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Impacts of Conservation Tillage and Crop Residue Management on Soil Properties: A Short-Term Trial in Iran

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ABSTRACT Soil quality is the basis of agricultural production in each country. Conservation tillage systems and cover cropping methods have an immensely positive effect on physical and chemical soil characteristics which maintain the sustainable agriculture. This study aimed to assess the impact of different tillage practices on soil's physical, chemical, and biological characteristics. This research was conducted in growing season 2017-2018 in the field station in College of Agriculture and Natural Resources, University of Tehran. Furthermore, three files with different soil management were chosen, and some physical, chemical, and biological soil properties were determined. Different tillage systems included traditional soil management, no-tillage & cover cropping for six years, and no-tillage & cover cropping for one year. Results showed that no-tillage management had higher aggregate stability compared to traditional soil management. The quantity of organic carbon and soil microbial respiration was significantly higher in "no-tillage & cover cropping (for six years) management compared to other soil management systems. Due to soil moisture and nitrogen content, no significant differences were observed among different tillage systems. Managing cover crops in conservation tillage systems has a key role to improve soil water holding capacity in addition to soil erosion reduction. However, socioeconomic and environmental factors are needed to consider when making soil management decisions.
Key Words: no-tillage, soil properties, sustainable agriculture.

Introduction

Intensive and continued tillage have caused enormous moisture and organic carbon losses, and eventually erosion and soil quality degradation for agriculture. Iran has a dry climate, and its soil is subjected to severe erosion. The total amount of soil erosion in the world is estimated at 36 billion tons per year. The erosion rate in Iran is estimated at about 2 billion tons per year (about 16.7 tons per hectare) (Asadi, et al. 2016). A large amount of soil is annually exposed to erosion and destruction (Elmuti, et al. 2015) due to traditional tillage in the country. Almost 65 percent of agricultural land was reduced through human activities such as continuous tillage and permanent cultivation (Oldeman, et al. 1991), so preserving arable land nowadays seems vital. Sustainable agricultural development using no-tillage techniques can be an effective method of reducing soil erosion. Sustainable agriculture refers to the management of agricultural resources which can provide human needs, while also preserving the quality of environment and the capacity of water and soil resources (Reijntjes, et al. 1992).

In general, the advantages of non-tillage practices over conventional tillage include reducing destruction of soil and energy (Morales-Rosales and Franco-Mora, 2009 and Abbaspour-Gilandeh, et al. 2005), reducing water and wind erosion and required manpower (Ito, et al. 2007), the improvement in soil structure and stability and maintaining more soil moisture (Zahng and Fang, 2007 and Kirkegaard, 2000; and Colton and Potter 1999), increasing soil organic matter (Morell, et al. 2011 and Nyagumbo, 1999), and accelerating second planting time (Herridge and Holland, 1992). A no-tillage system helps control erosion, conserve less water, save energy, and reduce labor supply (ElTiti, 1999). However, due to retail farming and other inaccurate strategies, sustainable farming and no-till cultivation are scarce in Iran.

Potential physical benefits of non-tillage systems are increasing soil stability, reducing evaporation from soil surface, and increasing soil moisture (Zhang, et al, 2008 and Baker, et al. 2007), and its chemical benefits are increasing amount of organic carbon and also nitrogen content (Al-Kaisi and Kwaw-Mensah, 2020 and Pandiaraj, et al. 2018 and Ghimire, et al. 2012) and decrease in the number of lost elements in the form of greenhouse gases. About 60 percent of organic carbon in temperate regions and 75 percent in tropical areas are removed by plowing which accounts for about 23 percent of greenhouse gas concentrations in atmosphere and increasing the soil tillage, increases the CO2 flux from the soil (Kristof, et al. 2014 and Silva-Olaya, et al. 2013 and Lal, 2004 and Intergovernmental Panel on Climate Change, 1996). Finally, from a Biological perspective, soil microbial respiration is increased in no-tillage & cover cropping systems (Fonte, et al. 2009). Microbial characteristics are very sensitive indicators of soil quality that respond to land management changes in a short run (Raiesi, 2007). Considering all the benefits of no-tillage management, and due to using traditional methods and the low depth of soils in arable lands, studying the effect of different managements on soil properties and quality is an unavoidable issue. Although no-till systems have been adopted by a wide range of farmers for the last four decades

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worldwide, but in Iran where severe land degradation affects a significant portion of the arable lands, very little attention has been paid to this type of cultivation. Therefore, demonstrating the benefits of no-till cultivation using the results of this study can be a significant solution for preserving arable land in the country. This study aimed to quantify the effects of no-tillage management on the soil's physical, chemical and biological properties.

