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Effects of cover crops on soil hydraulic properties and yield in a persimmon orchard

Zeynep Demir[1,*], Doğan Işık[2]

1.Soil, Fertilizer and Water Resources Central Research Institute - Soil Science and Plant Nutrition Department, Ankara, Turkey.
2.Erciyes University - Faculty of Agriculture - Department of Plant Protection, Kayseri, Turkey

ABSTRACT: This study evaluated the effects of cover crops on yield and soil hydraulic properties of a persimmon orchard in Turkey. Soil samples were taken from 0-20 and 20-40 cm. Profiles of a clay soil and field capacity, permanent wilting point, available water capacity and saturated hydraulic conductivity of the samples were determined. *Festuca rubra* subsp. *rubra*, *Trifolium repens*, *Festuca arundinacea*, a mixture of them [*Trifolium repens* (40%) + *Festuca rubra rubra* (30%) + *Festuca arundinacea* (30%)], *Vicia villosa* R., and *Trifolium meneghinianum* were used as the cover crops. The experiment was conducted in a randomized complete blocks design with four replications including a mechanically cultivated and herbicide treated control plots. The greatest mean persimmon yield (16.2 $Mg \cdot ha^{-1}$) was observed in the *Vicia villosa* treatment and the lowest mean yield (3.6 $Mg \cdot ha^{-1}$) was observed in the bare control. The cover crops increased soil hydraulic properties, with increased aggregate stability, total porosity, reduced bulk density, and penetration resistance. The greatest increases in organic matter contents at 0-20 cm soil depth in the persimmon orchard were observed in the *Vicia* treatments (73.4% in the first and 74.5% in the second year). The highest aggregate stability (67.4%) and total porosity (60.9%) values were obtained on the *Vicia* treatments. To increase persimmon yield and improve soil physical and hydraulic properties, cover crops, especially *Vicia villosa* and *Trifolium repens* are suggested for clay soils.

Key words: Cover crops, available water capacity, saturated hydraulic conductivity, soil quality, persimmon orchard.

*Corresponding author: zdemir06@yahoo.com

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INTRODUCTION

Fruit culture has played an important role in agricultural history of Turkey. Currently, Turkey is considered to be one of the most important countries in the world from the point of fruit diversity. Persimmon production, mainly practiced in the subtropical sections of Turkey, has expanded rapidly during the last decade and reached about 20,000 tons per year. Persimmon is grown mostly in the Mediterranean, Black Sea and Northeastern Anatolia regions. The production is mainly based on seedling materials of local astringent types, either as isolated trees or mixed with other fruit trees (Onur 1990).

In agricultural systems, cover crops, especially legumes are usually incorporated into cropping systems to improve soil and plant quality attributes (Fageria et al. 2005). Cover crops improve soil quality, but the impacts on crop yield largely depend on the type of cover crops, main crops and climate conditions (Alvarez et al. 2017). Cover crops can also provide significant contributions to soil fertility (Robacer et al. 2016). They also increase soil organic matter content, stimulate repelling forces among soil particles through negative charges over clay particles, and thus increase dispersion of soil colloids (Emerson 1984). Cropping systems play an important role in soil physical properties, since they improve soil structure through several mechanisms, such as aggregate enrichment by fine roots and associated fungal hyphae, stimulation of microbial carbohydrate production or modified soil–water relationships (Tisdall and Oades 1982; Angers 1998).

