SCIENTIFIC ARTICLE

Effect of tillage and no-tillage on aggregate stability, organic matter content, and microbial activity in the Babylon province, Iraq

Salwan M. AL-Maliki*, Hadie A. Jasim, Abbas .S AL-Watefi, Alaa A. Abdulabbas
Department of Soil & Water Sciences
College of Agriculture, University of Al-Qassim,
Babylon, Iraq.
email: salwan.mohammed@yahoo.com
* For correspondene

Abstract

The present study demonstrates the effect of no-tillage (NT) and conventional tillage (CT) on soil aggregates, organic carbon, moisture content and microbial activity in clay loam soil. The results reveal that, upto the depth of 0-10 cm, the percentage of water stable macroaggregates >2000 μm (45.48%) were high in NT soils compared with CT (16.49%). Furthermore, NT retained more organic carbon (72.13 g/kg), reduced water evaporation (18.77%) and increased microbial activity compared to CT (59.11 g/kg) and hence, soil increased its aggregate stability and caused higher protection of organic carbon. This finding suggests that the large macroaggregates (>2000 μm) were distinctively governed by tillage system whereas other sizes tended less likely to be affected.

Keywords: Tillage, macroaggregate and microaggregate stability, microbial activity, organic carbon, water content

Introduction

Soil aggregates are the arrangement of soil particles (Six *et al.*, 2004). The aggregate stability can be used as an index of soil structure (Amezketa, 1999) and it physically protects organic carbon from the degradation process. Conservation tillage is a widely used practice to improve sustainability of agricultural ecosystems and minimise input costs and hence, there is a rising interest in determining the effect of conservation tillage. In contrast, it is assumed to have a major impact on soil carbon loss and induces soil degradation by disrupting soil aggregates and depleting soil organic carbon content (Kay, 1990) due to wind forces and water erosion (Drury *et al.*, 1998). Six *et al.* (2002) reported that the macroaggregate turnover is greatly reduced under NT promoting the formation of C-enriched microaggregates within macroaggregates. Furthermore, the sequestration of organic carbon within microaggregates was highly protected from microbial attack (Blanco-Canqui and Lal, 2008). Likewise, microbial biomass was found to be higher in NT than CT (Alvear *et al.*, 2005; Madejon *et al.*, 2009). The higher microbial activity can promote the production of organic binding agents which contribute to stabilization of soil aggregates.

Improving water efficiency appears to be a promising goal in agriculture due to water scarcity. The availability of crop residues reduce water evaporation, leading to a lower soil temperature and reducing wind influences (Klocke *et al.*, 2009). Crop systems play an important role on soil aggregation. The extensive roots system from grasses and fungal hypae has the greatest effect on the aggregation resulting in a high aggregate stability (Harris *et al.*, 1966). However, studies on the effect of NT and CT on microbial activity, organic carbon, moisture content and the distribution of soil aggregates were not undertaken in Iraq. Therefore an attempt has been made to evaluate soil aggregate stability in a no-tillage and conventional tillage, and to study the effects of no-tillage and conventional tillage on organic carbon, moisture content and on soil microbial activity.

Materials and Methods

Study area

Soil samples, from two depths 0-10 cm, and 10-20 cm, were collected from Almhanawiya farms, Hillah city, Babylon province, Iraq using a hand spade and cores and stored in soil sampling bags. Soil samples were taken from a field with an area of 2 hectares; the first hectare contains alfalfa plant (*Medicago sativa L.*) and was left without tillage for 5 years. The second hectare was tilled periodically during the last five years for the cultivation purposes. Moreover, it was left without cultivation for 16 months. It had a wheat plant (*Triticum aestivum L.*) 3 years ago. Mouldboard plowing technique was used as a conventional tillage. Soil had a clay loam texture (25 % sand, 40 % silt, and 35 % clay) with pH of 6.5. and electric conductivity of 4 ds/m.