Materials and methods

1. Site description

The study was conducted at the research field station, Agriculture and Natural Resources Research and Education Center of Tehran University, Alborz Province, in Iran, were located in the Tehran-Karaj plain, south of the Caspian Sea, with arid climate and annual precipitation of about 250 mm (35°48′23″N and 50°57′12″E at 1292.9 meters above sea level) (asl). The study area is 200 hectares in which winter wheat and corn were locally produced for a long time and intensive farming. In this region, the soil is classified as fine, carbonatic, termic. The soil was classified as Entisol (United States Department of Agriculture, 2014). The (soil texture) topsoil (0-30 cm soil depth) is generally loam and sandy loam.

2. The experimental procedure

In this research, three plots with three different tillage practices were selected: conventional tillage (T), no-tillage for one year (NT_1) and no-tillage for six years (NT_6). Also, plant residues are returning to soil in NT_1, and NT_6 plots, but in T plot, the plant residue of previous cultivation was entirely collected before plowing to prepare the field for next cultivation.

In this study, soil samples were taken from 0-30 cm depth in each plot using a randomized design method. In general, 60 samples were taken, 20 samples from each plot. The locations of samples were originally determined on Google Earth images using the Arc GIS software and then located in the field by global positioning system (GPS). Also, a deep soil (0-150 cm) profile was arranged in each field due to soil genetic type and profile forming process. *Horizon samples* were taken from e*ach profile* for soil analysis. The soil descriptions, as well as the most important soil chemical properties of each soil profile, are shown in table 1. Samples were transferred to the laboratory after collection. Some soils of each sample were air-dried for 24 hours, and remaining soils were stocked for experiments which needed intact soil. After air drying, the soil was passed from the 2 mm sieve, and soil was collected for experiments.

Experiments were divided into three physical, chemical, and biological groups. Soil texture, moisture and stability of soil aggregates were considered in the physical properties. To compare the moisture content among the three sites, two points of field capacity (FC) and permanent wilting point (PWP) were used, and our benchmark for comparison was actually the distance between these two points. To measure these two points, the pressure plate was used, samples were brought to a target pressure of - 33kPa and -1500kPa using Pressure Plate apparatus (Pla, 1983). Soil stability was evaluated by the wet sieving method, and four sieve sizes were used. 4 g of sieved soil poured into a special sieve of wet sieving apparatus. After 5 minutes, the sieve was manually moved up and down 50 times in 3 minutes, and then soil aggregates retrieved at each sieve were carefully backwashed into beakers, oven-dried at 110°C for 24 hours, and then weighed back. (Van Bavel, 1950). Chemical properties included Organic Carbon and nitrogen, respectively, determined with the Walkley-Black's titration method (Walkley and Black, 1934) Kjeldahl method (ISRIC, 1986). From a biological point of view, the Isermeyer method was considered to assess soil microbial. Soil CO2-evolution was measured by the Isermeyer method using NaOH, whereby 20 grams of soil were moistened to 60% of water-holding capacity determined separately for each soil and samples incubated for 7-days at 27 °C. Eventually the amount of CO2 was determined by titration with HCl. (Isermeyer, 1952).

Analyzing variance and significance difference tests was carried out with SPSS. Means are presented with standard errors. A P-value of 0.05 or smaller was considered significant.

3. Results ＆ Discussion

The study results showed that no-tillage systems' stability was significantly higher than conventional tillage systems of all sizes. ($P<0.05$) (fig1). Stability in Nt_6 was significantly higher than Nt_1 and t, and Nt_1 was significantly higher than t, except in size sieve 1% , Nt_1 was higher than t, the differences among them were not significant. Also, as expected, the chart shows that stability in smaller size is lower than the other sizes (the number of stability increases when the aggregates' size gets bigger).