Leguminous and grass cover crops have been successfully used to improve soil properties in many regions (Lal et al. 1979). Beneficial effects of crop residues on soil surface under conservation tillage include increased water conservation and soil aggregation (Lal 1976; Blevins et al. 1983). The effectiveness of cover crops in improving soil structure has been reported in many studies (Tisdall et al. 1979; Haynes and Beare 1997). Blanchart et al. (2004) studied the effects of grass roots on properties of a degraded Vertisol and reported that restoration of physical properties was quicker and greater in treatments with plants than in treatments without plants. Plants also played a dominant role through rhizosphere effects and possible carbon rhizodeposition. It has been shown that cover crops added organic matter to the soil and promoted soil faunal activity. Soil organic matter has significant impacts on soil physicochemical attributes. Organic matter also improves soil porosity and, therefore, has indirect effects on soil hydraulic properties. Increased organic matter can lead to improved soil aggregation and infiltration (Demir, 2019). The chemical composition of cover crop residues has also effects on soil aggregation, aggregate stability and, thus, soil hydraulic properties (FAO 2005). Water infiltration into soil is influenced by several factors, such as aggregate stability, pore structure, and plant cover. In the long run, improved infiltration can lead to increased production due to a more efficient use of rainfall (Freebairn et al. 1986).

Studies dealing with the effects of cover crops on soil quality attributes of persimmon orchards are quite limited. Thus, the specific objective of this study was to investigate the effect of cover crop treatments on yields and soil hydraulic properties of a persimmon orchard. It was hypothesized that increased soil organic matter content with the cover crop treatments may enhance soil physical and hydraulic properties as compared to control treatments without any cover crops.

MATERIAL AND METHODS

Experimental Site

The present study was conducted in 2013-2014 in a persimmon (*Diospyros kaki* L.) orchard located at the Experiment Station of the Black Sea Agricultural Research Institute in Samsun province (lat 36’30” N; long 41’13” E; alt 20 m). Analyses revealed that orchard soils were unsaline, clayey in texture (31.05% sand, 14.15% silt, 54.80% clay) with neutral pH (7.46) and low in organic matter (0.94%) (Soil Survey Staff 1993). The orchard is located in the Middle Black Sea region. Annual average precipitation is 685.5 mm and annual average temperature is 14.5 °C. The orchard was 12 years old and each plot had 3 trees. There was 1 m spacing between the plots and 3 m between the blocks. Each plot has a size of 35 m^2 (5 × 7 m). The total experimental area was 1728 m^2.

NPK fertilization was performed according to analyses conducted on soil samples prior to experiment initiation. Herbicides were also applied prior to experiment initiation. Soil aeration was provided with a hoeing machine in the spring.

Field Trial

Cover crop treatments consisted of *Trifolium repens* L., *Festuca rubra rubra* L., *Festuca arundinacea*, a mixture →

[*Trifolium repens* (40%) + *Festuca rubra rubra* (30%) + *Festuca arundinacea* (30%)], *Vicia villosa* and *Trifolium meneghinianum*. Control treatments included mechanically cultivated (weed-free), herbicide treated (weed-free) and weed control plots, i.e., bare ground plots (with no cover crop) were allowed to become weedy. Mechanical weed control was practiced with a rotary hoeing machine. Glyphosate isopropylamine salt (360 g a.i·L^{-1}) was applied at a dose of 2880 ml·ha^{-1} (1.39 kg a.i·ha^{-1}) in herbicide control plots. Glyphosate was applied at 3 atm pressure (303.97 kPa) and 250 L·ha^{-1} spraying volume with a portable hand sprayer (Honda WJR 2225). Herbicide application and mechanical weed control were practiced when the weeds were at the 4-8 leaf stage. *Trifolium meneghinianum* seeds were supplied from the Black Sea Agricultural Research Institute and the others were purchased from private seed companies. Experiments were conducted in randomized complete blocks design with four replications. The cover crop treatments were maintained in the same (respective) plots throughout the experiment. During the vegetation period, no fertilizer was applied. Consecutive plots were separated with a buffer zone without any cover crops. Before planting of the cover crops, weeds were removed either manually or mechanically. The Black Sea region has abundant precipitation, thus irrigation was performed twice in July and in August. Annual precipitation was measured as 616.6 mm in 2013 and 637.2 mm in 2014 (MGM 2014). Cover crops were respectively broadcast seeded at 50, 80, and 70 kg·ha^{-1} for *T. repens, Festuca* spp. and a mixture of perennials on April 2012. *Vicia 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 cover crops were mowed at the flowering stages of the plants (Işık et al. 2014; Tursun et al. 2018). The mowing was performed with a motorized scythe. Following the mowing, the cover crops were incorporated into the soil by disking. The cover crops were mowed at the flowering stage on 23 June 2013 and on 26 June 2014, first and second year of the study.

