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Quantifying some physical properties and organic matter of soils under different management systems in cherry orchard

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Abstract

Effects of different cover crops (CCs), mechanically cultivation and herbicide treatments on soil organic matter (SOM) content and some physical properties of soils were investigated in a cherry orchard with clay soil in 2013 and 2014. The present study was conducted in a cherry orchard located at the Experiment Station of Black Sea Agricultural Research Institute in Samsun province in the Northern region of Turkey. As the CCs, Trifolium repens L. (TR), Festuca rubra subsp. Rubra (FRR), Festuca arundinacea (FA), T. repens (40%)+F. rubra rubra (30%)+F. arundinacea (30%) mixture (TFF), Vicia villosa (VV) and Trifolium meneghinianum (TM) were utilized. Experiment also included plots mechanically cultivation (MC), herbicide treatment (HC) and control (C) plot without CCs. Experiment was conducted in randomized complete blocks design with four replications. The CCs were mowed in the flowering period of the plants. After 90 d following seed harvest, soil samples were collected from two depths (0-20 and 20-40 cm) in each plot. The CCs treatments decreased bulk density, volumetric water content, relative saturation, penetration resistance and increased SOM, field capacity, permanent wilting point, available water capacity, total porosity, gravimetric water content, mean weight diameter, structural stability index. The differences in the SOM contents and physical soil properties of all treatments as compared to the control were not found to be significant for the 20-40 cm soil depth in both years of experiments. The CCs, especially TR and VV treatments as legume plants improved SOM and physical soil properties, but longer term studies are needed to evaluate the long-term effects.

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Introduction

Among major countries producing cherry in the world, Turkey ranks the first both in the northern hemisphere and in the world with 599.650 tons of production in 2017, corresponding to 20.3% of world cherry production (FAOSTAT, 2017). Cherry fruit cultivation is carried out in an area of 847.461 da in Turkey (TURKSTAT, 2018). The U.S. with 288.480 tons of production and 13.8% share and Iran with 220.393 tons of production and 11.8% follow it. Turkey is leader country in terms of volume of cherry production in the World (FAOSTAT, 2017). Owing to the temperate zone it is located in and its geographical advantages, Turkey is a country that has appropriate conditions for cherry production. Cherry production in Turkey can be seen that there has been a continuous increase in production since 2004. Proper weather conditions as well as the increase in the interest of cultivators towards cherry were influential on this increase (Anonymous, 2008). It was also understood that Turkish cherry market has been growing due to the demand from the western European countries, especially Germany. While cherry production has been increasing permanently since 1980s, Turkish cherries constitute 19 % of supplies. The most prominent competitors have been the United States, Iran, Poland, Italy, Spain, Romania and Russian Federation, with inclusion of Chile recently (Gul et al., 2016). Many soils in Turkish orchards are low in organic matter and

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nutrients, resulting in poor soil structure and nutrient deficiencies in the fruit trees (Zengin et al., 2016). This situation negatively affects the growth of trees, which is detrimental to the yield and the quality of the fruit. The use of cover crops (CCs) as a source of organic matter may be potential solution to these problems. CCs are described as crops grown primarily for the purpose of improving and protecting soil between periods of regular crop production (Schnepf and Cox, 2006). CCs have been used to improve soil quality and reduce nonpoint sources of nutrient pollution, e.g., NO3. Thus, it is significant from both an environmental and economic standpoint to indicate how cover crop systems effect soil organic matter characteristics and the biogeochemical cycling of carbon (Daliparthy et al., 1994). Spatial variability and the dependence of soil properties are controlled by inherent variations in soil characteristics (e.g., parental material, vegetation, and climate) or are affected by exogenous factors such as crop production practices (tillage, fertilization, and crop rotation) (Gülser et al., 2016). CCs provide canopy cover outside of the normal cropping season and their residues contribute to surface residues and organic matter left by the preceding crop (Reicosky and Kemper, 1995). Cropping treatments are also used to enhance SOM contents and therefore soil quality and fertility (Demir and Gülser, 2015; Demir et al., 2019; Demir and Işık, 2019b). CCs can enhance soil quality through addition of organic matter when incorporated into the soil, helping to reduce compaction and increase infiltration; thus reducing runoff and immobilizing soil nitrogen, and reducing non-point source pollution (Dabney et al., 2001). CCs have been determined to increase soil organic matter and aggregation and generally increasing cropping intensity enhances soil quality (Kabir and Koide, 2000; Fageria et al., 2005; Villamil et al., 2006). CCs also improves soil physical properties which contribute to increase soil water storage. The overall effects of CCs on soil water availability depends largely on the amount of precipitation, water infiltration, evaporation, and transpiration by the CCs (Unger and Vigil, 1998). CCs helps to increase water at field capacity (Bilek, 2007). Intensive rainfall over short periods of time can cause the soil to 'settle', thus decreasing the proportion of large pores quickly. Soil physical properties are significant factors that can determine agricultural productivity and environmental sustainability. These properties influence the water and nutrient holding capacity of the soil and they serve as indicators of soil quality. Most CCs are grown in periods when the field is left bare and they can help prime the soil for the corresponding cash crops by influencing soil physical properties (Yunusa and Newton, 2003). The inclusion of CCs can help transpire some water from the soil, and their roots may hold the soils in place. This can help nutrient loss and mitigate soil. Management practices like CCs can improve porosity, increase soil organic matter and aggregation, transpire water and increase infiltration (Joyce et al., 2002). Because of their potential ability to reduce water evaporation (Blanco-Canqui et al., 2011), increase soil organic matter and aggregation (Dabney et al., 2001) and increase porosity (Williams and Weil, 2004). In addition, CCs control soil erosion, improve soil quality and fertility, suppress weeds and provide insect control (Sarrantonio, 2008). At the same time CCs are suitable implements for weed control in orchards (Mennan et al., 2009; Işık et al., 2009). Using cover crops for weed control in cherry orchards is one of the broadly applied alternative methods to the mechanically cultivated and herbicide treatment. Herbicide application and mechanical cultivation treatment are important among the current weed control practices in cherry farming. Herbicide and mechanical cultivation treatment are expected to provide weed-free cherry fields. However, coverless (bare) cherry fields may bring about increased erosion and run-off, reduced organic matter and moisture contents, and damage the soil chemical and physical properties (Keesstra et al., 2016). In addition, a few other problems are also associated with the use of herbicides for weed control in cherry fields. Evolution of herbicide resistance in weeds and environmental pollution are the most important among these (Annett et al., 2014).

Agricultural lands of Turkey are particularly prone to erosion after the crop harvests. Severe rainstorms negatively affect physical properties of the bare soil by deteriorating aggregates and clogging macropores leading to an increased erosion risk. Choosing a crop that increases aggregate stability during the growing season is one strategy to reduce the risk for post-harvest erosion (Yakupoğlu et al., 2011). Previous studies already reported on the positive effects of plant cover and aggregate stability (Gülser, 2006; Gol and Dengiz, 2008). Thus, crop residue management is a key element of sustainable crop production. Crop residues were incorporated into cropping systems in previous studies to improve and maintain soil structure and fertility. Legume and grass species are the most significant annual and perennial forage crops in Turkey and are preferred by farms because of providing sufficient plant cover and improving the percentage of organic matter (Nyakatawa et al., 2001). Soil structure improvements associated with legume based rotations also increase the drought tolerance of soils and moisture holding capacity (Goldstein, 1989).

In this study, influences of the different cover crops, mechanically cultivation and herbicide treatments on some physical properties and organic matter content of soils were investigated in a cherry orchard with clay soil in Samsun province in the Northern region of Turkey in 2013 and 2014.

Material and Methods

The present study was conducted between 2013 and 2014 in a cherry orchard located at the Experiment Station of Black Sea Agricultural Research Institute in Samsun (Latitude, 41° 22′ 93′′ N; Longitude, 36° 50′ 19′′ E) province in the Northern region of Turkey. Annual average precipitation was 685.5 mm and annual average temperature was 14.5 °C as stated by the Turkish Republic General Directorate of Meteorology (Anonymous, 2015). There was 1 m spacing between the plots and 3 m between the blocks. Each plot had a size of 35 m2 (5 × 7 m).

