Türk Tarım ve Doğa Bilimleri Dergisi 6(2): 137–147, 2019
https://doi.org/10.30910/turkjans.556592

TÜRK
TARIM ve DOĞA BİLİMLERİ
DERGİSİ

TURKISH
JOURNAL of AGRICULTURAL
and NATURAL SCIENCES

www.dergipark.gov.tr/turkjans

Research Article

Comparison of Different Cover Crops on DTPA-Extractable Micronutrients in Hazelnut and Apple Orchards

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Received: 07.07.2018 Received in Revised: 11.02.2019 Accepted: 12.02.2019

Abstract

This study was conducted to compare the effect of different cover crop treatments on DTPA-extractable micronutrients (Fe, Mn, Zn, Cu) and soil pH in a hazelnut orchard with clay loam texture located in Samsun province and in an apple orchard with sandy loam texture located in Kayseri province of Turkey. For this purpose, *Trifolium repens* (TR), *Festuca rubra* subsp. *rubra* (FRR), *Festuca arundinacea* (FA), *T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%) mixture (TFF), *Vicia villosa* Roth. (VV) and *Trifolium meneghinianum* Celm. (TM) were used as cover crops in the experiments. Experiments also included a plot mechanically cultivated (MC), herbicide treatment (HC) and bare control plot (BC). Soil samples were taken from two different depths (0-20 and 20-40 cm) in each plot. Experiments were conducted in randomized complete blocks design with 4 replications. While the highest mean extractable Fe content was determined in the VV treatment in the hazelnut orchard (74.35 mg kg^{-1}) and in the apple orchard (3.12 mg kg^{-1}), the highest mean extractable Zn content in the hazelnut and apple orchards were obtained in the TR treatment (2.45 and 1.08 mg kg^{-1}, respectively). While the highest mean extractable Mn content was also obtained in the VV (92.87 mg kg^{-1}) in the hazelnut orchard, the highest mean extractable Mn content was determined in the TR (6.35 mg kg^{-1}) in the apple orchard. The greatest significant negative correlations in the TFF treatment were observed between pH and extractable Mn content (0.914**) in the hazelnut orchard and in the TR treatment between pH and extractable Fe content (0.968**) in the apple orchard.

Key words: Cover crops, DTPA-extractable micronutrients, clay loam texture, sandy loam texture, soil pH.

Fındık ve Elma Bahçelerinde DTPA ile Ekstrakte Edilebilir Mikro Element İçeriklerine Farklı Örtücü Bitkilerin Etkilerinin Karşılaştırılması

Özet

Bu çalışma, ülkemizin Samsun ilinde yeralan killi tın tekstürlü bir fındık bahçesinde ve Kayseri ilinde yeralan kumlu tın tekstürlü elma bahçesinde DTPA ile ekstrakte edilebilir mikro besin elementi (Fe, Mn, Zn and Cu) içerikleri ve toprak pH'sı üzerine farklı örtücü bitkilerin etkilerini karşılaştırmak için yürütülmüştür. Denemede örtücü bitki olarak *Trifolium repens* (TR), *Festuca rubra* subsp. *rubra* (FRR), *Festuca arundinacea* (FA), *T. repens* (40%) + *F. rubra rubra* (30%) + *F. Arundinacea* (30%) karışımı (TFF), *Vicia villosa* Roth. (VV) ve *Trifolium meneghinianum* Celm. (TM) kullanılmıştır. Denemede mekanik mücadele (MC), herbisitle mücadele (HC) ve yalın kontrol (BC) parselleri de yer almıştır. Toprak örnekleri her parselden olmak üzere iki faklı derinlikten (0-20 and 20-40 cm) alınmıştır. Denemeler, tesadüf blokları deneme desenine göre dört tekerrürlü olarak yürütülmüştür. En yüksek alınabilir Fe fındık bahçesinde (74.35 mg kg^{-1}) ve elma bahçesinde (3.12 mg kg^{-1}) VV uygulamasında elde edilirken, en yüksek alınabilir Zn içeriği ise fındık bahçesinde (2.45 mg kg^{-1}) ve elma bahçesinde (1.08 mg kg^{-1}) TR uygulamasında belirlenmiştir. Fındık bahçesinde en yüksek alınabilir Mn içeriği VV uygulamasında (92.87 mg kg^{-1}) tespit edilirken, elma bahçesinde ise TR uygulamasında (6.35 mg kg^{-1}) bulunmuştur. En yüksek önemli negatif korelasyonlar fındık bahçesinde TFF uygulamasında pH ve alınabilir Mn içeriği (0.914**) arasında ve elma bahçesinde TR uygulamasında pH ve alınabilir Fe içeriği (0.968**) arasında elde edilmiştir.

Anahtar kelimeler: Örtücü bitkiler, mikro besin elementleri, killi tın toprak, kumlu tın toprak, toprak pH.