Soil sampling

Soil samples were taken with a soil auger from 0-20 and 20-40 cm depths in each plot 90 days after mowing. To represent each plot, about 3 kg sample was taken from equal distances from the trees. Soil samples were then placed into labeled plastic bags. Air-dried samples were sieved through a 2 mm sieve. Statistical analyses were performed to determine the effects of cover crop treatments on soil hydraulic properties.

Soil analysis

The modified Walkley-Black method was used to determine organic matter (OM) content of the samples (Tüzüner 2018). A wet sieving apparatus was used to determine aggregate stability (AS) (Kemper and Rosenau 1986). Following bulk density (BD) analyses, total porosity (F) of the samples was determined by using Eq. 1 (Hillel 1982):

$$F = 1 - (BD/2.65) \quad (1)$$

Bulk density was multiplied by gravimetric water content (W) to obtain volumetric water content (θ). Volumetric water content was then divided by total porosity to get relative saturation (RS). A standard cone penetrometer was used to determine soil penetration resistance (PR) at 0-20 cm depth (Bradford 1986). Saturated hydraulic conductivity (Ks, cm·h^{-1}) of the samples was determined with a constant head permeameter (US Salinity Lab. Staff 1954):

$$Ks = \frac{Q}{A\,t}\left(\frac{S}{S+H}\right) \quad (2)$$

where Q is the water flow through soil sample (cm^3), A is the sample cross-sectional area (cm^2), t is the time (h) passed to flow volume Q, S is the sample length (5 cm), H is the water head over soil sample (cm).

Mean weight diameter (MWD) values were determined with the dry sieving method as specified by Hillel (1982):

$$MVD = \sum_{i=1}^{k} W(i)\,\bar{x}i \quad (3)$$

Soil field capacity (FC) and the permanent wilting point (PWP) were determined according to Tüzüner (2018). After saturating soil samples with tap water for 24 h, soil water content at the field capacity was measured through equilibrating soil moisture for 24 h at 33 kPa on a ceramic plate, and the permanent wilting point was measured through equilibrating soil moisture for 96 h at 1500 kPa on a pressure plate apparatus (Tüzüner 2018). Available water content →

(AWC) was then calculated as the difference between FC and PWP (Hillel 1982). The hydrometer method was used to calculate soil structural stability index (SSI) values as SSI= ∑ b- ∑ a, where b represents dispersed silt + clay (%) and a represents suspended silt + clay (%) (Leo 1963).

Statistical analysis

Experiment data were subjected to analysis of variance using a randomized block design. Means were compared with Duncan's test at $p < 0.05$ and $p < 0.01$. Pearson's correlations ($p < 0.01$ and $p < 0.05$) were also investigated. Year × treatments interactions at 0-20 cm soil depth was found significant in the statistical analysis ($p < 0.01$). Correlation coefficients were calculated to express the relationships between investigated traits (Yurtsever 2011). SPSS 16.0 software was used in the statistical analyses.

RESULTS AND DISCUSSION

Compared to control treatments, cover crop treatments (only observed with *Vicia* on the second year) increased yields in persimmon ($p < 0.01$) (Table 1). While the greatest mean persimmon yield was observed with the *Vicia* treatment (16.2 $Mg \cdot ha^{-1}$), the lowest mean yield was observed in the control plots (3.6 $Mg \cdot ha^{-1}$). Demir et al (2019) found that different cover crops including *Vicia* spp., generally increased mean yield levels in apricot orchard with clay soil compared to control without cover crops. Crop yields primarily depend on organic matter contents of soils (Demir et al 2019; Demir and Işik 2019). Even with the use of cover crops the addition of organic fertilizers is necessary in order to maintain good yields and sufficient tree vigor (Sánchez 2007). Organic matter directly improves physicochemical and biological quality attributes of the soils, improving then yield levels (Franzluebbers 2002). However, the amount of increase in crop yield depends upon crops grown. In addition, species of cover crop also have effects on yield increases (Chalk 1998).

