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The Effects of Living and Non-Living Mulches on Soil Chemical Properties in Apple Tree

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Abstract

To study the effects of living and non-living mulches on soil chemical properties in apple trees, a randomized complete block design (RCBD) with eight treatments and three replications was implemented. Soybean, clover, alfalfa and mungbean mulches incurred a significant increase in soil organic carbon (SOC). In addition, leguminous plants mulches incurred a significant increase in available total nitrogen (TN), phosphorus (P), potassium (K), manganese (Mn), zinc (Zn) and iron (Fe) in the topsoil. Application of treatments caused a significant decrease in soil salinity. The salt reduction can be due to salts absorption by the cover crop in cover crops and due to an increased leaching process and reduction of evaporation in plastic mulch. Green mulches improved physicochemical, biological properties and rhizosphere soil quality by increasing organic soil matters and nutrient availability.

Keywords: Living, Non-Living Mulches, Apple, Soil, Tillage

Introduction

Management and type of vegetation among tree rows has an important impact on health, growth and flourishing production of fruit trees. Raheb et al., 2007, reported (orchards of northern Iran) that different cover crop treatments (soybeans, beans, mungbean and clover) have a significant impact on soil potassium, organic matter, and nitrogen. The highest K was achieved by green beans/mungbeans at a depth of 0-30 cm and clover treatment at a depth of 30-60 cm after two months after returning the plants to the soil. Regarding the percentage of nitrogen, the highest rate was obtained from the treatment in which soybeans were used as a cover crop, the amount of which is about 4 times more than the control treatment (no cover crop). Regarding the percentage of organic matter, the highest rate was obtained from soybeans at the depth of 0-30 cm and green beans at the depth of 0-60cm (Raheb and et al, 2006).

It was reported that paper mulches(such as newspapers, etc.) is a perfect tool to control the growth of weeds and protection of soil moisture in orchards, nurseries, fruit plants production pots(containers) and ornamental plants. Benefits of paper mulch compared to black plastic mulch are as follows: it is in harmony with nature, decayed over time, added to the soil in humus form, does not have weed seed contamination in it, does not need to be collected, used in herbicide-sensitive plants such as watermelon, control weeds near plant crowns that cannot be sprayed, economical, and not an obstacle to the next plow. Although some weed seeds germinate even in the dark, however, mulches prevent from deepening its root system and a subsequent production of strong foliage (Hamzei and Abutalebian, 2012; Mervine and Alex, 2003; Preusch and Tworkoski 2000).

Reganold et al., 2006 and Reijneveld et al., 2009, reported that different species of clover are cultivated in Pennsylvania orchards. Perennial cover crops may reduce soil erosion, create a smooth surface for machinery traffic, avoid dust and its sitting on fruits, insulate against the cold in winter, increase the movement of key nutrients including calcium into the root zone of trees, and become a winter shelter to beneficial insects as well. Furthermore, they increase soil organic matter (SOM) over time, and if a suitable soil pH is guaranteed, the need for phosphorus fertilizer decreases during the growing season (Reganold and et al, .2006; Reijneveld and et al, 2009; Samadani and Montazeri, 2009). The research aims were to determine the effects of different weed control on the soil chemical properties, the maintenance of production stability, soil fertility, and lack of environmental pollution.

Material and Methods

The plan was implemented in the form of randomized complete block design (RCBD) with eight treatments and three replications. Each plot consists of two golden apple tree cultivars, a tree was placed as a guard between each plot. A border row was set between each block. Treatments were 1) control (traditional tillage), 2) clover(Trifolium resupinatum L.) cover in inter-tree spacing and return it to the

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soil at the end of the season, 3) mungbean cover (Vigna radiate L.) in inter-tree spacing and return it to the soil at the end of growing season, 4) soybean cover (Glycin max L.) in inter-tree spacing and return it to the soil at the end of growing season, 5) alfalfa cover (Medicago sativa L.) in inter-tree spacing and return it to the soil at the end of the season, 6) rotivator+the application of black plastic mulch between trees, as an integrated treatment, 7) use of Glyphosate(Roundup) as herbicide, 8) use of rotivator in inter-tree spacing.