The results revealed that aggregates' sustainability in all sizes in the field with no-till for six years were significantly more than two other treatments, and in the fields with no-till for a year, aggregate sustainability is more than conventional tillage which was significant at 5% probability. These results were aligned by reports by Paul, et al. (2013), Taki and Assad's (2009) and Pagliai, et al. (1995). The aggregate stability is a sign of better soil texture conditions in the no-till system compared to conventional tillage systems due to its high carbon content. In conservation systems, the effects of remaining plant residues on the land would help to increase the stability of soil aggregates. From a biological point of view, the presence of organic matter in soil stimulates microorganism activity (such as fungi) and coarse animals (such as earthworms). Consequently, it would increase the stability of aggregates. From chemical perspective, decomposition of organic matter causes to release of polysaccharides, humic substances, and mucilage which they have a positive role in sticking soil particles together (Blanco- Conqui and Lal, 2009). Bonding among soil particles increases size and stability of aggregates against destructive forces. Therefore, any decrease in the amount of organic matter content of soil would lead to instability of soil structure. On the other hand, land preparation processes for conventional cultivating methods were heavy, causing large amounts of soil particles to move from their exact places and crush soil aggregates under the plow. As a result, more air conditioning in the soil accelerates the oxidation of organic matter, and one other of its consequences is the degradation in soil aggregation and stability. The dryness of soil in summer and plowing it in arid regions are the reason for clod formation. Solving this problem requires a lot of equipment for secondary tillage, resulting in the powdering and displacement of soil particles and, consequently, soil stability degradation.

The results of soil moisture showed that no significant differences were observed among different tillage systems (fig2). The highest soil moisture content was obtained, respectively in soils with conventional tillage systems (13.71%), six years no-tillage (12.91%), and one year of no-tillage (12.35%). The differences among them were not significant.

Table1 Soil profile description and examination

Management	Horizon	Depth (cm)	Texture	Structure	Color		EC (dc/m)	PH	Na (mg/kg)	K (mg/kg)	Mg (meq/l)	Ca (meq/l)
					Dry	Moist						
T	Ap1	0-30	Loam	1 sbkc	$10\ YR\frac{5}{3}$	$10\ YR\frac{4}{2}$	0.56	7.51	44.81	14.65	47.6	4.4
	Ap2	30-45	Loam	1 sbkc	$10\ YR\frac{5}{2}$	$10\ YR\frac{4}{2}$	0.601	7.36	43.19	11.29	52	4
	Bw	45-65	Sandy loam	Massive	$10\ YR\frac{6}{3}$	$10\ YR\frac{5}{3}$	0.312	7.65	36.71	5.04	20.4	1.6
	Bc	65-90	Sandy clay loam	Massive	$10\ YR\frac{6}{3}$	$10\ YR\frac{5}{3}$	0.36	7.7	39.95	5.52	25.6	2.4
Nt1	Ap1	0-15	Loam	2 sbk coarse-granul	$7.5\ YR\frac{6}{2}$	$7.5\ YR\frac{5}{3}$	0.357	7.4	38.33	15.13	38.4	1.6
	Ap2	15-30	Loam	1 abk coarse-plowpan	$10\ YR\frac{6}{3}$	$10\ YR\frac{5}{3}$	0.352	7.5	36.71	11.05	28	2.6
	C1	30-55	Loam	Massive	$10\ YR\frac{6}{3}$	$10\ YR\frac{4}{3}$	0.428	7.14	35.3	4.8	31.4	2.6
	C2	55-95	Sandy loam	Massive	$10\ YR\frac{6}{4}$	$10\ YR\frac{4}{3}$	0.352	7.21	32.93	3.8	25.8	2.2
Nt6	A	0-30	Loam	2 sbk	$10\ YR\frac{5}{2}$	$10\ YR\frac{5}{3}$	0.983	7.34	49.89	184.9	26.2	1.8
	Bw	30-60	Loam	1 abk	$10\ YR\frac{6}{3}$	$10\ YR\frac{4}{3}$	0.988	7.88	232.17	273.8	18.2	2.8
	C	60-100	Sandy loam	1 abk	$10\ YR\frac{6}{3}$	$10\ YR\frac{4}{3}$	1.11	7.57	307.71	4.8	64.8	5.2