Introduction

Micronutrients play an important role in maintaining soil fertility and also efficiency of crops. These nutrients are needed in smaller amounts than macronutrients, an inadequate supply will make it impossible to acquire maximum yields, even if the supply of the micronutrients is balanced and high yielding diversities are grown (Yadav, 2011). Micronutrient deficiencies in soil have been defined as one of primary factors influencing human health, crop yield and food quality (Masunaga and Fong, 2018). There are many soil factors influencing the solubility of micronutrients and their accessibility for plants, including moisture, pH, texture, temperature, soil type, cation exchange capacity, organic matter (OM), structure and calcium carbonate ($CaCO_3$) (Schoonover and Crim, 2015). Soil pH can impact plant growth depends on its effect on the availability of fundamental plant these nutrients and on the concentration of elements toxic to plants (Brady and Weil, 2002). Iron (Fe), copper (Cu), managanese (Mn) and zinc (Zn) are more available within a pH range of 4 to 6. Micronutrients are firmly bound to the soil at great pH and are thus more available at low pH levels than high pH levels (Havlin et al., 2010). Even small changes in the soil pH can cause large variations in the availability of nutrients. A high content of organic matter in soil also increases the uptake of micro elements. Manufactured chemical fertilizers are typically fast acting and soluble. They involve high-analysis materials, have a high level of micronutrients with several impurities, have a promptly reply in the field, and are greatly soluble in water (Silva, 2000). However, they may become inactive in alkaline soil and thus unable to be absorbed by plants (Osman, 2013). They are also reported to cause long-term adverse effects, while bio-based produces are more likely to dissolve easily and thus not pollute the environment (Ying, 2006). The availability of Fe, Mn, Zn and Cu in soil depends on their solubility and their ability to be mobilized (Chatzistathis, 2014). Methods of providing these nutrients to plants contain the utilize of organic matters like green manure, organic wastes, tree leaves and grass clippings (Sekhon, 2003; Demir and Gülser, 2010). Incorporation of the following amendments develop the these nutrients additional contents in soil: ruined remains of crops and plants, compost, crop residues, silage juice, beddings, wash water, spent supplement solutions, spent soilless media and spent mushroom media (Zu et al., 2005). Crop residue management is a key element of sustainable crop production. Crop residues have been used for soil and water conservation as mulch. Besides crop residues permit to sustain soil organic matter and to return nutrients to. It is important to use cover crops to accomplish the objectives of sustainable cropping systems (Ruffo and Bollero, 2003). Therefore, new approaches should be evaluated for sustainable soil management, environmental protection and human health. While there are many studies on cover crops, studies dealing with effects on diethylene triamine penta acetic acid (DTPA)-extractable micronutrients of the *Trifolium repens* L. (TR), *Festuca rubra* subsp. *rubra* L. (FRR), *Festuca arundinacea* (FA), *Trifolium repens* (40%)+*Festuca rubra* subsp *rubra* (30%)+*Festuca arundinacea* (30%) mixture (TFF), *Vicia villosa* Roth. (VV) and *Trifolium meneghinianum* Celm. (TM) in orchards are very limited. The aims of this study were: i) to compare the effect of different cover crop treatments on DTPA-extractable micronutrients (Fe, Mn, Zn and Cu) and soil pH in a hazelnut orchard with clay loam texture and in an apple orchard with sandy loam texture, ii) to identify relationship between soil pH and DTPA-extractable Fe, Mn, Zn and Cu.

Material and Methods

Experiments were conducted over the experimental fields of Erciyes University Agricultural Faculty and Black Sea Agricultural Research Institute between the years 2013-2014. Experimental site of Erciyes University Agricultural Faculty is located between 41.38 N - 36.38 E, had an annual average temperature of 14.6°C between 2012-2014 growing season, an average annual precipitation of 675.6 mm. Experimental site of Black Sea Agricultural Research Institute is located in Middle Black Sea region (Latitude, 37° 05 N; Longitude, 41° 07 E; elevation 50 m). Annual average temperature was 14.5 °C and annual average precipitation was 685.5 mm. The cover crop treatments consisted of *Trifolium repens* L. (TR), *Festuca rubra* subsp. *rubra* L. (FRR), *Festuca arundinacea* (FA), *Trifolium repens* (40%)+*Festuca rubra* subsp. *rubra* (30%)+*Festuca arundinacea* (30%) mixture (TFF), *Vicia villosa* Roth. (VV) and *Trifolium meneghinianum* Celm. (TM). Experiments also included a plot mechanically cultivated (MC), herbicide treatment (HC) and bare control plot (BC). The species chosen for cover cropping are generally those that are familiar to the grower and are known to perform well in a particular environment, and for which seed can be cheaply and readily obtained (Penfold, 2010). Randomized complete blocks design was used in these experiments and all cover crops were grown on the same plot during the experimental periods. Experiments were conducted in 4 replications. Each ocak comprises ten to twelve stems with average heights of 3 m. The ocak interval was 3 m in the row and 4 m between rows. Glyphosate isopropylamine salt (360 g a.i L^{-1}) was implemented at 2880 ml ha^{-1} (1.39 kg a.i ha^{-1}) in the herbicide plots. Glyphosate was applied at 3 atm pressure (303.97 kPa) with 250 L ha^{-1} spraying volume with a portable hand sprayer (Honda WJR 2225). The cover crops were broadcast seeded at 50, 80 and 70 kg ha^{-1} for *T. repens, Festuca* spp. and mixture of perennials respectively on April 20, 2012. *V. villosa* (100 kg ha^{-1}) and *T. meneghinianum* (40 kg ha^{-1}) were sown October, 20 2012 and November 2, 2013. The cover crops were mowed in the flowering stages of the cover crops. After spreading, the seed of cover crops was incorporated into the soil by a shallow cultivation. Soil samples were taken from 0-20 and 20-40 cm depths 90 d after crops mow with a soil auger. Two different sampling depths were selected since root densities of crops are different for top- and subsoil (Steingrobe, 2005). After collecting the soil samples, it was stored in a plastic bag and identified. Air dried samples were made ready for analyses through sieving from 2 mm sieve. Some soil characteristics were determined as follows; particle size distribution by hydrometer method (Demiralay, 1993), soil reaction (pH) in 1:1 (w:v) soil water suspension by pH meter; electrical conductivity ($EC_{25ºC}$) in the same soil suspension by EC meter (Kacar, 1994); extractable cations [calcium (Ca), potassium (K), magnesium (Mg), and sodium (Na)] by ammonium acetate (CH_3COONH_4) extraction (Kacar, 1994); lime content by Scheibler calsimeter (Soil Survey Staff, 1993); micronutrients (Fe, Mn, Zn, and Cu) by the extraction with DTPA extraction solution by using atomic absorption spectrophotometers according to Kacar (1994). Organic matter content was identified by modified Walkley–Black method (Kacar, 1994). Initial soil characteristics are provided in Table 1. Initial analyses revealed that experimental soil of apple orchard were sandy loam in texture, slightly alkaline with low organic matter contents (Soil Survey Staff, 1993). Results revealed that soil of hazelnut orchard were unsaline, clay loam in texture with slightly acidic pH and moderate in organic matter (Soil Survey Staff, 1993). Experimental results were subjected to statistical analyses with SPSS software. Data were subjected to ANOVA. Treatment means were compared with Duncan's multiple range test at the 0.01 probability level except for extractable Zn (at the 0.05 probability level) in the hazelnut orchard and correlation analyses were performed to express the relationships between experimental parameters (Yurtsever, 1984).