Significant increases were observed in organic matter content at a 0-20 cm soil depth with cover crop treatments (Table 2). Cover crop treatments increased the soil organic matter content from 0.99% in the control to 1.72% in the *Vicia* treatment in the second year of the experiments. Cover crop treatments increased organic matter content of clay soils and, thus, likely improved soil physicochemical and hydraulic properties. Compared to the bare control, the highest increases in organic matter contents in both years of the experiments were observed in the *Vicia* treatments, respectively with 73.4 and 74.5%. Similarly, Demir et al. (2019) determined that different cover crops including *Vicia* spp. increased soil organic matter in an apricot orchard with a clay soil over a two-year period. In the present study, the *Vicia* and *Trifolium repens* L. treatments as leguminous cover crops had the greatest soil organic matter content.

Compared to the control, bulk density decreased and total porosity increased with cover crop treatments ($p < 0.01$) (Table 2). Bulk density was significantly higher in control treatment in both years of the experiment. The cover crop treatments decreased bulk density from 1.2 $g \cdot cm^{-3}$ in the bare control to 1.04 $g \cdot cm^{-3}$ in the *Vicia* treatment. The cover crop treatments significantly increased total →

Table 1. Effects of cover crop treatments on yield in a persimmon orchard in the Samsun province of Turkey (lat 36°30 N; long 41°13 E; alt 20 m).

Treatments	Persimmon yield, $Mg \cdot ha^{-1}$			
	2013**		2014**	
Trifolium repens L.	14.2	a	6.6	ab
Festuca rubra rubra L.	8.2	ab	3.4	b
Festuca arundinacea	14.2	a	9.7	ab
Mix. [*T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%)]	14.3	a	3.8	ab
Vicia villosa Roth	13.8	a	18.5	a
Trifolium meneghinianum Celm	13.2	a	2.3	b
Herbicide control	8.8	ab	8.9	ab
Mechanical control	9.7	ab	7.6	ab
Bare control	5.6	b	1.5	b

Numbers followed by different letters, within columns, are considered to be significantly different according to Duncan's new multiple range test (**$p < 0.01$).

Table 2. Effects of cover crop treatments on soil physical properties at 0-20 cm soil depth in a persimmon orchard in the Samsun province of Turkey.