Cover crop treatments (CCs)

The cover crop (CCs) treatments consisted of *Trifolium repens* L. (TR), *Festuca rubra rubra* L. (FRR), *Festuca arundinacea* (FA), *Trifolium repens* (40%) + *Festuca rubra rubra* (30%) + *Festuca arundinacea* (30%) mixture (TFF), *Vicia villosa* (VV) and *Trifolium meneghinianum* (TM). *Vicia villosa* and *Trifolium meneghinianum* are annual legume plants and *Trifolium repens* L. are perennial legume plants. *Festuca rubra rubra* L. and *Festuca arundinacea* are perennial grass cover plants. Experiments also included plots mechanically cultivation (MC), herbicide treatment (HC) and control (C) plot without CCs. *Trifolium meneghinianum* seeds were supplied from Black Sea Agricultural Research Institute and the others were purchased from private seed companies. For the aim of the experiment, the randomized complete block design was used and the experiment was carried out as four repetitions. Throughout the experiment, the CCs were continued to be applied in the same plots. During the vegetation period, no fertilizer was applied. To be able to separate the consecutive plots, buffer zones that did not include CCs were used. Before the plantation of the CCs, existing weeds were manually or mechanically removed. Irrigation was performed twice (one in July and the other in August). CCs were planted through broadcast seeding at 50, 80 and 70 kg ha^{-1} for *T.repens*, *Festuca* spp. and mixture of perennials respectively in April 2012. *V.villosa* (100 kg ha^{-1}) and *T.meneghinianum* (40 kg ha^{-1}) were sown in October 2012 and November 2013. Following the sowing, seeds were incorporated into the soil by shallow cultivation. Primary tillage was performed through chisel plow and disk harrow. The CCs were mowed at the flowering period of the plants. Mowing was carried out with a motorized back-scythe. Following mowing, incorporation of the CCs into the soil was done by disking. While mowing of the CCs was performed on 23 June 2013 during the flowering stage in the first year, it was performed on 26 June 2014 in the second year of the study. Mechanical weed control was practiced with a rotary hoeing machine. In the herbicide control plots, the glyphosate isopropylamine salt (360 g a.i L^{-1}) was implemented at a dose of 2880 ml ha^{-1} (1.39 kg a.i ha^{-1}). Glyphosate was implemented at 3 atm pressure (303.97 kPa) and 250 L ha^{-1} spraying volume with a portable hand sprayer Honda WJR 2225.

Soil sampling

Soil samples were taken from 0–20 and 20-40 cm depths in each plot 90 d after plant harvest using a corkscrew-shaped soil drill and some physical properties of soil were determined. Cover crops mowed when Festuca spp. in the flag leaf periods, others were at the beginning of the flowering periods (Işık et al., 2014; Tursun et al., 2018). Samples were sieved through 2 mm sieve and made ready for soil physical analyses. Soil physico-chemical characteristics at the beginning of the experiments were given in Table 1. Soil analyses revealed that soils in the experimental field site have a fine-textured soil (61.28% Clay, 21.37% Silt, 17.35% Sand), were neutral soil pH (7.1) and low organic matter (1.81%) contents (Soil Survey Staff, 2014).

Table 1. Soil physico-chemical characteristics at the beginning of the experiments

Properties	Soil depth (cm)	
	0-20	20-40
Texture class	C	C
Clay, %	61.28	54.04
Silt, %	21.37	30.86
Sand, %	17.35	15.10
Organic carbon (OC), %	1.05	0.74
pH	7.11	7.28
$EC_{25°C}$, mmhos cm^{-1}	0.81	0.67
Ca, me 100g^{-1}	29.1	25.2
Mg, me 100g^{-1}	10.32	8.41
K, me 100g^{-1}	1.09	0.85
Na, me 100 g^{-1}	0.17	0.15

Soil chemical analysis

Soil reaction (pH) was measured by using a pH meter with glass electrode in a 1:1 (w:v) ratio soil-water suspension (Jackson, 1958). Electrical conductivity ($EC_{25°C}$) was measured with an EC meter in a 1:1 (w:v) ratio soil-water suspension (Richards, 1954). Exchangeable cations (Ca, Mg, K, Na) were determined with the 1N ammonia acetate (NH_4OAc) extraction (Rowell, 1996). Soil organic matter was determined by the modified Walkley-Black method (Black, 1965).

Soil physical analysis

Soil particle size distribution was determined by using Bouyoucos hydrometer method (Richards, 1954). Bulk density (BD) was carried out with the cylinder method (Black, 1965). After saturating soil samples with tap water for 24 hours, soil water content at the field capacity (FC) was determined through equilibrating soil moisture for 24 hours at 33 kPa on a ceramic plate, and the permanent wilting point (PWP) was measured through equilibrating soil moisture for 96 hours at 1500 kPa on a pressure plate apparatus (Hillel, 1982). Available water content (AWC) was then calculated as the difference between FC and PWP (Hillel, 1982). Soil gravimetric moisture content (W) was determined by drying samples at 105 °C for 24 h. Volumetric water content (θ) was estimated from the following equation (Hillel, 1982);

$$\theta = W\ (g\ H_2O\ g^{-1}\ \text{soil at the sampling time})\ x\ BD\ (g\ cm^{-3}) \tag{1}$$

Then, Eq. 2 was used to calculate the total porosity (F) (Hillel, 1982):

$$F = 1 - (BD/2.65) \tag{2}$$

Volumetric water content (θ) was then divided by total porosity (F) to get relative saturation (RS). A standard cone penetrometer was used to determine soil penetration resistance (PR) at 0–20 cm depth (Bradford, 1986).

Hydrometer method and the following equation were used to determine soil structural stability index (SSI):

$$SSI = \sum b - \sum a \tag{3}$$

Where "b" is clay percantage in suspension and "a" is silt + clay percentage in mechanical analysis (Leo, 1963).

Dry sieving method (with 4.00, 3.35, 2.00, 1.40, 1.20, 1.00, 0.50, 0.425 and 0.25 mm sieves) was used to calculate mean weight diameter (MWD) (Black, 1965):

$$MVD = \sum_{i=1}^{k} W(i)\,\bar{x}i \tag{4}$$

Statistical analysis

Experimental results were subjected to statistical analyses with SPSS. Data were subjected to ANOVA and treatment means were compared with Duncan's multiple range test. Correlation analyses were performed to express the relationships between experimental parameters (Yurtsever, 2011).

Results and Discussion

Descriptive statistics for the soil organic matter (SOM) and some soil physical properties in 0-20 cm soil depth of the cherry orchard under cover crops (CCs) and other treatments are given in Table 2. Organic matter (1.84 to 3.95%), FC (38.25 to 45.53%), PWP (21.00 to 24.59%), AWC (17.17 to 20.99%), total F (55.27 to 65.01%), W (31.59 to 36.46%), ϴ (32.86 to 37.55%), RS (53.85 to 63.47%), MWD (0.84 to 1.00 mm), SSI (54.96 to 61.67%) showed variations among the treatments at 0-20 cm soil depth in the cherry orchard. While BD values varied between 0.95 and 1.14 g cm^{-3}, PR values varied between 1.94 and 2.92 MPa in 0-20 cm soil depth (Table 2).

Table 2. Descriptive statistics for the soil properties in the 0-20 cm soil depth at the end of the experiment

Soil properties	Minimum	Maximum	Mean	Std. Deviation	CV, %	Skewness	Kurtosis
SOM (soil organic matter), %	1.84	3.95	2.97	0.76	25.7	-0.411	-1.441
BD (bulk density), g cm^{-3}	0.95	1.14	1.02	0.07	6.5	0.716	-1.405
FC (field capacity), %	38.25	45.53	42.75	2.05	4.8	-0.794	-0.646
PWP (permanent wilting point), %	21.00	24.59	23.23	0.97	4.2	-0.826	-0.239
AWC (available water capacity), %	17.17	20.99	19.56	1.14	5.8	-0.765	-0.892
Total F (total porosity), %	55.27	65.01	61.34	2.76	4.5	-0.787	-0.533
W (gravimetric water content), %	31.59	36.46	34.38	1.67	4.9	-0.478	-1.378
ϴ (volumetric water content), %	32.86	37.55	34.58	1.30	3.7	0.751	-0.281
RS (relative saturation), %	53.85	63.47	57.55	3.45	6.0	0.684	-1.430
PR (penetration resistance), Mpa	1.94	2.92	2.35	0.34	14.5	0.515	-1.458
MWD (mean weight diameter), mm	0.84	1.00	0.92	0.06	6.4	-0.310	-1.541
SSI (structural stability index), %	54.96	61.67	58.73	2.26	3.9	-0.489	-1.424

Soil organic matter (SOM)

Cover crop (CCs) treatments increased soil organic matter (SOM) contents at 0-20 cm soil depth as compared to the soil of an untreated control plot (Figure 1). CCs increased SOM content from 1.95% in the herbicide treatment (HC) to 3.47% in Vicia villosa (VV) treatment in the first year of the experiments (2013). SOM contents at 0-20 cm soil depth in the second year of the experiment (2014) were ordered as; HC (1.91%) < MC (1.98%) < C (2.00%) < FA (3.18%) < TM (3.24%) < TFF (3.27%) < FRR (3.40%) < TR (3.84%) < VV (3.89%) (Figure 1). Because CCs are normally grown during fallow periods of cropping systems, the addition of CCs to a cropping system may increase total residue C inputs to soil and has the potential to increase soil organic carbon (Jarecki and Lal, 2003). Bertin et al. (2003) reported that SOM content was increased in the cover crops through root activity, i.e. exudation of low-molecular weight organic compounds. In addition, the root systems of perennials are more randomly branched and have larger diameter roots than annual. This may explain the nutrient conservative strategy of perennials and the high nutrient uptake capacities of annuals (Roumet et al., 2006). On the other hand, salt tolerance in Trifolium repens appears to be correlated with (i) a capacity to restrict and regulate the transport of these ions from the roots to the shoots, leading to lower concentrations of Na^+ and Cl^- in the shoot, and (ii) lower uptake rates of Na^+ and Cl^- per unit of root tissue (Rogers et al., 1997). Sainju et al. (2002) and Villamil et al. (2006) have determined higher organic matter content when cover crop roots decompose and when their above ground biomass is incorporated into the soil. Most studies determined that the amelioration of soil physical properties is largely based on increases of organic carbon in the soils (Gülser and Candemir, 2015). Previous studies conducted on same experimental plots with the similar treatments showed that soil organic matter increased by CCs (Wegner et al., 2015; Demir and Işık, 2020). Blanco-Canqui and Lal (2007) reported that CCs treatments also found an increase in soil organic carbon with higher residue retention rate in silt loam soil. The increase in soil organic carbon was due to the input of additional carbon in the soil surface (Stetson et al., 2012). These other studies support the present results of increasing SOM with cover crop treatments. Sainju et al. (2006) reported that soil organic carbon at 0-10 cm fluctuated with plant carbon input and was greater from the CCs (hairy vetch, rye, mixture of hairy vetch and rye) as compared to the control. Gülser (2004) reported that cropping treatments increased the SOM content from 2.28% for bare soil to 3.18% for bromegrass treatment. In this study, the greatest increases in SOM contents at 0-20 cm soil depth of cherry orchard as compared to the control were observed in VV treatment in 2014. CCs have also been reported to increase SOM compared to the bare control (Sainju et al., 2002; Villamil et al., 2006) and this can lead to improved soil aggregate formation and increased water infiltration (Joyce et al., 2002). This better soil cover and aggregation can be the difference in agricultural sustainability after a few decades.