Table 1. Some physical and chemical properties of the soils at the beginning of the experiment

Soil properties	Hazelnut orchard		Apple orchard	
	Soil depth, cm		Soil depth, cm	
	0-20	20-40	0-20	20-40
Sand, %	32.11	32.69	74.41	73.51
Silt, %	37.63	31.10	15.23	15.41
Clay, %	30.26	36.21	10.37	11.08
Soil textural class	CL	CL	SL	SL
pH (1:1)	6.51	6.52	7.57	7.55
$EC_{25°C}$, dS m^{-1}	0.491	0.383	0.45	0.44
OM, %	2.25	0.70	0.61	0.53
$CaCO_3$, %	0.85	0.78	0.79	0.74
Ext. Ca, me 100 g^{-1}	11.99	10.42	6.24	6.36
Ext. Mg, me100g^{-1}	3.65	3.03	2.40	1.96
Ext. Na, me 100 g^{-1}	0.36	0.31	0.32	0.31
Ext. K, me 100 g^{-1}	0.82	0.59	0.25	0.20
Ext. Fe, mg kg^{-1}	53.95	31.01	1.96	1.94
Ext. Mn, mg kg^{-1}	63.36	60.79	4.31	3.28
Ext. Zn, mg kg^{-1}	2.12	0.49	0.68	0.32
Ext. Cu, mg kg^{-1}	1.14	0.58	0.87	0.59

Results and Discussion

The extractable micronutrients (Fe, Mn, and Zn) and soil pH values were significantly influenced by the cover crop treatments at 0-20 cm soil depth. While cover crop treatments in the hazelnut orchard with clay loam texture (Figure 1) and in the apple orchard with sandy loam texture (Figure 2) importantly reduced pH values of soils according to the bare control, the cover crop treatments increased the DTPA-extractable micronutrients (Fe, Mn, and Zn) of soils in the 0-20 cm soil depth. Higher improvement rates were generally observed in the second year of the experiments. In both years of the experiment, significant differences were generally not observed in the extractable micronutrients (Fe, Mn and Zn) and pH values of a plot mechanically cultivated, herbicide treatment and bare control at 0-20 cm soil depth in the orchards (Figure 2, 3).

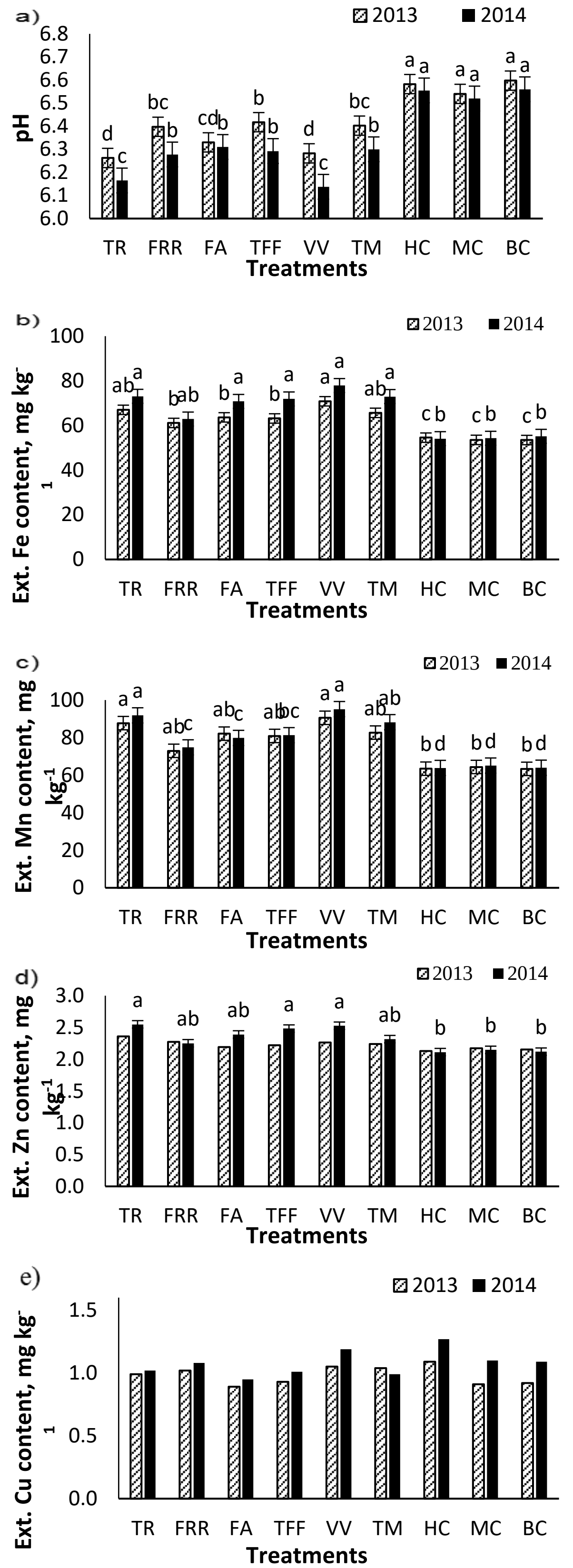

Figure 1. Effects of cover crop and other treatments on a) pH, b) Fe, c) Mn, d) Zn, and e) Cu of the hazelnut orchard soils at 0-20 cm soil depth.