Treatments	2013								
	OM %**	BD gr.cm^{-3}**	F %**	W %**	θ, %**	PR Mpa**	AS, %**	MWD mm**	SSI %**
Trifolium repens L.	1.58 a	1.040 d	60.8 a	34.7 a	36.1 bc	1.86 d	67.0a	0.844 a	54.1 ab
Festuca rubra rubra L.	1.22 c	1.076 b	59.4 a	33.0 b	35.5 cd	2.15 b	64.1 bc	0.805 bc	53.6 b
Festuca arundinacea	1.34 b	1.074 b	59.5 a	33.8 b	36.3 b	2.19 b	63.4 cd	0.790 c	53.7 b
Mix. [*T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%)]	1.42 b	1.048 cd	60.5 a	33.6 b	35.2 d	2.10 bc	66.3 a	0.838 ab	54.1 b
Vicia villosa Roth	1.65 a	1.041 d	60.7 a	34.8 a	36.2 b	1.84 d	67.4 a	0.842 a	55.5 a
Trifolium meneghinianum Celm	1.34 b	1.068 bc	59.7 a	33.1 b	35.4 d	2.00 c	64.7 b	0.794 c	53.5 b
Herbicide control	1.02 d	1.206 a	54.5 b	32.0 c	38.6 a	2.79 a	62.7 d	0.779 c	49.4 c
Mechanical control	1.05 d	1.197 a	54.8 b	32.1 c	38.4 a	2.75 a	62.6 d	0.766 c	50.0 c
Bare control	0.95 d	1.201 a	54.7 b	31.7 c	38.0 a	2.81 a	62.6 d	0.778 c	49.5 c
Treatments			**2014**						
Trifolium repens L.	1.68 a	1.038 c	60.8 a	34.7 a	36.0 b	1.79 d	67.1 a	0.845 a	54.6 ab
Festuca rubra rubra L.	1.25 c	1.065 b	59.8 a	33.6 ab	35.8 b	2.16 b	64.4 b	0.803 b	52.7 c
Festuca arundinacea	1.42 b	1.067 b	59.7 a	33.1 b	35.3 b	2.12 b	64.4 b	0.797 b	53.5 bc
Mix. [*T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%)]	1.52 b	1.051 bc	60.4 a	33.8 ab	35.5 b	1.93 c	65.9 a	0.839 a	54.1 b
Vicia villosa Roth	1.72 a	1.037 c	60.9 a	34.7 a	36.0 b	1.77 d	67.3 a	0.846 a	55.6 a
Trifolium meneghinianum Celm	1.50 b	1.061 bc	60.0 a	34.0 ab	36.1 b	1.97 c	64.3 b	0.805 b	54.1 b
Herbicide control	0.97 d	1.209 a	54.4 b	31.3 c	37.8 a	2.77 a	61.9 c	0.780 b	49.6 d
Mechanical control	1.07 d	1.205 a	54.5 b	31.7 c	38.2 a	2.80 a	62.7 c	0.778 b	49.8 d
Bare control	0.99 d	1.204 a	54.6 b	31.5 c	37.9 a	2.82 a	62.2 c	0.773 b	49.3 d

Numbers followed by different letters, within columns, are considered to be significantly different according to Duncan's new multiple range test (**$p < 0.01$). Organic matter (OM), bulk density (BD), total porosity (F), gravimetric water content (W), volumetric water content (θ), penetration resistance (PR), aggregate stability (AS), mean weight diameter (MWD), structural stability index (SSI).

porosity (F) from 54.6% in the control to 60.9% in the *Vicia* treatment. Compared to the other treatments, the *Vicia* and *Trifolium repens* L. treatments had the greatest effects on soil physical and hydraulic properties. Total porosity values generally increased with decreasing bulk density. Field capacity (FC) was positively correlated with total porosity (F) (0.841**) and aggregate stability (AS) (0.608*).

Compared to the bare control, the cover crop treatments significantly increased aggregate stability (AS) in both years ($p < 0.01$). The cover crop treatments significantly increased soil aggregate stability from 62.2% in the herbicide treatment to 67.3% in the *Vicia* treatment in the second year of the experiments. The highest AS (67.3%) and F (60.9%) values were obtained from the *Vicia* treatments (Table 2). Soil structure has significant effects on soil health, water infiltration, aeration and root development. In the present study, significant positive correlations were observed among OM, AS and F (Table 4). It was reported in a previous study that AS was positively correlated with the soil organic carbon content (Hati et al. 2006). In the present study, the cover crop treatments increased SSI, F, AS and Ks and decreased BD and PR values (Tables 2 and 3). Percent increases in SSI compared to the control in the second year of the experiment (2014) varied between 6.79% in *Festuca rubra* and 12.69% in the *Vicia* treatments. Cover crops may decrease soil bulk density, increase pore volume, improve soil aeration and root growth. Organic matter decomposition facilitates soil aggregation. Increasing organic carbon contents also decreases soil bulk density and, thus, increases total porosity (Candemir and Gülser 2010). In the present study, leguminous cover crops increased soil organic matter in a clayey soil, resulting in higher F and lower BD values. Compared to the other treatments, the *Vicia* treatment increased AS values of clay

Table 3. Effects of cover crop treatments on soil hydraulic properties at 0-20 cm soil depth in a persimmon orchard in the Samsun province of Turkey.