The differences in SOM contents were not found to be significant for the 20-40 cm soil depth in both years of experiments (Figure 1). SOM contents ranged from 1.19% in HC treatment to 1.36% in VV treatment for the 20-40 cm soil depth in 2013. SOM contents ranged from 1.21% in MC treatment to 1.40% in VV treatment for the 20-40 cm soil depth in 2014.

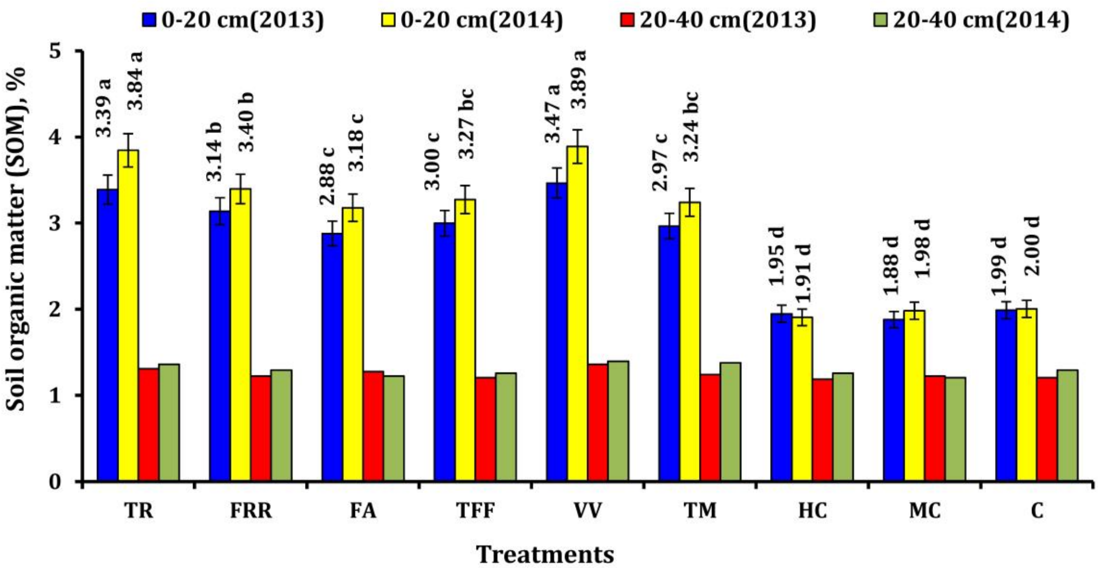

Figure 1. Effects of cover crops (CCs) and other treatments on soil organic matter (SOM) at 0-20 cm and 20-40 cm soil depths in a cherry orchard with clay soil (*Trifolium repens* L. (TR), *Festuca rubra rubra* L. (FRR), *Festuca arundinacea* (FA), *T. repens* (40%)+*F. rubra rubra* (30%)+*F. Arundinacea* (30%) mixture (TFF), *Vicia villosa* (VV), *Trifolium meneghinianum* (TM), a plot mechanically cultivated (MC), herbicide treatment (HC) and control plot (C)).

Bulk density (BD) and total porosity (F)

There were significant decreases in bulk density (BD) values (P< 0.01) and significant increases in total porosity (F) (P< 0.01) with CCs treatments at 0-20 cm soil depth when compared to values of the control (Table 3). As compared to control, the percent changes in BD and total F are provided in Table 4.

Table 3. Effects of the treatments on some soil physical properties at 0-20 cm soil depth in a cherry orchard

Treatments	BD, g cm^{-3}	FC, %**	PWP, %**	AWC, %**	Total F, %**	W, %**	Θ, %**	RS, %**	PR, Mpa**	MWD, mm**	SSI, %**
2013											
TR	0.987 b	44.2 a	23.5 a	20.6 a	62.8 a	35.2 a	34.7 ab	55.4 bc	2.09 c	0.984 a	60.23 a
FRR	1.015 b	43.3 a	23.0 ab	20.3 a	61.7 a	33.5 b	34.0 b	55.1 c	2.35 b	0.942 b	59.20 ab
FA	1.017 b	43.6 a	23.2 a	20.3 a	61.6 a	34.3 ab	34.9 ab	56.6 b	2.33 b	0.926 b	59.03 ab
TFF	1.001 b	43.9 a	23.4 a	20.5 a	62.2 a	34.1 ab	34.1 b	54.9 c	2.29 b	0.976 a	58.57 b
VV	0.988 b	44.1 a	23.5 a	20.6 a	62.7 a	35.3 a	34.9 ab	55.6 bc	2.07 c	0.979 a	60.20 a
TM	1.011 b	43.5 a	23.2 a	20.4 a	61.8 a	33.6 ab	34.0 b	54.9 c	2.28 b	0.933 b	58.67 ab
HC	1.150 a	40.0 b	21.5 c	18.5 b	56.6 b	31.0 c	35.7 a	63.0 a	2.89 a	0.835 c	55.86 c
MC	1.130 a	40.1 b	21.9 bc	18.2 b	57.4 b	31.7 c	35.8 a	62.5 a	2.80 a	0.848 c	55.89 c
C	1.124 a	40.1 b	21.8 bc	18.3 b	57.6 b	31.7 c	35.6 a	61.9 a	2.85 a	0.849 c	55.68 c
2014											
TR	0.965 b	44.5 a	24.0 a	20.5 a	63.6 a	36.1 a	34.84 b	54.8 b	2.00 d	0.988 a	60.76 a
FRR	0.982 b	43.7 a	23.6 a	20.1 a	62.9 a	35.1 bc	34.47 b	54.8 b	2.28 b	0.940 b	59.64 a
FA	0.992 b	43.9 a	23.6 a	20.3 a	62.6 a	34.6 c	34.33 b	54.9 b	2.24 b	0.933 b	60.25 a
TFF	0.982 b	44.0 a	23.8 a	20.2 a	62.9 a	35.3 bc	34.67 b	55.1 b	2.10 c	0.981 a	59.85 a
VV	0.975 b	44.3 a	23.9 a	20.4 a	63.2 a	36.2 a	35.30 b	55.8 b	1.98 d	0.986 a	60.73 a
TM	0.986 b	44.1 a	23.9 a	20.2 a	62.8 a	35.5 ab	35.02 b	55.8 b	2.14 c	0.944 b	60.11 a
HC	1.130 a	40.1 b	21.8 b	18.3 b	57.4 b	31.8 d	35.93 a	62.6 a	2.83 a	0.849 c	55.83 b
MC	1.110 a	40.5 b	22.4 b	18.0 b	58.1 b	32.5 d	36.08 a	62.1 a	2.77 a	0.847 c	55.51 b
C	1.114 a	40.1 b	22.1 b	18.0 b	58.0 b	32.3 d	35.98 a	62.1 a	2.80 a	0.844 c	55.88 b

Numbers followed by different letters, within columns, are considered to be significantly different according to Duncan's new multiple range test (**P < 0.01, *P < 0.05). (BD: bulk density, FC: field capacity, PWP: permanent wilting point, AWC: available water capacity, F: total porosity, W: gravimetric water content, Θ: volumetric water content, RS: relative saturation, PR: penetration resistance, MWD: mean weight diameter, SSI: structural stability index).