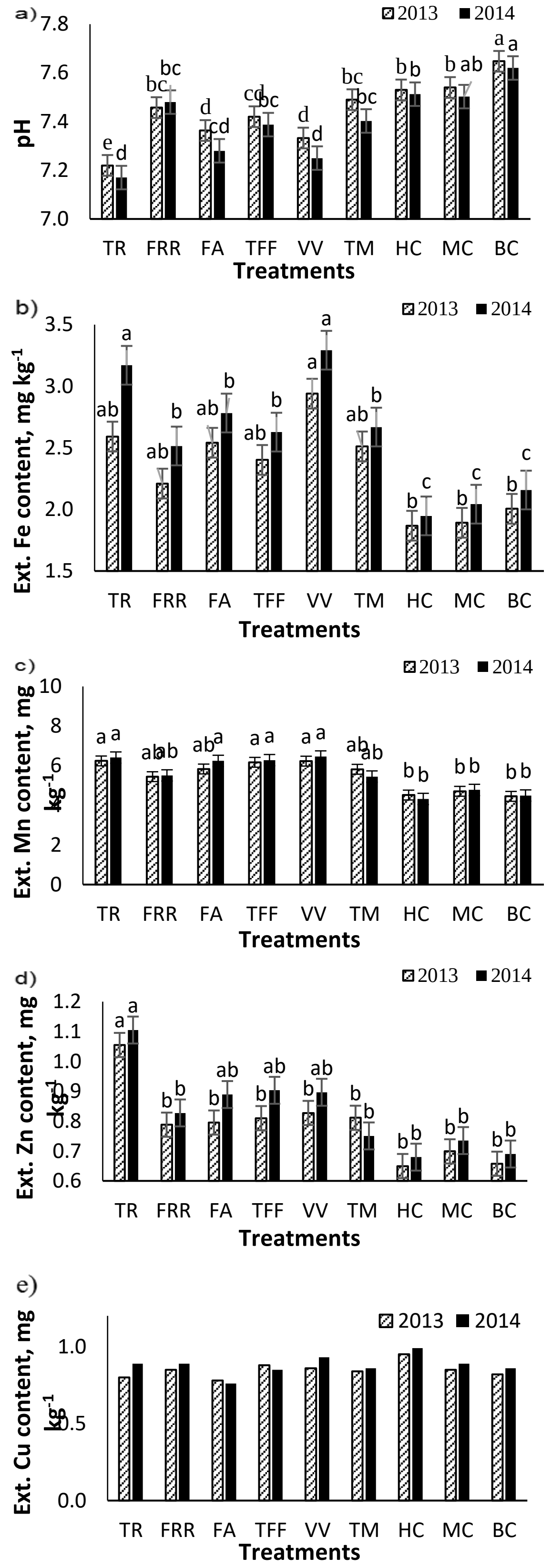

Figure 2. Effects of cover crop and other treatments on a) pH, b) Fe, c) Mn, d) Zn, and e) Cu of the apple orchard soils at 0-20 cm soil depth.

pH values of the soils generally decreased with cover crops treatments according to the bare control in the hazelnut and apple orchards. Changes in pH values at 0-20 cm soil depth in the hazelnut orchard were given Figure 1a. Irrespective of years, mean pH value in the hazelnut orchard was ordered as; VV (6.21) < TR (6.22) < FA (6.32) < FRR (6.34) < TM (6.35) < TFF (6.36) < MC (6.53) < HC (6.57) < BC (6.58). As compared to bare control, percent decreases in mean pH values at 0-20 cm soil depth varied between 3.40% in TFF and 5.61% in VV treatments in the hazelnut orchard (Figure 3a). While the highest mean pH value was found in the BC treatment (7.63), the lowest pH value was found in the TR treatment (7.20) at 0-20 cm soil depth in the apple orchard (Figure 2a). Irrespective of years, mean soil pH in the apple orchard was ordered as; TR (7.20) < VV (7.29) < FA (7.32) < TFF (7.40) < TM (7.45) < FRR (7.47) < MC (7.51) < HC (7.52) < BC (7.63). As compared to bare control, percent decreases in pH values at 0-20 cm soil depth varied between 2.16% in FRR and 5.75% in TR treatments in the apple orchard (Figure 4a). Moreti et al. (2007) identified that cover crop treatments may considerably influence the soil pH. The soil pH is a key component of soil fertility. Increasing or decreasing the rate of soil pH influences the micronutrient availability to plants and is considered to be a primary factor for these nutrient inadequacy. Soils of high pH ranges (> 6.5) can have restricted these nutrient availability to plants, thus requiring fertilizer amendment (Poh et al., 2009). Cover crops may considerably influence the soil pH. Plants have transudation of acids to the soil from their roots that may perform directly on the soil pH (Moreti et al., 2007). In this study, the cover crops used as a source of organic matter supplied for a decrement of the soil pH. Additionally, when soil organic matter is mineralized there is production of organic acids that can make a contribution to increased soil acidity (Garcia and Rosolem, 2010).