Treatments	2013				
	RS %**	Ks cm.h^{-1}**	FC %**	PWP %*	AWC %*
Trifolium repens L.	59.36 cd	1.09 a	41.97 a	23.84	18.13 a
Festuca rubra rubra L.	59.82 bc	0.70 c	40.68 a	23.05	17.63 a
Festuca arundinacea	61.05 b	0.75 bc	40.94 a	23.26	17.68 a
Mix. [*T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%)]	58.23 d	0.90 b	41.26 a	23.37	17.90 a
Vicia villosa Roth	59.67 bcd	1.11 a	41.78 a	24.12	17.66 a
Trifolium meneghinianum Celm	59.21 cd	0.73 bc	41.14 a	23.20	17.93 a
Herbicide control	70.81 a	0.36 d	38.02 b	22.53	15.49 b
Mechanical control	70.12 a	0.43 d	38.55 b	22.68	15.87 b
Bare control	69.53 a	0.35 d	38.39 b	22.57	15.82 b
Treatments	**2014**				
Trifolium repens L.	59.16 b	1.12 a	42.35 a	24.31 a	18.04 a
Festuca rubra rubra L.	59.87 b	0.78 c	41.56 a	23.90 a	17.66 a
Festuca arundinacea	59.14 b	0.80 bc	42.00 a	24.29 a	17.70 a
Mix. [*T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%)]	58.83 b	1.05 ab	42.29 a	24.38 a	17.91 a
Vicia villosa Roth	59.08 b	1.18 a	42.50 a	24.50 a	18.00 a
Trifolium meneghinianum Celm	60.16 b	0.83 c	42.13 a	24.12 a	18.01 a
Herbicide control	69.59 a	0.32 d	38.01 b	22.65 b	15.37 b
Mechanical control	70.01 a	0.49 d	38.32 b	22.72 b	15.61 b
Bare control	69.50 a	0.36 d	38.46 b	22.69 b	15.77 b

Numbers followed by different letters, within columns, are considered to be significantly different according to Duncan's new multiple range test (**$p < 0.01$, *$p < 0.05$). Relative saturation (RS), saturated hydraulic conductivity (Ks), field capacity (FC), permanent wilting point (PWP), available water content (AWC).

Table 4. Correlation matrix among the soil properties in a persimmon orchard in the Samsun province of Turkey (lat 36° 30 N; long, 41° 13 E; alt 20 m).

	BD	F	W	θ	PR	AS	MWD	SSI	RS	Ks	FC	PWP	AWC
OM	-0.819**	0.818**	0.812**	-0.505*	-0.950**	0.825**	0.657**	0.922**	-0.761**	0.938**	0.794**	0.749*	0.750**
BD		-0.948**	-0.866**	0.900**	0.972**	-0.779**	-0.963**	-0.938**	0.985**	-0.851**	-0.895**	-0.775**	-0.931**
F			0.955**	-0.793**	-0.958**	0.714**	0.981**	0.976**	-0.939**	0.843**	0.841**	0.806**	0.945**
W				-0.617**	-0.918**	0.913**	0.941**	0.971**	-0.825**	0.911**	0.854**	0.771**	0.876**
θ					0.816**	-0.499**	-0.799**	-0.732**	0.926**	-0.725**	-0.780**	-0.660**	-0.818**
PR						-0.868**	-0.983**	-0.974**	0.950**	-0.920**	-0.886**	-0.791**	-0.906**
AS							0.894**	0.921**	-0.747**	0.885**	0.608*	0.732**	0.758**
MWD								0.986**	-0.951**	0.961**	0.906**	0.809**	0.927**
SSI									-0.913**	0.959**	0.891**	0.805**	0.910**
RS										-0.890**	-0.902**	-0.781**	-0.938**
Ks											0.740**	0.808**	0.859**
FC												0.936**	0.980**
PWP													0.865**

Organic matter (OM), bulk density (BD), total porosity (F), gravimetric water content (W), volumetric water content (θ), penetration resistance (PR), aggregate stability (AS), mean weight diameter (MWD), structural stability index (SSI), relative saturation (RS), saturated hydraulic conductivity (Ks), field capacity (FC), permanent wilting point (PWP), available water content (AWC).