Soil Quality

Aggregate stability

Aggregate stability was performed using a wet sieving machine technique. Aggregate materials were gently sieved through a set of sieves (2 and 4 mm) and the materials remained over the sieve were used in measuring aggregate stability. According to the size, the particles were classified as Large macroaggregates (>2000 μm) small macroaggregates (250-2000 μm) and microaggregates (53-250 μm) . The calculation of aggregate stability was done using the following formula:

$$\text{Stability (\%)} = \frac{\text{weight of aggregates on sieves}}{\text{weight of total aggregates}} \times 100\%$$

Organic Carbon

Soil organic carbon was estimated by the muffle furnace method (Ball, 1964). Soil samples were sieved through 2 mm sieve. Ten grams of soil was placed into a crucible after recording its weight. Crucibles were heated at 105°C over-night and then were reweighed after taking them from the oven. Crucibles were placed into a muffle furnace and ignited at 400°C for 16 hrs. After 16 hours, crucibles were taken out and reweighed again. The percentage of ignition loss was calculated using standard method. For soil organic matter percentage, the above equation was divided by 1.724.

Basal Respiration by static alkali method

Twenty grams of soil sample was placed inside a flask, containing 5 ml of 0.62M NaOH. 0.5 M HCl was used to neutralize 5 ml of NaOH containing a phenolphthalein indicator. The endpoint of the titration had the appearance of pale colour. The amount of carbon dioxide evolved in soil respiration was estimated.

Statistical analysis

All the data were subjected to two-way ANOVA. Differences between means were further evaluated and significant treatment effects were obtained, using Tukey's Studentized range test with a significance level of $P < 0.05$. For this, statistical software, Minitab version 14 was used.

Results and Discussion

Effect of NT and CT on water stable aggregates

The overall results showed that the aggregate stability was significantly higher in no-tillage (NT) compared to the conventional tillage (CT) (Table 1). This increase can be attributed to the highest amount of organic carbon which was observed in NT. Organic carbon is an important factor contributing to linked soil particles leading to a higher stability. In addition, the availability of alfalfa plant in NT can provide the organic materials in soil. The alfalfa rooting system can release exudates and increase carbon in soil (Angers, 1992). These results are consistent with other studies which found more stable structure accompanied by high organic carbon resulted in a marked increase in aggregates stability with a size larger than 2 mm (Angers *et al.*, 1992). Earlier studies on the long-term tillage have indicated that NT soils retained higher soil organic matter and had a greater percentage of water-stable macroaggregates than CT soils (Beare *et al.*, 1994). The higher increase in aggregate stability in NT can also be related to the microbial activity which was higher in NT than CT, leading to a greater production of organic binding by-products (Abiven *et al.*, 2009). These organic by-products play an important role in macroaggregate formation and stability. It was also found that the aggregate stability was significantly higher at a depth of 0-10 cm compared to that of 10-20 cm (Fig. 1). Increase in organic carbon content in soil can improve aggregation status and decrease dispersion ratio. Aggregate size distributions were significantly influenced by tillage regime at a depth of 0-10 cm ($P< 0.05$) (Table 1). Large macroaggregates (>2000 μm) in NT were significantly higher (45.48%) than conventional tillage (CT) (16.49%). It seems that CT had degraded the largest aggregates due to the physical effect of mouldboard plow and depletion of organic matter from soils. At a depth of 10-20 cm, large macroaggregates (>2000 μm) in the NT regime were significantly higher (16.64%) than CT (7.11%). However, the reverse was true in the CT at a depth of 10-20 cm which tended to have more stable compared to the microaggregates (53-250 μm). This confirm that CT more likely make the largest macraggregates to disintegrate into microaggregates which showed a capacity of resistance to fast wetting method. Macroaggregates are composed of microaggregates that are capable of resisting the disruptive forces of wetting technique. The microaggregates can be more persistent against the field conditions. The large macroaggregates (>2000 μm) in the NT regime performed more pronounced increase in aggregate stability compared to the rest of the sizes. While in the conventional tillage, large macroaggregates (>2000 μm) showed a substantial decline but no changes were recorded in small macroaggregates (250-2000 μm) and microaggregates (53-250 μm). This is due to deterioration of the large macroaggregates (>2000 μm) by the CT and field stress such as excessive cultivation and tillage.