BD values at 0-20 cm soil depth in 2013 were ordered as; HC > MC > C > FA > FRR > TM > TFF > VV > TR treatments. While the highest BD was found in HC treatment (1.130 g cm^{-3}), the lowest bulk density was obtained in *Trifolium repens* (TR) treatment (0.965 g cm^{-3}) at 0-20 cm soil depth in 2014. The greatest increase in total F (9.70%) and the greatest decrease in BD (13.38%) were observed in *Trifolium repens* (TR) treatment in 2014. Troeh et al. (2003) reported that the influence of CCs on changes in BD and total F usually results from the roots of the crops. CCs have been found to decrease soil BD and increase soil macroporosity (Villamil et al., 2006; Candemir and Gülser, 2010; Blanco-Canqui et al., 2011; Demir and Işık, 2019a). These researchers explained that CCs protect the soil from compaction, as well as it increases soil organic carbon concentrations which lowered the soil BD in the subsurface depth. The hairy vetch treatment also had a lower BD, greater porosity, and greater water holding capacity than the control in the surface soil (Patrick et al., 1957). Subedi-Chalise (2017) found that those cover crop treatments reduced the BD for the 0-5 cm soil depth. Similar results were determined by the study of Moebius-Clune et al. (2008) where stover returned had 5% lower BD compared with stover harvested. Gülser (2004) reported that cropping treatments significantly reduced BD from 1.45 g cm^{-3} for control plot to 1.27 g cm^{-3} for bromegrass treatment. In addition, due to cropping effects, total F significantly increased from 45% for control plot to 52% for bromegrass treatment. The increases in total porosity were determined in the following order; control < ryegrass < alfalfa < crownvetch < small burnet < subterranean clover < bromegrass treatments. A similar finding was determined in a research conducted on silt loam with cover crop treatments which showed reduced soil compatibility by 5% (Blanco-Canqui et al., 2011). The study of Lorenz and Lal (2005) showed that if organic matter is higher in the upper surface, it can be transported to the deeper soil to promote soil micro and macro organisms. Therefore, crop residues provide food and habitat for micro and macro organisms those preserve and increase porosity in the soil. In this study, CCs treatments significantly increased total F for surface depth in both years of the experiment. While the highest total F was found in TR treatment (63.6%), the lowest total F was obtained in HC treatment (57.4%) at 0-20 cm soil depth in 2014. In the study conducted by Villamil et al. (2006), they found that the introduction of winter CCs decreased BD and therefore significantly increased total F at the soil surface. Auler et al. (2014) found that annual ryegrass used as a cover crop decreased soil BD and microporosity, but increased macroporosity and total F, which can lead to better water flow in the soil. This is similar to the findings of Lal et al. (1991), Villamil et al.

(2006), and Haruna and Nkongolo (2015). Bodner et al. (2013), in a study conducted on an arable field in Austria found that was importantly effected by the soil cover treatment was the pore radius, with cereal rye (*Secale cereal* L.) having a significantly higher average pore radius compared to no cover crop. CCs as an effective way to alleviate soil compaction due to root-induced biopores being used by the following crop to penetrate the soil (Williams and Weil, 2004). The differences in mean BD and total F values of CCs treatments were not found to be significant for the 20-40 cm soil depth in both years of the experiment. The mean BD values varied between 1.17-1.21 g cm^{-3}, the mean total F values between 54.3-55.8% in the 20-40 cm soil depth (Table 5).

Table 4. Percent (%) changes in physical soil quality variables as compared to control at the 0-20 cm soil dept

Treatments	BD	FC	PWP	AWC	Total F	W	Θ	RS	PR	MWD	SSI
					2013						
TR	-12.19	10.24	7.94	12.99	8.98	11.04	-2.49	-10.53	-26.73	15.90	8.18
FRR	-9.70	8.07	5.51	11.13	7.14	5.68	-4.57	-10.93	-17.68	10.95	6.32
FA	-9.52	8.74	6.65	11.24	7.01	8.20	-2.10	-8.51	-18.32	9.07	6.02
TFF	-10.94	9.57	7.39	12.17	8.06	7.57	-4.20	-11.35	-19.69	14.96	5.19
VV	-12.10	10.05	7.80	12.74	8.91	11.36	-2.12	-10.13	-27.41	15.31	8.13
TM	-10.05	8.59	6.24	11.40	7.40	5.99	-4.66	-11.24	-20.18	9.89	5.37
HC	2.31	-0.09	-1.33	1.40	-1.70	-2.21	0.05	1.79	1.38	-1.65	0.33
MC	0.53	0.14	0.41	-0.19	-0.39	0.00	0.53	0.93	-1.72	-0.12	0.37
					2014						
TR	-13.38	11.04	8.64	13.99	9.70	11.76	-3.18	-11.75	-28.56	17.06	8.74
FRR	-11.84	8.90	6.70	11.60	8.58	8.67	-4.19	-11.77	-18.61	11.37	6.72
FA	-10.94	9.37	6.83	12.49	7.93	7.12	-4.60	-11.61	-20.01	10.55	7.83
TFF	-11.84	9.77	7.83	12.16	8.58	9.29	-3.65	-11.27	-24.96	16.23	7.10
VV	-12.48	10.35	8.05	13.16	9.05	12.07	-1.91	-10.05	-29.25	16.82	8.68
TM	-11.45	9.92	7.92	12.38	8.31	9.91	-2.68	-10.14	-23.71	11.85	7.57
HC	1.44	-0.10	-1.49	1.61	-1.04	-1.55	-0.13	0.92	1.12	0.59	-0.09
MC	-0.36	0.90	1.54	0.13	0.26	0.62	0.26	0.00	-0.93	0.36	-0.67

TR: *Trifolium repens* L., FRR: *Festuca rubra* subsp. *rubra*, FA: *Festuca arundinacea*, TFF: *T. repens* (40%) + *F. rubra rubra* (30%) + *F. arundinacea* (30%) mixture, VV: *Vicia villosa*, TM: *Trifolium meneghinianum*, MC: Mechanically cultivated, HC: Herbicide treatment, C: Control. (BD: bulk density, FC: field capacity, PWP: permanent wilting point, AWC: available water capacity, F: total porosity, W: gravimetric water content, Θ: volumetric water content, RS: relative saturation, PR: penetration resistance, MWD: mean weight diameter, SSI: structural stability index).

Table 5. Effects of the treatments on some soil physical properties at 20-40 cm soil depth in a cherry orchard

Treatments	BD, g cm^{-3}	FC, %	PWP, %	AWC, %	Total F, %	W, %	Θ, %	RS, %	MWD, mm	SSI,%
TR	1.20	41.0	22.1	18.9	54.7	25.5	30.6	55.9	0.812	53.4
FRR	1.17	40.6	22.1	18.4	55.8	26.3	30.8	55.1	0.786	52.8
FA	1.19	40.2	22.2	18.0	55.1	26.0	30.9	56.2	0.795	53.3
TFF	1.19	40.2	22.3	17.9	55.1	26.1	31.1	56.4	0.835	52.9
VV	1.17	41.1	22.3	18.8	55.8	26.4	30.9	55.3	0.823	53.5
TM	1.18	40.5	22.3	18.2	55.5	25.6	30.2	54.5	0.796	53.7
HC	1.21	40.1	21.1	19.0	54.3	25.0	30.3	55.7	0.798	52.7
MC	1.20	40.0	21.1	18.9	54.7	25.5	30.6	55.9	0.789	52.1
C	1.19	40.1	21.6	18.5	55.1	25.3	30.1	54.6	0.801	52.3

TR: *Trifolium repens* L., FRR: *Festuca rubra* subsp. *rubra*, FA: *Festuca arundinacea*, TFF: *T. repens* (40%) + *F. rubra rubra* (30%) + *F. arundinacea* (30%) mixture, VV: *Vicia villosa*, TM: *Trifolium meneghinianum*, MC: Mechanically cultivated, HC: Herbicide treatment, C: Control. (BD: bulk density, FC: field capacity, PWP: permanent wilting point, AWC: available water capacity, F: total porosity, W: gravimetric water content, Θ: volumetric water content, RS: relative saturation, MWD: mean weight diameter, SSI: structural stability index).

Field capacity (FC), permanent wilting point (PWP) and available water content (AWC)

There were significant increases in field capacity (FC), permanent wilting point (PWP), available water capacity (AWC) ($P<0.01$) with cover crop treatments at 0-20 cm soil depth in the second year of the experiment (2014) as compared to control (Table 3). As compared to control, the percent changes in FC, PWP and AWC are provided in Table 4. Percent increases in AWC values as compared to the control treatment at 0-20 cm soil depth in 2013 varied between 11.13% in the FRR treatment and 12.99% in the TR treatment (Table 4). As compared to control, the greatest increase in FC, PWP and AWC values was respectively observed as 11.04%, 8.64% and 13.99% in TR treatment in 2014. Soil organic matter supplementation to soils improves water holding capacity (Candemir and Gülser, 2010; Demir and Gülser, 2015; Demir, 2019). Daigh et al. (2014) reported that CCs increased soil water storage by 1.9 cm compared with no cover crop plots. A similar result was found in a research conducted in Boone County, IA where long-term incorporation of CCs increased the plant available water by 21–22% and field capacity water content by 10–11% (Basche et al., 2016). Many studies showed that CCs increase soil organic matter concentration on soil and have a positive relationship with soil water storage (Rawls et al., 2003; Olson et al., 2010). A review showed that addition of CCs may improve soil water condition by improving the soil infiltration rate, reducing evaporation, and increasing soil water storage (Unger and Vigil, 1998). Similar results were observed in a study, where cover crops improved soil moisture (Obalum et al., 2011). Demir et al. (2019) found that highest rises were in the Vicia villosa Roth treatment, diminishing the BD by 12.7% while rising the AWC by 19.4%, SOM by 63.5%, and SSI by 9.4% in the 0-20 cm soil depth in the apricot orchard with clay soil. Steele et al. (2012) reported that CCs improved physical properties of soils. The differences in FC, PWP and AWC values of cover crop treatments were not found to be significant for the 20-40 cm soil depth in both years of the experiment. The mean FC values varied between 40.0-41.1%, the mean PWP values between 21.1-22.3%, the mean AWC values between 17.9-19.0% (Table 5).