soils. In addition, increased organic matter content improved soil particle mean weight diameter values (Table 2). Similarly, Kushwaha et al. (2001) determined that residue retention with reduced tillage increased the mean weight diameter of aggregates by 71-98% over the control due to rising soil organic matter quantity in macroaggregates. Chantigny et al. (1997) observed close relations between mean weight diameter and both fungal glucosamine and bacterial numeric acid, and reported that increased soil aggregation under perennial grasses was mainly mediated by fungi. Organic matter content had positive correlations with F (0.818**), W (0.812**), AS (0.825**), MWD (0.657**), SSI (0.922**), Ks (0.938**), FC (0.794**), PWP (0.749*), and AWC (0.750**), and negative correlations with PR (-0.950**), BD (-0.819**), θ (-0.505*), and RS (-0.761**). In addition, AS had positive correlations with F (0.714**). Gülser (2006) reported that penetration resistance also had significant negative correlations with OC (-0.677**), AS (-0.599**), and mean weight diameter (-0.627**) (Table 4).

The cover crop treatments also resulted in significant changes in gravimetric water content (W) and volumetric water content (**θ**) values compared to the bare control ($p < 0.01$). Significant increases were observed in W and significant decreases were observed in θ with the cover crop treatments. Compared to the controls, the cover crop treatments studied in the present study increased W and decreased θ and relative saturation (RS) values (Table 2). Increases in W ranged from 5.08% in *Festuca arundinacea* to 10.16% in the *Trifolium repens* treatments in the second year of the experiments. Brown and Cotton (2011) reported increasing W with compost treatments. Previous researchers also reported preserved soil moisture with crop residues. Such crop residues improve soil infiltration rates and decrease evaporation from the soil surface (Sustainable Agriculture Network 1998). Generally lower RS and higher total porosity (F) values were observed with the cover crop treatments. Similar to the present findings, Chikowo et al. (2004) also reported decreased bulk density, improved soil aggregation and porosity with leguminous cover crops. Increasing W values in the present study were attributed to the cover crop treatments. Decreases in the RS content varied between 12.20% in *Festuca arundinacea* and 16.25% in the mixture treatment in the first year of the experiments.

Cover crop treatments improved soil physical properties, reduced BD, PR, and RS and increased AS, W and Ks values. Significant decreases were observed in RS values and significant increases were observed in Ks values with the cover crop treatments (Table 3). The highest Ks was observed in the *Vicia* treatment (1.18 $cm \cdot h^{-1}$), and the lowest Ks was observed in the herbicide treatment (0.32 $cm \cdot h^{-1}$). Cover crop treatments increased F and AS and thus Ks values of the soil samples. Percent increases in Ks compared to the control treatment in the second year of the experiments (2014), varying from 117.8% in *Festuca rubra* to 229.9% in the *Vicia* treatment in the second year of the experiment. Saturated hydraulic conductivity is directly proportional to soil pore sizes (amount of macro and micropores) (Ahuja et al. 1984). Increasing macroporosity or decreasing microporosity in soil structure causes increases in soil hydraulic conductivity (Ahuja et al. 1984). Cover crop treatments in the present study increased total porosity and, thus, decreased soil bulk density and penetration resistance. Compared to the other treatments, *rubra* and *arundinacea* had the least effects on F, BD and PR. Compared to the bare control treatment, grass and legumes had lower bulk density and penetration resistance. Obi (1999) also reported significantly lower Ks and AWC values for degraded sandy clay loam than for the control soils. In the present study, the cover crop treatments increased Ks values (in $cm \cdot h^{-1}$) significantly. Lal et al. (1979) reported significant improvements in soil hydraulic properties with three grasses (*Brachiaria, Paspalum,* and *Cynodon* spp.) and five leguminous covers (*Pueraria, Stylosanthes, Stizolobium, Psophocarpus,* and *Centrosema*). Similarly, Demir et al. (2019) determined that different cover crop treatments including *Vicia* spp., increased soil physical properties in an apricot orchard with clay soil. Cover crop treatments in the present study, especially leguminous crops, resulted in higher AS and F, and consequently higher Ks values. In both years of the experiments, there were not statistically different soil physical properties and hydraulic properties of the treatments at a 20-40 cm soil depth (Table 5). Saturated hydraulic conductivity had the greatest significant positive correlation with F (0.843**) and AS (0.885**) and the greatest significant negative correlation with PR (-0.920**) (Table 4). Ks had also significant correlations with FC (0.740**) and BD (-0.851**) (Table 4). Boparai et al. (1992) reported increased porosity, water-stable aggregate and Ks values with green manure treatments. Rosolem et al. (2002) determined that root growth decreased with rising bulk density and observed →