Extractable Fe contents of the soils generally increased with cover crops treatments according to the bare control in the hazelnut and apple orchards. While the highest mean extractable Fe content was found in the VV treatment (74.35 mg kg^{-1}), the mean lowest Fe content was found in the MC treatment (53.90 mg kg^{-1}) at 0-20 cm soil depth in the hazelnut orchard (Figure 1b). Mean extractable Fe contents (mg kg^{-1}) in the hazelnut orchard was ordered as; MC (53.90) < BC (54.32) < HC (54.33) < FRR (62.00) < FA (67.20) < TFF (67.51) < TM (69.30) < TR (70.03) < VV (74.35). As compared to bare control, percent increases in mean extractable Fe content at 0-20 cm soil depth varied between 14.15% in FRR and 36.82% in VV treatments in the hazelnut orchard (Figure 3b). While the highest mean extractable Fe content was found in the VV treatment (3.12 mg kg^{-1}), the mean lowest extractable Fe content was found in the HC treatment (1.91 mg kg^{-1}) at 0-20 cm soil depth in the apple orchard (Figure 2b). Mean extractable Fe contents (mg kg^{-1}) in the apple orchard was ordered as; HC (1.91) < MC (1.97) < BC (2.08) < FRR (2.36) < TFF (2.51) < TM (2.59) < FA (2.66) < TR (2.88) < VV (3.12). As compared to bare control, percent increases in mean extractable Fe content at 0-20 cm soil depth varied between 13.51% in FRR and 49.72% in VV treatments in the apple orchard (Figure 4b). The determined result is comply with the result acquired by Mathur et al. (2006); Sharma et al. (2003); Sidhu and Sharma (2010), and Yadav (2011). Cover crop treatments may increase the quantities of micronutrients in the soil and decrease the treatment of fertilizers, cause to lower costs of production and contributing to the maintainability (Bernardi et al., 2003). Besides, Franzluebbers and Hons (1996) identified increases in Mn, Fe and Zn in soil under cover crops.

Extractable Mn contents of the soils generally increased with cover crops treatments according to the bare control in the hazelnut and apple orchards. While the highest mean extractable Mn content was found in the VV treatment (92.87 mg kg^{-1}), the lowest mean extractable Mn content was found in the HC treatment (63.64 mg kg^{-1}) at 0-20 cm soil depth in the hazelnut orchard (Figure 1c). Mean extractable Mn contents (mg kg^{-1}) in the hazelnut orchard was ordered as; HC (63.64) < BC (63.65) < MC (64.73) < FRR (73.87) < FA (80.96) < TFF (81.08) < TM (85.44) < TR (89.78) < VV (92.87). As compared to bare control, percent increases in mean extractable Mn content at 0-20 cm soil depth varied between 16.06% in FRR and 45.91% in VV treatments in the hazelnut orchard (Figure 3c). While the highest mean extractable Mn content was found in the VV treatment (6.35 mg kg^{-1}), the lowest mean extractable Mn content was found in the HC treatment (4.42 mg kg^{-1}) at 0-20 cm soil depth in the apple orchard (Figure 2c). Mean extractable Mn contents (mg kg^{-1}) in the apple orchard was ordered as; HC (4.42) < BC (4.47) < MC (4.74) < FRR (5.48) < TM (5.64) < FA (6.04) < TFF (6.23) < TR (6.33) < VV (6.35). As compared to bare control, percent increases in mean extractable Mn content at 0-20 cm soil depth varied between 6.01% in MC and 41.87% in VV treatments in the apple orchard (Figure 4c). Similar result was also identified by Mathur et al. (2006); Sharma et al. (2003); Sidhu and Sharma (2010) and Yadav (2011). Mn content in soil solution should theoretically reduce 100-fold for every unit of pH increase (Barber, 1995).

Extractable Zn contents of the soils generally increased with cover crops treatments according to the bare control in the hazelnut and apple orchards. While the highest mean extractable Zn content was found in the TR treatment (2.45 mg kg^{-1}), the lowest mean extractable Zn content was found in the HC treatment (2.12 mg kg^{-1}) at 0-20 cm soil depth in the hazelnut orchard (Figure 1d). Mean extractable Zn contents (mg kg^{-1}) in the hazelnut orchard was ordered as; HC (2.12) < BC (2.14) < MC (2.16) < FRR (2.26) < TM (2.28) < FA (2.29) < TFF (2.35) < VV (2.40) < TR (2.45). As compared to bare control, percent increases in mean extractable Zn content at 0-20 cm soil depth varied between 5.96% in FRR and 14.91% in TR treatments in the hazelnut orchard (Figure 3d). While the highest mean extractable Zn content was found in the TR treatment (1.08 mg kg^{-1}), the lowest mean extractable Zn content was found in the HC treatment (0.66 mg kg^{-1}) at 0-20 cm soil depth in the apple orchard (Figure 2d). Mean extractable Zn contents (mg kg^{-1}) in the apple orchard was ordered as; HC (0.66) < BC (0.67) < MC (0.72) < TM (0.78) < FRR (0.81) < FA (0.84) < TFF (0.85) < VV (0.86) < VV (1.08). As compared to bare control, percent increases in mean extractable Zn content at 0-20 cm soil depth varied between 6.41% in MC and 60.30% in TR treatments in the apple orchard (Figure 4d). High pH reduces the solubility and mobility of Zn in soils by stimulating its absorption to soil components and limiting its diffusion to plant roots (Sherene, 2010).

The differences in the extractable Cu contents of soils in the orchards were not found to be significant for 0-20 and 20-40 cm soil depths in both years of experiments. Mean extractable Cu content varied between 1.01 mg kg^{-1} in BC and 1.18 mg kg^{-1} in HC treatments in the hazelnut orchard (Figure 1e). Mean extractable Cu content varied between 0.84 mg kg^{-1} in BC and 0.97 mg kg^{-1} in HC treatments in the apple orchard (Figure 2e). Soil organic matter exerts a important and direct influence on the availability of Mn, Zn and Fe but has small impact on the availability of soil Cu (Zhang et al., 2001). Fageria (2009) determined that copper is taken up by the plants in only very little amounts. As compared to bare control, percent changes in extractable Cu content at 0-20 cm soil depth varied were given Figure 3e and 4e.

The differences in the extractable micronutrients (Fe, Mn, Zn, and Cu) and pH values of soils in the orchards were not found to be significant for 20-40 cm soil depth in both years of experiments (Table 4).