Table 1: Effect of NT and CT on water stable aggregates.

Water-stable aggregate (%)			
Depth (cm)	**Aggregate Size (µm)**	**No-tillage**	**Conventional tillage**
0-10	> 2000	45.48 0± 1.95^{a*}	16.49± 1.95^{a*}
	250-2000	3.513± 0.753	4.213± 0.428
	53-250	8.81± 1.95	5.833± 0.383
10-20	> 2000	16.64± 2.62*	7.11± 1.10
	250-2000	4.06± 0.783	1.54± 0.231
	53-250	6.007± 0.925	11.92± 2.25*

Mean ± standard error: (a) indicate significant differences (ANOVA/LSD; $P < 0.05$) compared to the lower depth within the column. (*) Main effects of the type of tillage on aggregate stability within row.

An interaction plot between type of tillage (NT and CT) and depths of soil is shown in Fig. 2. emphasising the aggregate stability in the NT regime (NT) at a depth of 0-10 cm was greater than the lower depth of 10-20 cm. The greater aggregate stability was caused by the higher amount of organic carbon at the surface soil. The interaction plot ($p< 0.05$) between type of tillage (NT, CT) and sizes of aggregate at a depth of 10-20 cm is shown in Fig. 3. These results pointed out that CT degraded preferentially the large macroaggregates

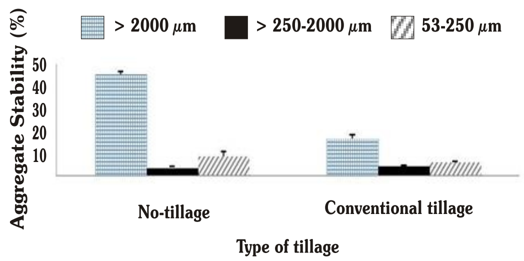

Fig. 1: Interaction (P<0.001) plot between type of tillage and size of aggregates for the aggregate stability % at a depth of 0-10 cm. Bars represent standard errors.

(>2000 µm) and small macroaggregates (250-2000 µm) but the opposite was true for the microaggregates (53-250 µm) which recorded a greater increase in aggregate stability as compared to the large macroaggregates (>2000 µm) and small macroaggregates (250-2000 µm) within the same tillage regime. The large increase in stability of microaggregates (53-250 µm) may be due to disintegrations of the large aggregate by the physical effect of mouldboard leading to finer aggregates consequently.

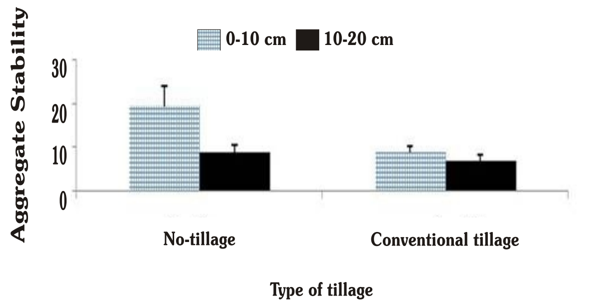

Fig. 2. Interaction (P<0.001) plot between type of tillage and depths for the aggregate stability %. Bars represent standard errors.