Table 5. Effects of cover crop treatments on soil physical properties at 20-40 cm soil depth in a persimmon orchard in the Samsun province of Turkey (lat 36° 30 N; long 41° 13 E; alt 20 m).

Treatments	BD $gr{\cdot}cm^{-3}$	F %	Ks, $cm{\cdot}h^{-1}$	FC %	PWP %	AWC %	AS %	MWD mm	SSI %
Trifolium repens L.	1.17	56.0	0.34	38.3	21.9	16.4	55.3	0.715	48.4
Festuca rubra rubra L.	1.15	56.8	0.37	37.8	21.6	16.2	57.1	0.725	47.6
Festuca arundinacea	1.17	56.0	0.32	37.9	21.3	16.6	55.8	0.718	48.6
Mix. [*T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%)]	1.18	55.7	0.32	38.1	21.9	16.2	56.4	0.714	47.4
Vicia villosa Roth	1.17	56.0	0.36	38.3	21.3	16.9	56.9	0.717	47.3
Trifolium meneghinianum Celm	1.15	56.6	0.35	38.2	21.7	16.5	57.7	0.717	48.7
Herbicide control	1.19	55.3	0.28	37.7	21.6	16.1	56.4	0.728	47.9
Mechanical control	1.18	55.7	0.32	37.4	21.6	15.8	55.2	0.711	48.2
Bare control	1.19	55.3	0.35	38.1	21.5	16.6	56.5	0.720	47.9

Organic matter (OM), bulk density (BD), total porosity (F), saturated hydraulic conductivity (Ks), field capacity (FC), permanent wilting point (PWP), available water content (AWC), aggregate stability (AS), mean weight diameter (MWD), structural stability index (SSI).

significant plant species × bulk density interactions for root growth in the upper uncompacted soil layer. In the present study, the *Vicia villosa* and *Trifolium repens* treatments, as leguminous cover crops, had the greatest organic matter, aggregate stability and total porosity values.

CONCLUSION

Cover crop treatments at a 0-20 cm soil depth in a persimmon orchard had positive effects on persimmon yields (only observed with *Vicia* on the second year) ($p < 0.01$), soil hydraulic properties and physicochemical attributes. While the greatest mean persimmon yield was observed in the *Vicia villosa* treatment (16.2 $Mg{\cdot}ha^{-1}$), the lowest mean yield was observed in the bare control plot (3.6 $Mg{\cdot}ha^{-1}$). Cover crop treatments increased soil organic matter content from 0.99% in the control to 1.72% in the *Vicia villosa* treatment in the second year of the experiments. Incorporating cover crops, especially legumes into a clay soil of a persimmon orchard at 0-20 cm soil depth improved soil physical properties through increased total porosity, aggregate stability and saturated hydraulic conductivity and reduced bulk density and soil penetration resistance. Cover crop treatments improved saturated hydraulic conductivity, attributable to improved structural stability and porosity, which in turn could improve soil water storage. To increase persimmon yield and improve soil physical and hydraulic properties, cover crops, especially *Vicia villosa* and *Trifolium repens* are suggested for clay soils.

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AUTHOR'S CONTRIBUTION

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ORCID IDs

Z. Demir
https://orcid.org/0000-0002-7589-3216
D. Işık
https://orcid.org/0000-0002-0554-2912

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