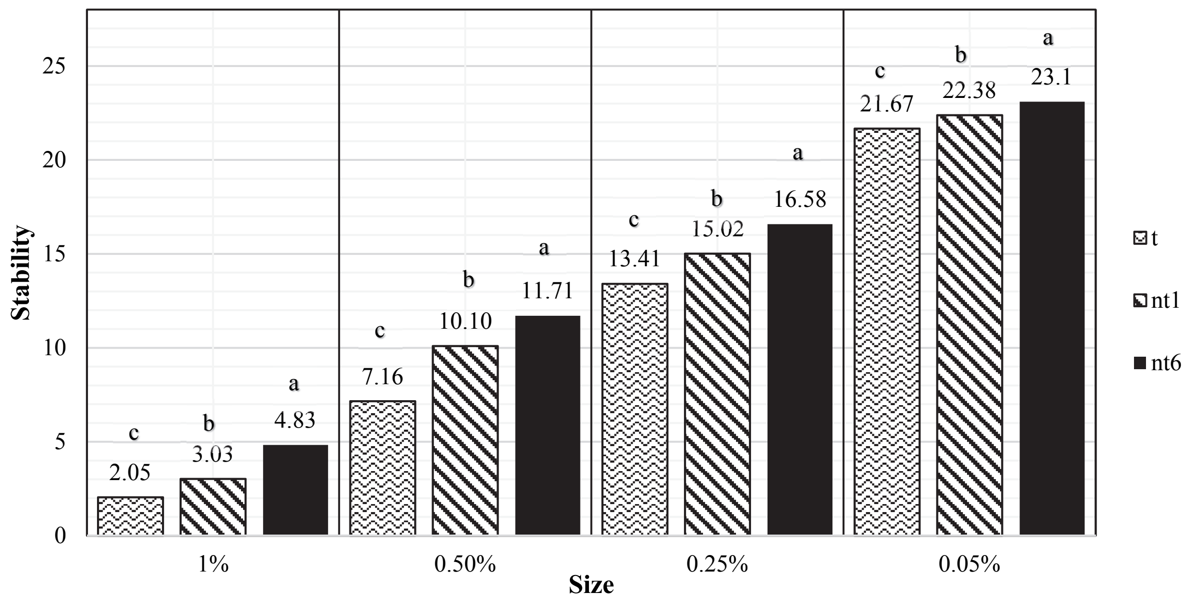

Fig.1 The comparison of averages for soil stability under different tillage practices

The results of this study about moisture are contrary to the results of Ussiri and Lal (2009), which claimed that land with a no-tillage system has a greater amount of moisture. In no-tillage systems, remaining plant residues on soil surface reduce evaporation and surface runoff and improve soil permeability, leading to increased soil moisture. Besides, considering the high amount of organic matter content in non-tillage treatments and organic matter effect on increasing water holding capacity, it was expected moisture content in this type of system would be higher. As Gomez, et al. (1999) claimed, comparing the amount of water penetration and soil moisture, there was no significant difference among soils under tillage operations and soils under no-tillage operations. Azooz and Arshad (1996) have said that the elimination of plowing operations will increase the penetration and maintenance of water in the soil after several years. In soil with conventional tillage, soil moisture content can be affected by various factors such as the type and amount of equipment used for plowing operations and plowing depths. Due to the retaining of plant residues on the soil surface in a non-tillage system, reduction of evaporation and surface runoff and soil permeability improvement were expected. The reason for higher soil moisture content for conventional tillage (compared with conservation tillage) in this study (although insignificant) is probably because conventional tillage has destroyed the plowing pan and reduced soil compaction result water penetration has increased in the soil. Although to achieve conclusive results, more studies for several years are needed.