Gravimetric water content (W)

There were important increases (P< 0.01) in gravimetric water content (W) with CCs treatments when compared to values of the control in both years of the experiment (Table 3). As compared to control, the percent changes in W are provided in Table 4. The greatest increases in W values at 0-20 cm depth in the cherry orchard in 2013 were observed in VV treatment (11.36%). The greatest increase in W was observed in VV treatment (12.07%) and the smallest increase in W was observed in FA treatment (7.12%) at the 0-20 cm soil depth in 2014. Data from the present study observed that in general CCs treatments have higher W compared with no cover crop treatments. Similar results were determined in another study conducted in Iowa uses of winter rye CCs increased soil water storage (Basche et al., 2016). It was observed that use of cereal rye as cover crop helped to enhance soil water in maize-soybean cropping system (Qi and Helmers, 2010). Similarly, another study conducted for 7 years by successive use of winter rye as cover crop in maize-soybean cropping system determined to be effective in enhancing soil water table and conserving soil moisture. Addition of organic matter to soils increases water holding capacity (Candemir and Gülser, 2010). CCs help to decrease evaporation from the soil surface, conserves moisture from the rainfall and irrigation, and help in soil moisture availability to the subsequent crops. CCs increased water retention in soil at water potentials related to plant available water and field capacity by 21-22% and 10-11%, respectively (Basche et al., 2016). Blanco-Canqui et al., (2011) showed that a cover crop conserved more soil water compared with a no cover crop treatment. These researchers found that CCs improved the field gravimetric water content and buffered soil temperature by acting as a cover, reducing sunlight penetration and water evaporation. Soil water content was greater under CCs compared to no CCs by an average of 35% at the 0-20 cm depth (Blanco-Canqui et al., 2011). The previous study found that preserving high moisture on surface depth was due to less evaporation and high soil organic matter on surface depth (VanLoocke et al., 2012). This is consistent with several researcher findings on the effect CCs has on soil physical properties (Jokela et al., 2011; Ward et al., 2012; Haruna and Nkongolo, 2015). The reason for higher W with CCs treatments may be due to that adopting cover crop protects the aggregates from breakdown and enhances soil physical properties (Stetson et al., 2012; Osborne et al., 2014; Johnson et al., 2016). The differences in W values of CCs treatments were not found to be significant for the 20-40 cm soil depth in both years of the experiment. Mean W values ranged from 25.0% in HC treatment to 26.4% in VV treatment for the 20-40 cm soil depth (Table 5).

Soil penetration resistance (PR)

The results of this study showed that there was an important effect of CCs treatments compared with no CCs treatments on soil penetration resistance (PR) (Table 3). In both years of the experiment, the PR significantly decreased with CCs treatments. Thus, CCs treatment reduced compaction. The reason behind low soil penetration resistance under CCs treatment may be due to cover crop and crop residue protect soil aggregates from the break down, protects soil from direct compaction due to raindrops (Blanco-Canqui et al., 2014). In addition, CCs reduce compaction by the accumulation of soil organic matter. Soil penetration resistance determines the soil compaction (Abdollahi et al., 2014). In this study, the greatest decrease in PR value was observed in VV treatment (-29.25Mpa) and the least decrease was observed in FRR treatment (-18.61Mpa) (Table 4). In 2013, PR value was the highest (2.89Mpa) in the HC treatment followed by HC > C > MC > FRR > FA > TFF > TM > TR > VV treatments. The highest PR value (2.83Mpa) was seen at 0-20 cm in 2014 in the HC treatment while the lowest PR value (1.98Mpa) was seen in VV treatment. The pervious study showed that soil penetration resistance is affected by soil moisture (Whalley et al., 2007). Cover crops play an important role to preserve the soil moisture. Gupta et al. (1987) explained that silt loam and clay loam soils have greater surface area, so the addition of residues will not allow physically separate mineral particles which result in friction force reduction and less compaction. Acuña and Villamil (2014) reported that similar results were obtained in a study conducted in Illinois on silty clay loam. Subedi-Chalise (2017) found that CCs reduced soil penetration resistance value by 23% compared with that under no cover crop treatment. In this study showed that CCs treatment reduced soil PR value by mean 24.2% compared with that under no cover crop treatment.

Mean weight diameter (MWD)

As compared to control, CCs treatments significantly increased the mean weight diameter (MWD) values at 0-20 cm soil depth in both years of the experiments (Table 3). CCs treatments increased MWD value from 0.835 mm in the HC treatment to 0.984 mm in TR treatment in 2013. The greatest MWD value (0.988 mm) was observed in TR treatment and least (0.844 mm) in control treatment in 2014. Changes in the MWD showed that aggregates were more resistant to physical abrasion under CCs. This study clearly shows that the legumes are the most effective plants in increasing MWD in 0-20 cm soil depth. *Trifolium repens* and *Vicia villosa* treatments as legume plant seems to perform best in increasing MWD of the 0-20 cm soil depth. This can be attributed to differences in efficiency of different species to different root densities in the upper soils. A closely related species, *Trifolium repens* has a robust root system that could provide drought resistance as compared to grass cover crops (Roumet et al., 2006). This study clearly shows that aggregate stability improvement by legume forage plants strongly depends on the plant species. Soil management with the use of CCs favored an increase in the number of macroaggregates, which can be due to the growth of these plants as they release their root exudates in the soil medium, favoring the formation and stabilization of aggregates in the A horizon, developing links among soil mineral particles (Bronick and Lal, 2005; Ferreira et al., 2007). In this study, the greatest increases in MWD values at 0-20 cm depth in the cherry orchard in both years were observed in TR treatment (15.90% in 2013 and 17.06% in 2014) (Table 4). Increasing SOM content in a clay soil by the different forage treatments increased MWD values according to the fallow control treatment (Gülser, 2006). Improved soil organic matter in a kiwifruit orchard with loamy textured soil increased MWD values (Demir and Işık, 2019a). Yakupoğlu et al (2011) reported that annual *V. lutea* L. and *Sphaericus* L. under Mediterranean climate significantly increased aggregate stability by 73% and 63%, respectively, in surface soil when compared to values of the control plot. The building of macroaggregates from microaggregates is a function of time and availability of SOM as the major binding agent (Hammerbeck et al., 2012). CCs improve soil aggregate stability (Mbah et al. 2007, Bhattacharyya et al. 2012) by contributing organic matter, which in turn contain active soil-binding agents (Liu et al., 2005; Mbah et al., 2007; So et al., 2009). The higher rates of soil aggregation may be due to the diversity of plant species with different sizes and shapes of the root system, which provided greater stability to the aggregates (Nascente et al., 2004). Patrick et al. (1957) found that after 25 yr of continuous cotton with tillage on a loam soil, 21.3% of the aggregates had diameters >0.21 mm when a hairy vetch cover crop was included in the cropping system compared with the 11.8% for a common vetch (*Vicia sativa* L.) cover crop treatment and 9.5% for a control without a cover crop. The differences in MWD values of CCs treatments were not found to be significant for the 20-40 cm soil depth in both years of the experiment. MWD values at 20-40 cm soil depth varied between 0.789-0.835 mm with a mean value of 0.804 mm (Table 5).

Structural stability index (SSI)

The highest SSI value was obtained from in TR treatment in 2013 (60.23%) and in 2014 (60.76%) (Table 3). Percent increase in the SSI values with CCs treatments as compared to control varied between 8.18 % in 2013 and 8.74% in 2014 in the TR treatment (Table 4). High root density produced by CCs provided exudates to the soil and importantly effected soil structure and enhanced microbial activity, and this also plays a fundamental role in soil aggregation (Bayer et al., 2000; Lovato et al., 2004). Souza et al. (2009) determined that the vigorous root system of forages contributed to the formation of aggregates and to enhancing soil physical properties, which could be obtained in the aggregates larger than 8 mm under the fallow, B. brizantha, B. ruziziensis and P. maximum treatments, especially at the soil depth of 0-5 cm. Gülser (2004) found that due to cropping effects, SSI values increased from 57.4% for control soil to 63.0% for the bromegrass treatment. Many studies indicated that CCs sustained a better soil structure, increased soil total F, aeration and water holding capacity and thus decreased BD (Steele et al., 2012). Similarly, Demir et al. (2019) determined that different CCs (Vicia pannonica Crantz, Vicia pannonica Crantz (70%) + Triticale (30%) mixture, *Phacelia tanacetifolia Benth*., *Vicia villosa*, and *Fagopyrum esculentum* (Moench.) increased available water capacity, total F, MWD, SSI values and significant decreases in BD values in an apricot orchard with clay soil.