The orchard in which the experiment took place consisted of fifteen-year-old Golden apple tree cultivars with an MM106 (dwarf) with densities of one thousands trees per hectare (4 x 2.5 m^2 planting pattern), respectively. Geographic coordinates of project implementation location (Horticulture research station, Vardasht, Semirom) is, latitude: 31° 37″ 20.7′E, longitude: 51° 32″ 36.8′E, and altitude: 2381 meters (7,812 feet).

In the composite soil samples provided at the end of growing season, organic carbon, pH, electrical conductivity, phosphorus, potassium, and metal microelements levels were determined. According to the results of soil testing, the necessary annual amount of fertilizer was provided for the trees. Analysis of variance (ANOVA) and Duncan's multiple-range test (compare means) test (SAS, MSTATC) were conducted. Irrigation water quality was suitable and there were no restrictions for irrigation (table1).

Table 1- Some of the irrigation water chemical properties

EC. dSm^{-1}	pH	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	Na^+	K^+	$Ca^{2+}+Mg^{2+}$
			meq l^{-1}					
0.73	7.6	4.4	0.4	1.5	0.45	0.5	1.45	4.8

Results and Discussion

Changes in soil organic carbon

Soybean, clover, alfalfa, and mung bean mulch treatments incurred a significant increase in soil organic carbon (table2). Due to the lack of organic carbon in the soil, the same research demonstrate the effectiveness of these treatments to improve one of the most important parameters affecting the biological, chemical, and physical properties of the soil. Among treatments, the greatest increase in soil organic carbon was obtained from the alfalfa mulch, which can be caused by the excessive growth (abundant foliage production), widespread and deep root system (significant increase in soil organic carbon is also found at a depth of 30-60 cm) of this plant. Mung bean, clover, and soybean mulches came next, which were in direct contact with the direct foliage production volume of these plants. Samadani and Montazeri, 2009 reported the positive effects of green mulch on SOC.

Table 2- Mean values of mulch effects on SOC (%) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	0.38a	0.65b	0.69b	0.58b	0.34a	0.39a	0.36a	1.0c
30-60	0.39a	0.59b	0.59b	0.5b	0.38a	0.33a	0.32a	0.7c

* Numbers followed by the same letter are not significantly different (P<0.05)

EC: The application of treatments incurred a significant decrease in soil salinity (table 3). The salinity reduction can be due to the absorption of soil salts by the plant in the vegetation, and due to an increased leaching process and reduced evaporation in plastic mulch treatment. Show 1982 reported the same results.

Table 3- Mean values of mulch effects on soil EC (ds m^{-1}) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	0.88a	0.93a	0.62b	0.61b	0.47b	0.55b	0.45b	0.68b
30-60	0.7a	0.55b	0.65b	0.78b	0.63b	0.63b	0.61b	1.0a

* Numbers followed by the same letter are not significantly different (P<0.05)

PH: Although the effect of treatments on changes in soil pH was not significant. As it is mentioned in scientific sources as well, the type of tree roots will have an interaction with soil rhizosphere pH. These effects include proton secretion and rhizosphere acidification (majority of plants) and chelating agents (cereal roots) by the root of plants, various kinds of symbiotic microorganisms and plants, and so on. Acidity is one of the most important factors affecting soil biological, chemical and physical interactions. Such that each unit decrease in pH, increases the solubility of elements like Fe, Zn, Mn etc., and a hundredfold in alkaline soils. Gandomkar, 2007 resulted the effect of living mulch to improved soil pH in a calcareous soil.

N:Clover, mung bean, soybean, and alfalfa mulches(leguminous treatments) significantly increased the quantity of soil nitrogen(table4).This reflects the importance of vegetation type in expanding soil nitrogen reserves and the effect of replacing weeds with leguminous plants. Raheb et al., 2007 and Perush et al., 2000, reported an increase in soil nitrogen by the use of leguminous mulch. The most important challenge of soil fertility in arid areas is the lack of nitrogen in the soil. The main source of nitrogen in the soil is organic matter. Leguminous plants play an effective role in providing soil nitrogen reserves due to their coexistence with rhizobia as well as supplying the carbon and energy required by the symbiotic and non-symbiotic bacteria.