Results of chemical experiments showed that the average of organic carbon in soil with six years without tillage was (1.42%), which was significantly higher than other two systems. The land with conventional tillage system contained more carbon than land under a one-year no-till system. Although this difference was not statistically significant (fig3).

The results of study about organic carbon are confirmed by most of the other researcher's findings (Hobbs, et al. 2008 and Lal. 1997). Reducing tillage slows down the organic matter degradation and stabilizes carbon in fine grains which reduces soil erosion. Consequently, ending the destructive effects of conventional tillage leads to an incensement in carbon content. For tropical areas (like Iran), it is especially important to consider that as soil temperature increases, organic matter decomposition will increase. Remained plant residues on soil surface (in protective tillage systems) reduce the temperature; thus, it would prevent soil from the loss of organic matter.

Results of variance analysis related to the effect of different tillage treatments on the amount of nitrogen in the soil indicate that different tillage systems had no significant effect on soil nitrogen content (fig4). Nitrogen in Nt_6 soil was 0.08 %, and higher than other two systems, and Nt_1 was higher than t, as mentioned the difference among them were not significant.

Several studies have shown that nitrogen in soil was increased by retaining plant residues on soil surface (Wood and Edwards, 1992. and Lopez-Fando and Pardo, 2009). The reason for increasing nitrogen accumulation in soils under conservation tillage system is to retain plant residues in the soil surface, increase granulation and formation of aggregates, increase the amount of carbon in large clods, and increase the activity of microorganisms. In this experiment, it would not be possible to present a definite reason to answer why differences are not meaningful. Due to the results of other researches, and the short application duration of non-till cultivation, if sustainable agriculture continues, in the following years, it is probably to see nitrogen increment in soil without plowing.

In biological experiments, soil microbial respiration results revealed that the average of soil microbial respiration in soil with six years without tillage was significantly higher than other two systems (1.11). The land with a one-year no-till had more microbial respiration than land with conventional tillage. However, this difference was not statistically significant (fig5).

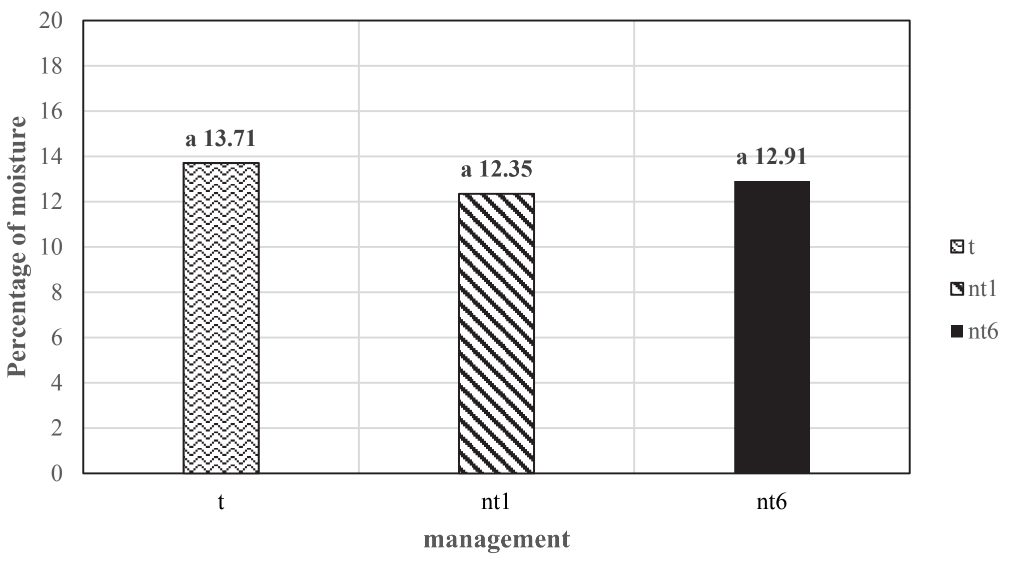

Fig.2 The comparison of averages for soil moisture under different tillage practices