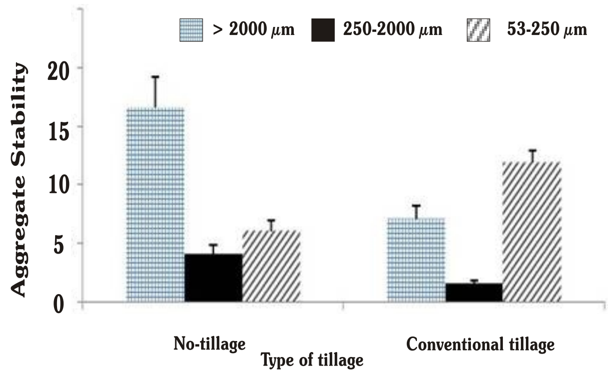

Fig. 3. Interaction (P<0.001) plot between type of tillage and size of aggregates for the aggregate stability % at a depth of 10-20 cm. Bars represent standard errors.

Effect of NT and CT on moisture content

It was observed that the NT regime preserved significantly much moisture content compared to CT (Fig. 4). No significant differences were noted between the two depths. CT can turn up soil thoroughly allowing an entrance of air to the soil causing less moisture content whereas the NT regime had retained much more moisture due to less air mobility throughout soil. This can be evident that the NT regime could improve the moisture content. In addition, NT regime can eventually increase the soil's water-holding characteristics.

Effect of NT and CT on organic carbon content

The soil organic carbon (SOC) results, revealed that the NT regime protected significantly more organic carbon than the CT (Fig. 5); declaring that CT caused losses of organic carbon. The disruption of aggregates under CT might have released the organic carbon to the mineralisation process. Moreover, CT brings subsurface soil to the surface where it is exposed to wet-dry cycles (Beare *et al.*, 1994) and increases the

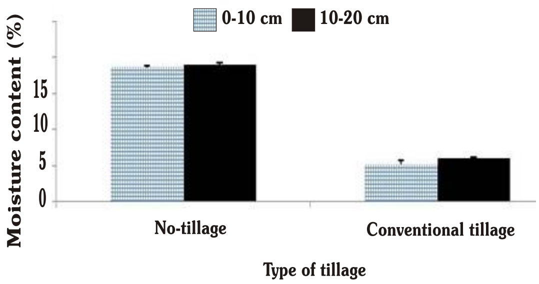

Fig. 4. Effect of tillage on moisture content (%) under two depths (0-10 and 10-20 cm). Bars represent standard errors.

decomposition of SOC. Furthermore, the importance of alfalfa plant in NT regime can increase SOC by releasing exudates from roots system (Angers, 1992). No-tillage regime can provide minimum soil disturbance and promotes soil aggregation through enhanced binding of soil particles (Six *et al*., 2002). This benefit can lead to the formation of aggregation causing higher SOC sequestration in NT soils (Denef *et al*., 2004).

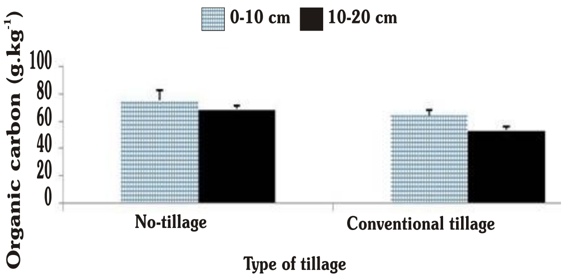

Fig. 5. Effect of tillage on organic carbon content under two depths (0-10 and 10-20 cm). Bars represent standard errors.

Effect of NT and CT on respiration rate

The measurement of microbial activity is an indicator of soil quality. Data on the respiration rate revealed that the microbial activity was significantly greater in NT regime compared to CT (Fig. 6). The organic carbon content was more in NT soil than CT. In the present study, the NT contained the alfalfa plant which provides the source of energy for microorganisms leading to higher microbial activity. The alfalfa's extensive rooting system can release exudates and availability of C substrates. The availability of nutrients in soil is of considerable importance for increasing microbial populations. Alfalfa had a capacity to produce greater root exudates and enrich the soil with nitrogen (Angers, 1992). In addition, moisture content can encourage the microbial population leading to greater respiration rate. Conventional tillage soil exhibited less microbial activity because of the reduction of organic carbon in soil which considers the main energy source of microorganisms; therefore there was a decline in microbial activity in CT soil, (Hendrix *et al.,* 1988; Franzluebbers *et al*., 1995). Similarly, Karlen *et al.,* (1994) proved also that the respiration rate in no tillage soil was higher (352 mg C/kg) than mouldboard plow (74 mg C/kg).