Table 4. Effects of different cover crops and other treatments on soil pH and extractable micronutrients (mg kg^{-1}) at 20-40 cm soil depth

	Hazelnut Orchard					Apple Orchard				
	pH	Fe	Mn	Zn	Cu	pH	Fe	Mn	Zn	Cu
2013										
TR	6.50	31.64	62.99	0.50	0.58	7.49	2.20	3.85	0.36	0.55
FRR	6.59	31.35	60.08	0.48	0.59	7.59	1.81	3.32	0.32	0.51
FA	6.38	32.87	60.42	0.52	0.61	7.59	1.90	3.45	0.30	0.56
TFF	6.44	33.64	62.12	0.48	0.60	7.58	2.06	2.87	0.33	0.53
VV	6.39	31.31	62.26	0.49	0.66	7.52	1.92	3.50	0.36	0.57
TM	6.40	31.36	59.07	0.50	0.56	7.64	1.78	2.89	0.34	0.53
HC	6.58	31.00	60.29	0.46	0.56	7.70	1.84	3.38	0.30	0.56
MC	6.55	30.60	61.56	0.46	0.59	7.64	2.13	3.35	0.29	0.55
BC	6.57	30.49	59.63	0.47	0.61	7.70	1.94	3.41	0.33	0.58
2014										
TR	6.39	36.61	62.85	0.61	0.59	7.40	2.02	3.46	0.41	0.55
FRR	6.61	31.68	63.99	0.55	0.60	7.39	1.97	3.60	0.39	0.54
FA	6.42	32.40	63.36	0.63	0.68	7.42	2.12	4.15	0.35	0.60
TFF	6.35	36.12	62.13	0.52	0.59	7.45	2.23	3.80	0.34	0.55
VV	6.34	35.10	61.74	0.52	0.64	7.48	2.06	3.17	0.35	0.67
TM	6.34	33.27	62.48	0.55	0.64	7.43	2.04	3.27	0.35	0.62
HC	6.58	30.29	60.28	0.49	0.66	7.45	1.90	3.23	0.33	0.64
MC	6.52	31.70	62.75	0.51	0.51	7.51	1.91	3.19	0.33	0.61
BC	6.59	32.00	60.24	0.55	0.57	7.50	1.93	3.13	0.34	0.60

Trifolium repens L. (TR), *Festuca rubra* subsp. *rubra* L. (FRR), *Festuca arundinacea* (FA), *Trifolium repens* (40%)+*Festuca rubra* subsp *rubra* (30%)+*Festuca arundinacea* (30%) mixture (TFF), *Vicia villosa* Roth. (VV) and *Trifolium meneghinianum* Celm. (TM), a plot mechanically cultivated (MC), herbicide treatment (HC) and bare control plot (BC).

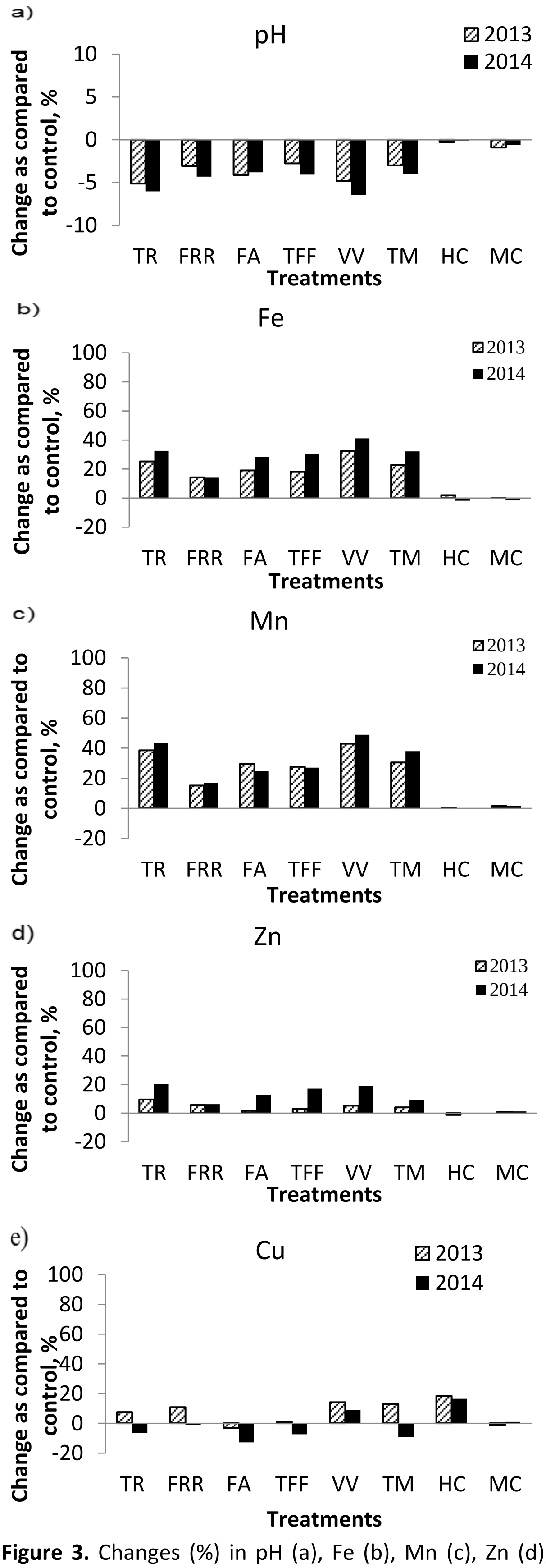

Figure 3. Changes (%) in pH (a), Fe (b), Mn (c), Zn (d), and Cu (e) contents at 0-20 cm soil depth as compared to the bare control in the hazelnut orchard