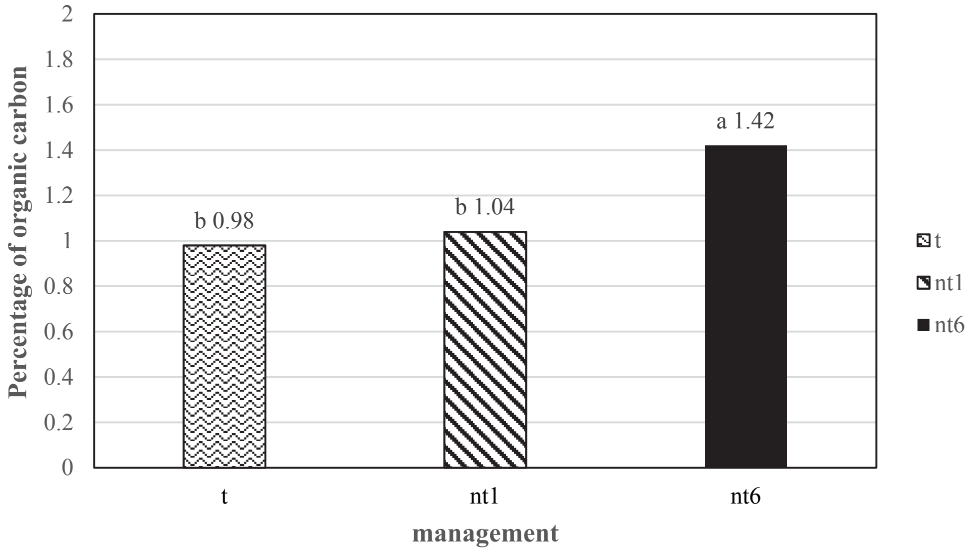

Fig.3 The comparison of averages for soil organic carbon under different tillage practices

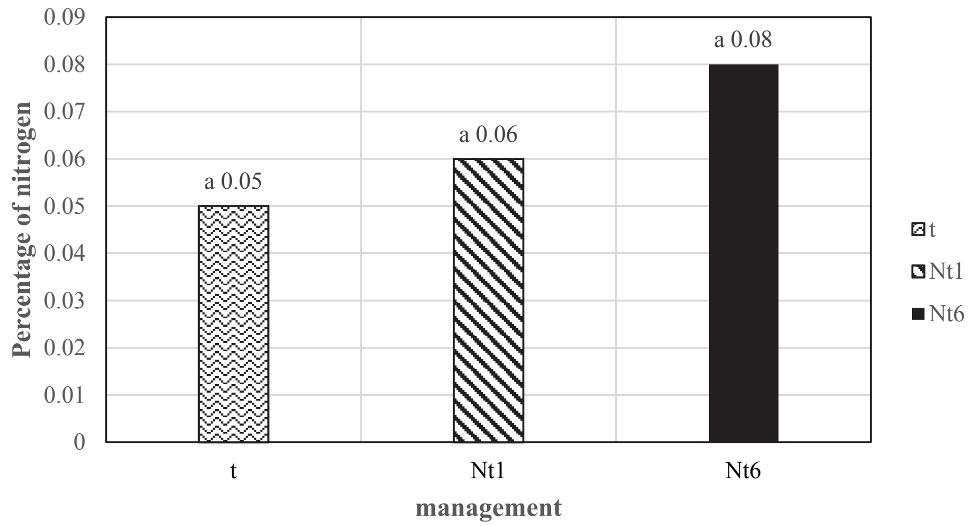

Fig.4 The comparison of averages for soil nitrogen under different tillage practices