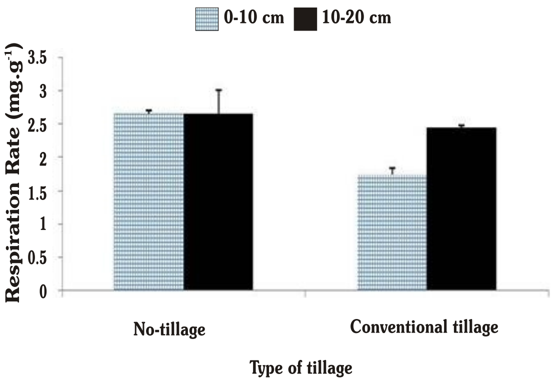

Fig. 6. Effect of tillage on respiration rate (mg/g) under two depths (0-10 and 10-20 cm). Bars represent standard errors.

Experimental results suggested that the tillage regime effected the aggregate size distributions at a depth of 0-10 cm and 10-20 cm respectively. Large macroaggregates (>2000 μm) in no-tillage were higher than conventional tillage at both depths. However, conventional tillage increased microaggregates (53-250 μm) at a depth of 10-20 cm compared to the microaggregates (53-250 μm) of the no-tillage soil. No-tillage soil protected more organic carbon, reduced the evaporation of water and increased soil microbial activity. Data presented here suggest also the contribution of no-tillage in improving the agricultural agroecosystem and soil health.

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RESEARCH REPORTS

Silver beware: Antimicrobial nano particles in soil may harm plant life

A new study finds that the popular microbicidal silver nanomaterial negatively impacts the growth of plants as well as kills the soil microbes that sustain them.

Silver (Ag) nanoparticles, used for their potent antimicrobial properties in hospitals and consumer products, may negatively impact plant growth as they make their way into the environment, according to a new study. Whereas it may not spell the end of all flora as we know it, the findings suggest that the nanomaterial has environmental impacts worthy of further investigation.

The antimicrobial properties of Ag in its ionized form have been recognized for centuries. When it is nanosize between one and 100 nanometers, which is smaller than many viruses (nanometer = one billionth of a meter) silver is even more effective at killing microbes. This antimicrobial potency has prompted manufacturers to include Ag nanoparticles in a wide variety of consumer products, such as odour-resistant clothing, hand sanitizers, water treatment systems and even microbe-proof teddy bears.

Although the microbicidal effects of Ag nanoparticles are well documented, their impact on the environment is less understood.

"There have been a lot of lab studies looking at silver nanoparticles showing that they are highly toxic to bacteria, fungi, other microorganisms," explains Ben Colman, postdoctoral researcher at Duke University who led the study. "Most of these studies have been conducted in very simple lab settings, [with] one species of bacteria often the "lab rat" of the bacteria

KNOW A SCIENTIST

Selman Abraham Waksman, Russian bacteriologist, together with H. Boyd Woodruff had devised a growth inhibition zone technique for identifying natural substances with antibacterial properties, specifically targeted for pathogenic bacteria. Dr. Waksman identified **actinomycin**, the first true antibiotic that had both bacteriostatic and bactericidal properties from the microbe ***Actinomyces antibioticus***. He identified more than 20 new natural inhibitory substances, including strepto-mycin and neomycin, and proposed the now standard term **"antibiotics"** for this class of natural growth inhibitors. During his lifetime, Waksman received some 66 awards and 22 honorary degrees, however, Waksman's greatest honor came when he won the **Nobel Prize in physiology or medicine in 1952** "for his discovery of **streptomycin**, the first antibiotic effective against tuberculosis." This distinction earned him the title of **"Father of Antibiotics"**.