The differences in SSI values of cover crop treatments were not found to be significant for the 20-40 cm soil depth in both years of the experiment. SSI values at 20-40 cm soil depth varied between 52.1-53.7% with a mean value of 53.0% (Table 5).

Relationships among the selected soil properties

The SOM had important positive correlations with AWC (0.924**), total F (0.896**), W (0.868**), MWD (0.862**), SSI (0.750**) and important negative correlations with BD (-0.954**), RS (-0.821**) and PR (-0.869**) at the 0-20 cm soil depth in a cherry orchard (Table 6). This could be because SOM directly effects on soil macroporosity and aggregation by the density of organic matter itself or through the affect of increasing the biological activity of the soil (Franzluebbers, 2002). Similar results were found by Stone and Silveira (2001) and Silveira Neto et al. (2006), who obtained that soil BD reduced through an increase in SOM in the surface layer. Significant negative correlations were observed between BD and total F (-0.873**), between BD and AWC (-0.907**), between the BD and MWD (-0.816**), total F and PR (-0.861**), W and PR (-0.950**). Gülser and Candemir (2012) reported that PR values gave significant negative correlations with F (-0.551**), W (-0.439**) and MWD (-0.509**), and significant positive correlations with BD (0.550**) and RS (0.374*). Veronese-Júnior et al. (2006) observed that reduces in soil moisture content increased PR in soil. Similarly, another study conducted by Gülser et al. (2011) spatial variability of PR values in a cultivated soil and determined that PR values had negative correlations with W. Gülser (2006) reported reduced the BD and increased total F with increasing the soil organic carbon contents. Gülser (2006) reported that MWD increased by the forage cropping treatments over the control had important negative correlations with PR and BD values. In this study, significant positive correlations were observed between BD and PR (0.948**), AWC and total F (0.963**), BD and θ (0.814**), between AWC and W (0.897**), between the AWC and MWD (0.793**). Although the W usually increased according to the control, the θ reduced due to decreasing BD by the CCs treatments. While the highest θ content (36.08%) was observed in the HC treatment, the lowest θ content (34.33%) was obtained in the FA treatment in the 0-20 cm soil depth at the end of the experiment.

Table 6. Correlation matrix among the soil properties in the 0-20 cm soil depth at the end of the experiment

	BD	FC	PWP	AWC	Total F	W	θ	RS	PR	MWD	SSI
SOM	-0.954**	0.916**	0.874**	0.924**	0.896**	0.868**	-0.702**	-0.821**	-0.869**	0.862**	0.7 50**
BD		-0.893**	-0.848**	-0.907**	-0.873**	-0.920**	0.814**	0.784**	0.948**	-0.816**	-0.833**
FC			0.782**	0.891**	0.677**	0.691**	-0.549**	-0.685**	-0.873**	0.879**	0.853**
PWP				0.963**	0.772**	0.872**	-0.455**	-0.632**	-0.844**	0.846**	0.719**
AWC					0.963**	0.897**	-0.592**	-0.897**	-0.895**	0.793**	0.765**
Total F						0.883**	-0.485**	-0.866**	-0.861**	0.866**	0.629**
W							-0.684**	-0.872**	-0.950**	0.666**	0.817**
θ								0.832**	0.747**	-0.693**	-0.666**
RS									0.925**	-0.682**	-0.718**
PR										-0.771**	-0.711**
MWD											0.810**

**correlation is significant at 0.01 level, *correlation is significant at 0.05 level. (SOM: soil organic matter, BD: bulk density, FC: field capacity, PWP: permanent wilting point, AWC: available water capacity, F: total porosity, W: gravimetric water content, θ: volumetric water content RS: relative saturation, PR: penetration resistance, MWD: mean weight diameter, SSI: structural stability index).

Conclusion

This study was conducted to investigate the effect of cover crops (CCs) soil management practices, mechanically cultivation and herbicide treatments on the organic matter and some physical properties of soil in a cherry orchard with clay soil in 2013 and 2014. SOM and soil physical properties were compared for two years at two soil depths (0-20 cm and 20-40 cm). In the present study, CCs treatments generally improved soil physical properties at 0-20 cm soil depth compared to the control. Mean SOM contents at 0-20 cm soil depth in a cherry orchard was ordered as; HC < MC < C < FA < TM < TFF < FRR < TR < VV treatments. CCs treatments in the cherry orchard with clay soil reduced PR and increased total F by decreasing bulk density and increasing SOM and MWD. Total F was one of the most significant soil properties that effected BD and PR in the clay textured soil. Soil organic matter supplementation to soils improved water holding capacity. The different CCs treatments had different effects on PR of clay soil due to changing soil structure with increasing total F and MWD. A combination of CCs also improved macroporosity. The differences in the SOM contents and physical soil properties of all treatments as compared to the control were not found to be significant for the 20-40 cm soil depth in both years of experiments. The results of this study showed that CCs treatments, especially Trifolium repens (TR) and Vicia villosa (VV) treatments as legume plants improved organic matter content and the selected physical properties of soils in the short term, but longer term studies are needed to evaluate the long-term effects.

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References

Abdollahi, L., Munkholm, L.J., Garbout, A., 2014. Tillage system and cover crop effects on soil quality: II. Pore Characteristics. *Soil Science Society of America Journal* 78(1): 271-279.

Acuña, J., Villamil, M.B., 2014. Short-term effects of cover crops and compaction on soil properties and soybean production in Illinois. *Agronomy Journal* 106(3): 860-870.

Annett, R., Habibi, H.R., Hontela, A., 2014. Impact of glyphosate and glyphosate-based herbicides on the freshwater environment. *Journal of Applied Toxicology* 34(5): 458-479.

Anonymous, 2008. Cherry production and trade in the World and Turkey. Akdeniz Exportation Associations. Research Series. Antalya, Turkey [in Turkish].

Anonymous, 2015. Turkish State, Meteorological Service [in Turkish]. Available at [Access date: 20.05.2015]: https://www.mgm.gov.tr

Auler, A.C., Miara, S., Pires, L.F., da Fonseca, A.F., Barth, G., 2014. Soil physico-hydrical properties resulting from the management in Integrated Production Systems. *Revista Ciência Agronômica* 45(5): 976–989.

Basche, A.D., Kaspar, T.C., Archontoulis, S.V., Jaynes, D.B., Sauer, T.J., Parkin, T.B., Miguez, F.E., 2016. Soil water improvements with the long-term use of a winter rye cover crop. *Agricultural Water Management* 172: 40-50.

Bayer, C., Mielniczuk, J., Amado, T.J.C., Martin-Neto, L., Fernandes, S.V., 2000. Organic matter storage in a sandy clay loam Acrisol affected by tillage and cropping systems in southern Brazil. *Soil and Tillage Research* 54: 101-109.

Bertin, C., Yan, X., Weston, L.A., 2003. The role of root exudates and allelochemicals in the rhizosphere. *Plant and Soil* 256: 67-83.

Bhattacharyya, R., Tuti, M.D., Bisht, J.K., Bhatt, J.C., Gupta, H.S., 2012. Conservation tillage and fertilization impact on soil aggregation and carbon pools in the Indian Himalayas under an irrigated rice-wheat rotation. *Soil Science* 177(3): 218–228.

Bilek, M.K., 2007. Winter annual rye cover crops in no-till grain crop rotations: ımpacts on soil physical properties and organic matter. M.S. Thesis, University of Maryland, College Park, MD (2007).

Black, C.A., 1965. Methods of soil analysis. Part 1 Physical and Mineralogical Methods including statistics of measurement and sampling, Agronomy Monograph 9.1, American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, USA.

Blanco-Canqui, H., Lal, R., 2007. Soil and crop response to harvesting corn residues for biofuel production. Geoderma 141(3-4): 355-362.

Blanco-Canqui, H., Mikha, M.M., Presley, D.R., Claassen, M.M., 2011. Addition of cover crops enhances no-till potential for improving soil physical properties. *Soil Science Society of America Journal* 75(4): 1471–1478.

Blanco-Canqui, H., Ferguson, R.B., Jin, V.L., Schmer, M.R., Wienhold, B.J., Tatarko, J., 2014. Can cover crop and manure maintain soil properties after stover removal from irrigated no-till corn? *Soil Science Society of America Journal* 78(4): 1368–1377.

Bodner, G., Scholl, P., Loiskandl, W., Kaul, H.P., 2013. Environmental and management influences on temporal variability of near saturated soil hydraulic properties. *Geoderma* 204-205: 120–129.

Bradford, J.M., 1986. Penetrability. In: Methods of soil analysis. Part 1 Physical and Mineralogical Methods. Klute, A. (Ed.). American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, USA. pp. 468–472.

Bronick, C.J., Lal, R., 2005. Soil structure and management: A review. *Geoderma* 124(1-2): 3-22.

Candemir, F., Gülser, C., 2010. Effects of different agricultural wastes on some soil quality indexes at clay and loamy sand fields. *Communications in Soil Science and Plant Analysis* 42(1): 13-28.

Dabney, S.M., Delgado, J.A., Reeves, D.W., 2001. Using winter cover crops to improve soil and water quality. *Communications in Soil Science and Plant Analysis* 32(7-8): 1221–1250.