Table 4- Mean values of mulch effects on soil N (%) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	0.033a	0.063b	0.047b	0.047b	0.023a	0.033a	0.03	0.05b
30-60	0.04a	0.05b	0.027a	0.03a	0.02a	0.03a	0.02a	0.03a

* Numbers followed by the same letter are not significantly different ($P<0.05$)

$CaCO_3$: The effects of treatments on soil $CaCO_3$ did not show any particular trend (table 5). That may be caused by buffering properties of the soil matrix (due to high amounts of lime) against localized reactions. A low amount of lime in soil surface layer may be due to leaching, root acid secretion, acids resulting from decomposition of organic matters, carbon dioxide activity (carbonic acid production), lime leaching by rainfall, irrigation and its.

Accumulation on lower horizons, and so on. One of the outstanding characteristics of arid area soils is an abundant amount of lime ($CaCO_3$) in the soil matrix, thereby affecting all soil chemical, physical, and biological equilibria and processes. Lime reduces the solubility of metallic elements required for the plant by alkalizing soil pH. Vegetation type, which interacts with rhizosphere, could moderate the effects of lime and thus increase the uptake of soil autochthonous elements by the plant.

Table 5- Mean values of mulch effects on soil $CaCO_3$ (%) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	30b	29.7b	27.7b	25.7a	28.3b	25.7a	29.3b	25a
30-60	35.7c	28.7b	27b	29.7b	30.7b	28.3b	33.3c	27b

* Numbers followed by the same letter are not significantly different ($P<0.05$)

P: Clover and mung bean mulch caused a significant increase in soil available phosphorus (table 6). Soil phosphorus chemical equilibria are one of the most complex interactions between nutrients. Phosphorus (P) has no mobility in soil and accumulates in the top soil layer. Phosphorus which enters into the soil through chemical fertilizers and organic resources have residual and long-term effects, thereby remains effective in the soil for several years. The use of cover crops is one of the mechanisms for increasing the availability of native phosphorus and soil residues.

Table 6- Mean values of mulch effects on soil available P (mg kg^{-1}) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	10.5b	20c	17.2c	13.7b	12.8b	10.4b	9.8b	13.5b
30-60	6.8a	13.8b	13.6b	10.7b	9.6b	6.3a	5.4a	11b

* Numbers followed by the same letter are not significantly different ($P<0.05$)

K: The largest increase in soil potassium (K) level was obtained from mung bean and alfalfa treatments, respectively. In these treatments, K concentration was significantly increased in surface layers as well, which reflects the impact of the transfer of potassium from the middle (depth) to the soil surface (table7). Raheb et al., 2007 reported as well an increase in the soil available K level due to the use of mung beans and green-beans as green mulch and fertilizer. Iranian soils are rich in K (Mica clay) due to youngness. Plants such as alfalfa, mung bean, and clover with deep root systems cause potassium transport from bottom layers of the soil to the surface layer, and then taken up by the main plant. Clover, mung bean, soybean, and alfalfa treatments incurred a significant increase in soil available K (table 7).

Table 7- Mean values of mulch effects on soil available K (mg kg^{-1}) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	351.3b	440c	466.7c	423.7c	315b	323.3b	346.7b	450c
30-60	280a	397b	362.7b	381.3b	287b	327.3b	364b	300a

* Numbers followed by the same letter are not significantly different (P<0.05).

Zn: As shown in(table 8), clover, soybeans, and alfalfa mulch treatments incurred a significant increase in soil available Zn. Organic compounds and proton pumps in roots as well as compounds resulting from plants residues decomposition increase Zn availability by chelation and rhizosphere acidification. Zn deficiency is very common in fruit orchards. The most obvious symptoms of Zn deficiency in apple trees include stubborn, die-back (wilting and declining of branches), small and low-quality fruits, and ultimately the death of the tree.

