growth and yield under wheat cropping.
3. The wide row cleaner offered the highest performance compared with the other two types.

DECLARATION OF COMPETING INTEREST

The authors of this research article declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
Abdullah Fathi Younis: Data collation, investigation, and writing the original draft.
Tariq Hama Karim: Literature review and review of the original draft.
Hussain Thahir Tahir: Methodology, design of experiment and data analysis.

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