Daigh, A.L., Helmers, M., Kladivko, E., Zhou, X., Goeken, R., Cavdini, J., Barker, D., Sawyer, J., 2014. Soil water during the drought of 2012 as affected by rye cover crops in fields in Iowa and Indiana. *Journal of Soil and Water Conservation* 69(6): 564-573.

Daliparthy, J., Herbert, S.J., Veneman, P.L.M., 1994. Dairy manure application to alfalfa: crop response, soil nitrate, and nitrate in soil water. *Agronomy Journal* 86(6): 927-933.

Demir, Z., 2019. Effects of vermicompost on soil physicochemical properties and lettuce (*Lactuca sativa* Var. *Crispa*) yield in greenhouse under different soil water regimes. *Communications in Soil Science and Plant Analysis* 50(17): 2151-2168.

Demir, Z., Gülser, C., 2015. Effects of rice husk compost application on soil quality parameters in greenhouse conditions. *Eurasian Journal of Soil Science* 4(3): 185-190.

Demir, Z., Işık, D., 2019a. Effects of cover crops on soil hydraulic properties and yield in a persimmon orchard. *Bragantia* 78(4): 596-605.

Demir, Z., Işık, D., 2019b. Effects of cover crop treatments on some soil quality parameters and yield in a kiwifruit orchard in Turkey. *Fresenius Environmental Bulletin* 28(9): 6988-6997.

Demir, Z., Tursun, N., Işık, D., 2019. Effects of different cover crops on soil quality parameters and yield in an apricot orchard. *International Journal of Agriculture and Biology* 21: 399-408.

Demir, Z., Işık, D., 2020. Using cover crops to improve soil quality and hazelnut yield. *Fresenius Environmental Bulletin* 29(4): 1974-1987.

Fageria, N.K., Baligar, V.C., Bailey, B.A., 2005. Role of cover crops in improving soil and row crop productivity. *Communications in Soil Science and Plant Analysis* 36(19-20): 2733-2757.

FAOSTAT, 2017. Food and agriculture data. The statistics division of the Food and Agriculture Organization of the United Nations (FAO): Available at [Access date: 10.06.2019]: http://faostat.fao.org/site

Ferreira, F.P., Azevedo, A.C., Dalmolin, R.S.D., Girelli, D., 2007. Organic carbon, iron oxides and aggregate distribution in two basaltic soils from Rio Grande do Sul State-Brasil. *Ciência Rural* 37(2): 381-388 [in Portuguese].

Franzluebbers, A.J., 2002. Soil organic matter stratification ratio as an indicator of soil quality. *Soil and Tillage Research* 66(2): 95-106.

Gol, C., Dengiz, O., 2008. Effect of modifying land cover and longterm agricultural practices on the soil characteristics in native forest-land. *Journal of Environmental Biology* 29: 677–682.

Goldstein, W., 1989. Thoughts on Drought Proofing Your Farm: A Biodynamic Approach. Michael Fields Agriculture Institute, Wisconsin, Madison, USA. 16p.

Gul, M., Kart, M.C.O., Yilmaz, S.G., Uzunkaya, K., 2016. Opportunities and constraints for cherry exporters in Turkey. *Custos e Agronegocio* 12(2): 156-169.

Gupta, S.C., Schneider, E.C., Larson, W.E., Hadas, A., 1987. Influence of corn residue on compression and compaction behaviour of soils. *Soil Science Society of America Journal* 51(1): 207-212.

Gülser, C., 2004. A comparison of some physical and chemical soil quality indicators influenced by different crop species. *Pakistan Journal of Biological Sciences* 7(6): 905-911.

Gülser, C., 2006. Effect of forage cropping treatments on soil structure and relationships with fractal dimensions. *Geoderma* 131(1-2): 33-44.

Gülser, C., Ekberli, I., Candemir, F., Demir, Z., 2011. İşlenmiş bir toprakta penetrasyon direncinin konumsal değişimi. Prof.Dr. Nuri Munsuz, Ulusal Toprak ve Su Sempozyumu, 25-27 Mayıs, Ankara, Turkey, p:244-250 [in Turkish].

Gülser, C., Candemir, F., 2012. Changes in penetration resistance of a clay field with organic waste applications. *Eurasian Journal of Soil Science* 1(1): 16-21.

Gülser, C., Candemir, F., 2015. Effects of agricultural wastes on the hydraulic properties of a loamy sand cropland in Turkey. *Journal of Soil Science and Plant Nutrition* 61(3): 384-391.

Gülser, C., Ekberli, I., Candemir, F., Demir, Z., 2016. Spatial variability of soil physical properties in a cultivated field. *Eurasian Journal of Soil Science* 5(3): 192–200.

Hammerbeck, A.L., Stetson, S.J., Osborne, S.L., Schumacher, T.E., Pikul, J.L., 2012. Corn residue removal impact on soil aggregates in a no-till corn/soybean rotation. *Soil Science Society of America Journal* 76(4): 1390–1398.

Haruna, S.I., Nkongolo, N.V., 2015. Effects of tillage, rotation and cover crop on the physical properties of a silt-loam soil. *International Agrophysics* 29: 137–145.

Hillel, D., 1982. Introduction to soil physics. Academic Press Inc. London, UK. 392p.

Işık, D., Kaya, E., Ngouajio, M., Mennan, H., 2009. Summer cover crops for weed management and yield improvement in organic lettuce (*Lactuca sativa*) production. Phytoparasitica 37: 193-203.

Işık, D., Dok, M., Ak, K., Macit, I., Demir, Z., Mennan, H., 2014. Use of cover crops for weed suppression in hazelnut (Corylus avellana L.) in Turkey. *Communications in Agricultural and Applied Biological Sciences* 79(2): 105-110.

Jackson, M.L., 1958. Soil Chemical Analysis, Prentice Hall Inc. Englewood Cliffs, New Jersey, USA. 498p.

Jarecki, M.K., Lal, R., 2003. Crop management for soil carbon sequestration. *Critical Reviews in Plant Sciences* 22(6): 471–502.

Johnson, J.M., Strock, J.S., Tallaksen, J.E., Reese, M., 2016. Corn stover harvest changes soil hydrology and soil aggregation. *Soil and Tillage Research* 161: 106-115.

Jokela, W., Posner, J., Hedtcke, J., Balser, T., Read, H., 2011. Midwest cropping system effects on soil properties and on a soil quality index. *Agronomy Journal* 103(5): 1552–1562.

Joyce, B.A., Wallender, W.W., Mitchell, J.P., Huyck, L.M., Temple, S.R., Brostrom, P.N., Hsiao, T.C., 2002. Infiltration and soil water storage under winter cover cropping in California's Sacramento Valley. *Transactions of ASAE* 45(2): 315-326.

Kabir, Z., Koide, R.T., 2000. The effect of dandelion or a cover crop on mycorrhiza inoculum potential, soil aggregation, and yield of maize. *Agriculture, Ecosystems & Environment* 78(2): 167–174.

Keesstra, S., Pereira, P., Novara, A., Brevik, E.C., Azorin-Molina, C., Parras-Alcántara, L., Jordán, A., Cerdà, A., 2016. Effects of soil management techniques on soil water erosion in apricot orchards. Science of the Total Environment 551-552: 357-366.

Lal, R., Regnier, E., Eckert, D.J., Edwards, W.M., Hammond, R., 1991. Expectations of cover crops for sustainable agriculture. In: Cover Crops for Clean Water. Hargrove, W.L. (Ed.). Soil and Water Conservation Society, pp. 1–11.

Leo, W.M., 1963. A rapid method for estimating structural stability of soils. *Soil Science* 96(5): 342-346.

Liu, A., Ma, B.L., Bomke, A.A., 2005. Effects of cover crops on soil aggregate stability, total organic carbon and polysaccharides. *Soil Science Society of America Journal* 69(6): 2041–2048.

Lorenz, K., Lal, R., 2005. The depth distribution of soil organic carbon in relation to land use and management and the potential of carbon sequestration in subsoil horizons. *Advances in Agronomy* 88: 35-66.

Lovato, T., Mielniczuk, J., Bayer, C., Vezzani, C., 2004. Carbon and nitrogen addition related to stocks of these elements in soil and corn yield under management systems. *Revista Brasileira de Ciência do Solo* 28(1): 175-87 [in Portuguese].

Mbah, C.N., Anikwe, M.A.N., Onweremadu, E.U., Mbagwu, J.S.C., 2007. Soil organic matter and carbohydrate contents of a Dystric Leptosol under organic waste management and their role in structural stability of soil aggregates. *International Journal of Soil Science* 2(4): 268–277.

Mennan, H., Ngouajio, M., Işık, D., Kaya, E., 2009. Effects of alternative winter cover cropping systems on weed suppression in organically grown tomato (*Solanum lycopersicum* L.). *Phytoparasitica* 37(4): 385-396.

Moebius-Clune, B.N., van Es, H.M., Idowu, O.J., Schindelbeck, R.R., Moebius-Clune, D.J., Wolfe, D.W., Abawi, G.S., Thies, J.E., Gugino, B.K., Lucey, R., 2008. Long-term effects of harvesting maize stover and tillage on soil quality. *Soil Science Society of America Journal* 72(4): 960-969.