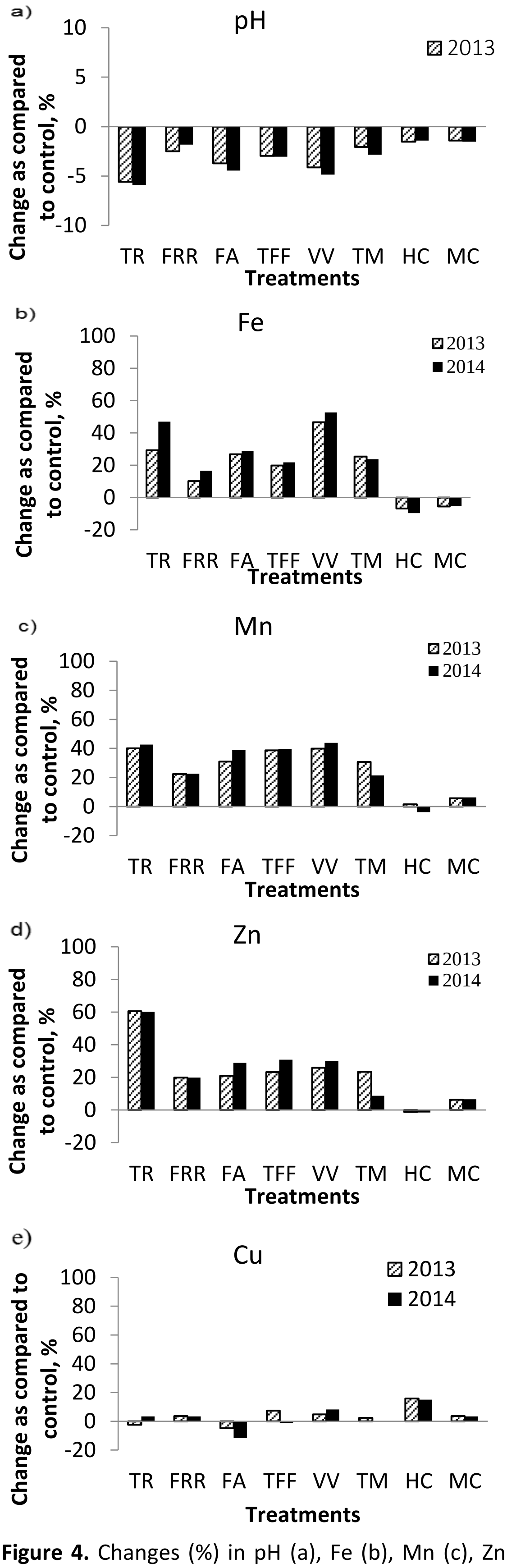

Figure 4. Changes (%) in pH (a), Fe (b), Mn (c), Zn (d), and Cu (e) contents at 0-20 cm soil depth as compared to the bare control in the apple orchard

Descriptive statistics of the orchard soils are given in Table 2. The extractable Mn, Fe, Zn, and Cu contents in the hazelnut orchard soils with clay loam texture were higher than that in the apple orchard soils with sandy loam texture. Regarding available DTPA-extractable micronutrients values, except mean extractable Mn value in the apple orchard were above the critical levels for deficiency in the soils of both orchards (Lindsay and Norvell, 1978). The use of cover crops supply for a important increment in the range of these nutrients in the soil (Nascente et al., 2013). Using cover crops may be a significant alternate to increment the maintaining of agricultural systems, which can prefer increasing soil fertility, and restoring remarkable quantities of these nutrients to crops. Cover crops with immense root systems may uptake Fe, Mn, Zn, and Cu from deep soil profiles and after chemical desiccation, during straw degradation, let out micronutrients in the soil surface (Cunha et al., 2011). Relations between the DTPA-extractable micronutrients (Fe, Mn and Zn) and pH values were statistically significant at the different significance level ($P< 0.01$ and $P< 0.05$) (Table 3). Significant negative correlations in the VV treatment were observed between soil pH and extractable Fe (-0.768*), between soil pH and extractable Mn (-0.912**), and between soil pH and extractable Zn (-0.842**) in the hazelnut orchard. Significant negative correlations in the TR treatment were observed between soil pH and extractable Fe (-0.841**), between soil pH and extractable Mn (-0.638*), and between soil pH and extractable Zn (-0.645*) in the hazelnut orchard (Table 3). Relations between soil pH and extractable Fe content in the all cover crop treatments were statistically important ($P< 0.01$) in the apple orchard. Significant negative correlations in the VV treatment were observed between soil pH and extractable Fe (-0.957**), between soil pH and extractable Mn (-0.941**), and between soil pH and extractable Zn (-0.718*) in the apple orchard. Significant negative correlations in the TR treatment were observed between soil pH and extractable Fe (-0.968**), between soil pH and extractable Mn (-0.898**), between soil pH and extractable Zn (-0.805**) in the apple orchard (Table 3). The results of this study are accordance with those of the studies mentioned above. The various researcher (Mathur et al. 2006; Sharma et al. 2003, and Sidhu and Sharma 2010) found important and negative correlation between soil pH and available Fe, Mn and Zn.