Table 8- Mean values of mulch effects on soil available Zn (mg kg^{-1}) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	1.1a	2.3b	1.9a	2b	1.23a	1.43a	1.3a	2.4b
30-60	0.87a	1.2a	1.3a	1.25a	0.61a	0.7a	0.7a	1.5a

* Numbers followed by the same letter are not significantly different (P<0.05).

Mn: The effect of treatments on soil available Mn changes are shown in (table 9). Available Mn in the soil surface layer showed a significant increase, especially in clover, mung beans and soybeans treatments, indicating the effectiveness of these treatments in increasing soil available manganese. Reactions of manganese in the rhizosphere are strongly influenced by redox reactions (Granastein and Sanchez, 2009).

Table 9- Mean values of mulch effects on soil available Mn (mg kg^{-1}) *

treatment / depth(cm)	1	2	3	4	5	6	7	8
0-30	9.6a	13.7b	12.5b	13b	12.6b	11a	12.7b	8.4a
30-60	91.6a	14.9b	11.6a	11.4a	9.8a	10.5a	9.7a	7.1a

* Numbers followed by the same letter are not significantly different (P<0.05).

Cu: The three-year average treatment effect on soil available copper is shown in (table 10). Only alfalfa mulch treatments caused a significant increase in soil available copper, which may be caused by a deep root system and its ability to transport copper from middle soil profile to the soil surface. Cu deficiency did not reported from Semirom apple orchard (Gandomkar, 2007a; Gandomkar, 2007b; Shahabi, 2001).

Table 10- Mean values of mulch effects on soil available Cu (mg kg^{-1}) *

treatment / Depth (cm)	1	2	3	4	5	6	7	8
0-30	1.4a	1.6a	1.8a	1.9a	1.3a	1.2a	1.2a	2.2b
30-60	1.3a	1.5a	1.5a	1.6a	1.3a	1.2a	1.1a	2b

* Numbers followed by the same letter are not significantly different (P<0.05).

Fe: As shown in (table 11), leguminous mulches incurred a significant increase in soil available iron (Fe) especially in the surface layers. The greatest amount of available (absorbable) Fe was obtained for the alfalfa mulch treatment. The most notable shortage of metal elements pertains to iron deficiency in apple orchards.

Table 11- Mean values of mulch effects on soil available Fe (mg kg^{-1}) *

treatment / depht(cm)	1	2	3	4	5	6	7	8
0-30	5.6a	6.4b	5.8a	6.1b	5a	4.2a	4.5a	9.3c
30-60	4.9a	6.2b	5.3a	5.6a	5a	4.2a	4.1a	7.7c

* Numbers followed by the same letter are not significantly different (P<0.05).

Symptoms of iron deficiency come in the forms of chlorosis between the veins, growth cessation and dormancy in the meristems, and finally dieback. Iron is an abundant metallic element in the soil (5% of the soil matrix is composed of iron), however, majority of this iron is unavailable (non-absorbable) and comes in the form of insoluble minerals. Cultivation of leguminous plants is one of the methods to increase the solubility of iron in the soil, particularly alfalfa with a strong and deep root system, which increases iron solubility in the soil based on the mechanisms mentioned in the previous sections.

Conclusion

The use of living and non-living mulches in the orchards is essential to maintain a sustainable soil fertility and to resolve the issue of extremely limited water resources. Leguminous plants mulch resulted in a significant increase in available total nitrogen (TN), phosphorus (P), potassium (K), manganese (Mn), zinc (Zn) and iron (Fe) in the topsoil. Soil texture was heavy (26 percent sand, 31 percent silt and 43 percent clay) therefore, soil organic carbon enhancement can improve soil structure and aeration that is vital importance for the development of the roots in apple trees. The use of treatments incurred a significant decrease in soil salinity. The salinity reduction can be due to the absorption of soil salts by the plant in the vegetation and due to an increased leaching process and reduced evaporation in plastic mulch treatment. These findings are in similar with Esfandiari 2011, Felix and Grabosky 2000.

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