Nascente, A.S., Pereira, W., Medeiros, M.A., 2004. Weed interference in processing tomato crops. *Horticultura Brasileira* 22(3): 602-606 [in Portuguese].

Nyakatawa, E.Z., Reddy, K.C., Lemunyon, J.L., 2001. Predicting soil erosion in conservation tillage cotton production systems using the Revised Universal Soil Loss Equation (RUSLE). *Soil and Tillage Research* 57(4): 213-224.

Obalum, S.E., Igwe, C.A., Obi, M.E., Wakatsuki, T., 2011. Water use and grain yield response of rainfed soybean to tillage-mulch practices in southeastern Nigeria. *Scientia Agricola* 68(5): 554-561.

Olson, K.R., Ebelhar, S.A., Lang, J.M., 2010. Cover crop effects on crop yields and soil organic carbon content. *Soil Science* 175(2): 89-98.

Osborne, S.L., Johnson, J.M.F., Jin, V.L., Hammerbeck, A.L., Varvel, G.E., Schumacher, T., 2014. The impact of corn residue removal on soil aggregates and particulate organic matter. *BioEnergy Research* 7: 559–567.

Patrick, Jr.W.H., Haddon, C.B., Hendrix, J.A., 1957. The effect of longtime use of winter cover crops on certain physical properties of Commerce loam. *Soil Science Society of America Journal* 21(4): 366–368.

Qi, Z., Helmers, M.J., 2010. Soil water dynamics under winter rye cover crop in central Lowa. Vadose Zone Journal 9(1): 53-60.

Rawls, W., Pachepsky, Y.A., Ritchie, J., Sobecki, T., Bloodworth, H., 2003. Effect of soil organic carbon on soil water retention. *Geoderma* 116(1-2): 61-76.

Reicosky, D.C., Kemper, W.O., 1995. Effecrs of crop residue on infiltration, evaporation, and water use efficiency. Pp 65-69. In: Crop Residue Management to Reduce Soil Erosion and Improve Soil Quality: Northern Great Plains. Moldenhauer, W.E., Mielke, L.N. (Eds.). U.S. Department of Agriculture, Agriculture Research Service. USDA, ARS Conservarion Research Report No. 42. USA. 85p.

Richards, L.A., 1954. Diagnosis and improvement of saline and alkali soil. U.S. Salinity Lab. Staff, U.S. Department of Agriculture, Agricultural Research Service, Handbook 60. Washington D.C. USA. 160p.

Rogers, M.E., Noble, C.L., Pederick, R.J., 1997. Identifying suitable temperate forage legume species for saline areas. *Australian Journal of Experimental Agriculture* 37(6): 639-645.

Rowell, D.L., 1996. Soil science: Methods and applications. Longman Scientific & Technical, Longman Group UK Ltd, Harlow, Essex, UK. 350 p.

Roumet, C., Urcelay, C., Díaz, S., 2006. Suites of root traits differ between annual and perennial species growing in the field. *New Phytologist* 170(2): 357-368.

Sainju, U.M., Singh, B.P., Whitehead, W.F., 2002. Long term effects of tillage, cover crops and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. *Soil and Tillage Research* 63(3-4): 167-179.

Sainju, U.M., Singh, B.P., Whitehead, W.F., Wang, S., 2006. Carbon supply and storage in tilled and nontilled soils as influenced by cover crops and nitrogen fertilization. *Journal of Environmental Quality* 35(4): 1507-1517.

Sarrantonio, M., 2008. Building soil fertility and tilth with cover crops. In: Managing Cover Crops Profitably. Third Edition, Clark, A. (Ed.). Sustainable Agriculture Network. Bestsville, USA. pp. 16-24.

Schnepf, M., Cox, C.A, 2006. Environmental benefits of conservation on cropland: the status of our knowledge. Soil and Water Conservation Society. Ankeny, Iowa, USA. 326p.

Silveira Neto, A.N., Silveira, P.M., Stone, L.F., Oliveira, L.F.C., 2006. Effects of soil tillage and crop rotation systems on soil physical attributes. *Pesquisa Agropecuária Tropical* 36(1): 29-35 [in Portuguese].

So, H.B., Grabski, A., Desborough, P., 2009. The impact of 14 years of conventional and no-till cultivation on the physical properties and crop yields of a loam soil at Grafton NSW, Australia. *Soil and Tillage Research* 104(1): 180–184.

Soil Survey Staff, 2014. Keys to soil taxonomy. 12rd Edition. United States Department of Agriculture (USDA), Natural Resources Conservation Service. Washington DC, USA. 360p. Available at [Access date: 17.05.2019]: https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1252094&ext=pdf

Souza, E.D., Costa, S.E.V.G.A., Anghinoni, I., Carvalho, P.C.F., Andrigheti, M.H., Cao, E.G., 2009. Soil organic carbon and nitrogen stocks in an untilled crop-livestock system under different grazing intensities. *Revista Brasileira de Ciência do Solo* 33: 1829-1836 [in Portuguese].

Steele, M., Coale, F., Hill, R., 2012. Winter annual cover crop impacts on no-till soil physical properties and organic matter. *Soil Science Society of America Journal* 76(6): 2164-2173.

Stetson, S.J., Osborne, S.L., Schumacher, T.E., Eynard, A., Chilom, G., Rice, J., Nichols, K.A., Pikul, J.L.Jr., 2012. Corn residue removal ımpact on topsoil organic carbon in a corn–soybean rotation. *Soil Science Society of America Journal* 76(4): 1399-1406.

Stone, L.F., Silveira, P.M., 2001. Effects of tillage and crop rotation on soil porosity and density. *Revista Brasileira de Ciência do Solo* 25(2): 395-401 [in Portuguese].

Subedi-Chalise, K., 2017. Impacts of crop residue and cover crops on soil hydrological properties, soil water storage and water use efficiency of soybean crop. South Dakota State University, Major in Plant Science, McS Thesis. 109p.

Troeh, F.R., Hobbs, J.A., Donahue, R.L., 2003. Soil and water conservation for productivity and environmental protection, 4th edition. Prentice Hall. USA. 656p.

TURKSTAT, 2018. Turkish statistical institute, crop production statistics. [in Turkish]. Available at [Access date: 17.05.2018]: http://www.tuik.gov.tr

Tursun, N., Işık, D., Demir, Z., Jabran, K., 2018. Use of living, mowed, and soil-incorporated cover crops for weed control in apricot orchards. *Agronomy* 8(8): 150.

Unger, P.W., Vigil, M.F., 1998. Cover crop effects on soil water relationships. *Journal of Soil and Water Conservation* 53(3): 200-207.

VanLoocke, A., Twine, T.E., Zeri, M., Bernacchi, C.J., 2012. A regional comparison of water use efficiency for miscanthus, switchgrass and maize. *Agricultural and Forest Meteorology* 164: 82-95.

Veronese-Júnior, V., Carvalho, M.P., Dafonte, J., Freddi, O.S., Vidal Vázquez, E., Ingaramo, O.E., 2006. Spatial variability of soil water content and mechanical resistance of Brazilian ferralsol. *Soil and Tillage Research* 85(1-2): 166–177.

Villamil, M.B., Bollero, G.A., Darmody, R.G., Simmons, F.W., Bullock, D.G., 2006. No-till corn/soybean systems including winter cover crops: Effects on soil properties. *Soil Science Society of America Journal* 70(6): 1936–1944.

Ward, P.R., Flower, K.C., Cordingley, N., Weeks, C., Micin, S.F., 2012. Soil water balance with cover crops and conservation agriculture in a Mediterranean climate. *Field Crops Research* 132: 33–39.

Wegner, B.R., Kumar, S., Osborne, S.L., Schumacher, T.E., Vahyala, I.E., Eynarde, A., 2015. Soil response to corn residue removal and cover crops in Eastern South Dakota. *Soil Science Society of America Journal* 79(4): 1179-1187.

Whalley, W.R., To, J., Kay, B.D., Whitmore, A.P., 2007. Prediction of the penetrometer resistance of soils with models with few parameters. *Geoderma* 137(3-4): 370-377.

Williams, S.M., Weil, R.R., 2004. Crop cover roots may alleviate of soil compaction effects on soybean crop. *Soil Science Society of America Journal* 68(4): 1403–1409.

Yakupoglu, T., Basaran, U., Özdemir, N., Acar, Z., 2011. Quantifying aggregate stability of a clay soil under annual forage crops. *Journal of Plant Nutrition and Soil Science* 174(3): 404-407.

Yunusa, I.A.M., Newton, P.J., 2003. Plants for amelioration of subsoil constraints and hydrological control: the primer-plant concept. *Plant and Soil* 257(2): 261-281.

Yurtsever, N., 2011. Experimental statistical methods. Soil, Fertilizer and Water Research Institute, Technical Publication No: 56, General Publication No: 121, Ankara, Turkey [in Turkish].

Zengin, M., Yılmaz, F.G., Gezgin, S., 2016. Reactions of apple tree and its fruit to compost use in Central Anatolia, Turkey. *Selcuk Journal of Agriculture and Food Sciences* 30(2): 96-110.