Table 2. Descriptive statistics for the soil properties

		Minimum	Maximum	Mean	Std. Dev.	CV, %
				Hazelnut orchard		
2013	pH	6.22	6.64	6.42	0.123	1.91
	Ext. Fe, mg kg^{-1}	46.97	72.52	61.46	6.767	11.01
	Ext. Mn, mg kg^{-1}	50.00	97.20	76.45	12.993	16.92
	Ext. Zn, mg kg^{-1}	1.95	2.5	2.22	0.112	5.02
	Ext. Cu, mg kg^{-1}	0.75	1.2	0.98	0.122	12.44
2014	pH	6.07	6.62	6.35	0.157	2.48
	Ext. Fe, mg kg^{-1}	46.20	88.03	65.88	10.870	16.50
	Ext. Mn, mg kg^{-1}	53.82	97.73	78.22	12.133	15.51
	Ext. Zn, mg kg^{-1}	1.85	2.89	2.32	0.246	10.57
	Ext. Cu, mg kg^{-1}	0.69	1.40	1.08	0.153	14.20
				Apple orchard		
2013	pH	7.11	7.67	7.44	0.129	1.73
	Ext. Fe, mg kg^{-1}	1.39	3.41	2.33	0.474	20.34
	Ext. Mn, mg kg^{-1}	3.78	7.95	5.49	0.913	16.63
	Ext. Zn, mg kg^{-1}	0.54	1.20	0.79	0.137	17.34
	Ext. Cu, mg kg^{-1}	0.70	1.05	0.85	0.087	10.24
2014	pH	7.08	7.71	7.40	0.144	1.95
	Ext. Fe, mg kg^{-1}	1.70	3.52	2.58	0.477	18.49
	Ext. Mn, mg kg^{-1}	3.00	7.12	5.55	0.982	17.69
	Ext. Zn, mg kg^{-1}	0.53	1.27	0.83	0.160	19.28
	Ext. Cu, mg kg^{-1}	0.65	1.13	0.88	0.114	13.01

Conclusion

This study showed that cover crop treatments generally increased DTPA-extractable micronutrients (Fe, Mn and Zn) at 0-20 cm soil depth both in the hazelnut orchard with clay loam texture and in the apple orchard with sandy loam texture. While the DTPA-extractable micronutrients (Fe, Mn and Zn) increased, soil pH decreased with cover crop treatments. The micronutrient (Fe, Mn and Zn) contents varied from cover crop to cover crop. Soil pH has generally significant negative correlations with the DTPA extractable micronutrients. The greatest positive effects of cover crop treatments were observed in *Vicia villosa* (VV) and *Trifolium repens* (TR) treatments. In both years of the experiments, there were not any significant differences in measured variables at 0-20 cm soil depths of a plot mechanically cultivated, herbicide treatment and bare control. It was concluded based on current findings that cover crops, especially VV and TR treatments could be incorporated into cropping systems to improve soil fertility and to provide sustainable soil management and also could contribute to improved soil, water, and environmental quality.

Table 3. Correlations among soil pH and extractable micronutrients (Fe, Mn, Zn, Cu)

		Hazelnut Orchard				Apple Orchard			
		Ext.Fe	**Ext.Mn**	**Ext.Cu**	**Ext.Zn**	**Ext.Fe**	**Ext.Mn**	**Ext.Cu**	**Ext.Zn**
pH	**TR**	-0.841**	-0.638*	0.489	-0.645*	-0.968**	-0.898**	-0.390	-0.805**
	FRR	-0.750*	-0.816*	-0.239	-0.530	-0.841**	-0.523	0.571	-0.498
	FA	-0.879**	-0.886**	0.512	-0.879**	-0.942**	-0.866**	-0.398	-0.741*
	TFF	-0.790*	-0.914**	0.205	-0.869**	-0.901**	-0.917**	-0.116	-0.797*
	VV	-0.768*	-0.912**	-0.467	-0.842**	-0.957**	-0.941**	-0.383	-0.718*
	TM	-0.760*	-0.882**	0.399	-0.679	-0.854**	-0.688	-0.230	-0.356
	HC	-0.243	0.242	0.100	-0.410	0.506	0.063	-0.133	0.049
	MC	-0.091	-0.366	-0.125	-0.105	0.320	-0.456	0.099	-0.245
Ext.Fe	**TR**	-	0.842**	-0.471	0.459	-	0.763*	0.190	0.839**
	FRR	-	0.575	0.425	-0.046	-	0.402	-0.542	0.548
	FA	-	0.696	-0.686	0.676	-	0.682	0.141	0.736*
	TFF	-	0.846**	-0.628	0.624	-	0.669	0.080	0.810*
	VV	-	0.902**	0.311	0.543	-	0.842**	0.241	0.738*
	TM	-	0.779*	-0.049	0.356	-	0.544	-0.248	0.540
	HC	-	-0.199	-0.432	-0.200	-	0.013	-0.120	0.606
	MC	-	0.423	0.299	0.142	-	-0.617	-0.207	-0.149
Ext.Mn	**TR**	-	-	-0.445	0.234	-	-	0.660	0.636
	FRR	-	-	-0.205	0.428	-	-	0.154	0.066
	FA	-	-	-0.336	0.712*	-	-	0.685	0.486
	TFF	-	-	-0.405	0.745*	-	-	0.100	0.592
	VV	-	-	0.431	0.763*	-	-	0.450	0.544
	TM	-	-	-0.585	0.455	-	-	0.085	-0.026
	HC	-	-	-0.293	-0.635	-	-	-0.073	0.091
	MC	-	-	0.103	0.129	-	-	0.309	-0.147
Ext.Cu	**TR**	-	-	-	0.241	-	-	-	0.250
	FRR	-	-	-	-0.205	-	-	-	-0.438
	FA	-	-	-	-0.170	-	-	-	0.264
	TFF	-	-	-	-0.169	-	-	-	0.104
	VV	-	-	-	0.770*	-	-	-	0.587
	TM	-	-	-	-0.376	-	-	-	-0.131
	HC	-	-	-	0.371	-	-	-	-0.400
	MC	-	-	-	0.611	-	-	-	-0.254

Trifolium repens L. (TR), *Festuca rubra* subsp.*rubra* L. (FRR), *Festuca arundinacea* (FA), *Trifolium repens* (40%)+*Festuca rubra* subsp *rubra* (30%)+*Festuca arundinacea* (30%) mixture (TFF), *Vicia villosa* Roth. (VV) and *Trifolium meneghinianum* Celm. (TM), a plot mechanically cultivated (MC), herbicide treatment (HC) and bare control plot (BC).

Acknowledgement

The authors express their sincere thanks to Turkish Scientific and Technological Research Council (TÜBİTAK) for financial support provided to present study (with the Project number of 111-O-647).

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