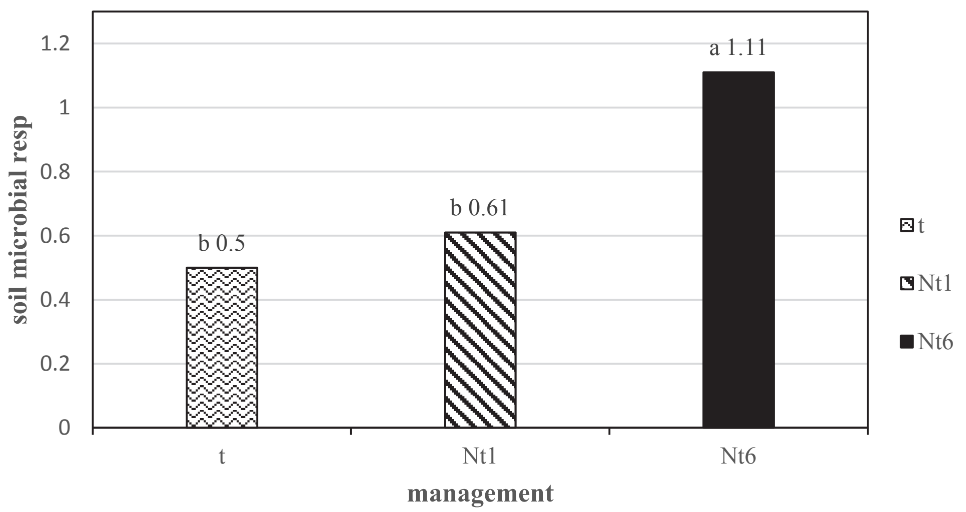

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Fig.5 The comparison of averages for microbial resp under different tillage practices

The soil microbial results are consistent with other researches that studied no-tillage cultivation in different periods. Pelosi, et al (2015) reported that the number of soil organisms in non-tillage crops was 1.5 times higher than conventional cultivation. In conventional farming, because of frequent tillage and transportation of tillage equipment; however, the soil conditioning is improved for the activity of microorganisms, soil organisms would disappear due to the lack of energy sources. Returning plant residue to the soil will provide more carbon substrates to generate energy for microbial colonization (Treseder, 2008). Govaerts et al. (2007), in a study about the effects of plant residue management on wheat and corn growth, reported that the microbial biomass carbon increased by a total reversal of plant residues with a coefficient of 1.2 and 1.3 times, compared with the total accumulation of residues.

As mentioned, three profiles were drilled on each land, and the same factors have experimented on the profile samples. Table 2 shows the results of these experiments. Results of the profile samples for five soil factors that are focused on in this research were similar to the main samples' results. After profile observation and analysis of experiment results, it can be said with confidence that the whole land's genetics is the same. The only thing that causes a difference in each land is using different management.

4. Conclusion

Results clearly indicated that, conservation tillage in compare with conventional tillage, improved the physical, chemical and biological properties of the soil. The aggregate stability in six years of no-tillage management, was significantly higher than that in the one year of no-tillage and conventional tillage managements. The amount of organic carbon and microbial respiration in six years of no-tillage was significantly higher than other two tillage managements. There was no significant difference between soil moisture and nitrogen content in different tillage treatments. The results of the three profiles indicate that the soil in the whole studied area is the same and it can be concluded that management is the only factor affecting soil properties. However, it should be noted that to observe the effects of conservation tillage on soil properties, in some cases long-term studies are required, e.g. up to twenty years.

Table2 Profile's samples

Management	Horizon	Stability				Moisture (%)	OC (%)	N (%)	Microbial respiration
		1mm (%)	0.5mm (%)	0.25mm (%)	0.05mm (%)				
t	Ap1	4.82	15.67	50.67	86.12	0.107	0.755	0.082	0.22
	Ap2	4.9	20.8	46.3	85.42	0.124	0.741	0.063	0.05
	Bw	6	29.02	61.32	88.1	1.473	0.351	0.03	
	Bc	6.4	16.02	45.24	82.77	0.114	0.273	0.023	
Nt1	Ap1	6.2	19.77	27.8	82.15	0.129	0.663	0.057	0.7
	Ap2	9	20.92	29.6	83.2	0.116	0.487	0.042	0.27
	C1	3.87	12.57	25.52	79.12	0.16	0.421	0.036	
	C2	3.67	10.82	24.67	75.95	0.13	0.409	0.035	
Nt6	A	8.85	25.67	48.6	80.37	0.498	0.936	0.08	1.16
	Bw	6.9	30.2	51.52	81.17	0.128	0.631	0.045	0.8
	C	11.2	30.97	51.95	58.8	0.148	0.214	0.018	

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