CHANGES IN ORGANIC MATTER CONTENT, AGGREGATE STABILITY AND MICROBIAL ACTIVITY UNDER TILLAGE AND NO-TILLAGE SYSTEM IN BABYLON PROVINCE

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Abstract :
This study was undertaken to determine the effect of no-tillage (NT) and conventional tillage (CT) on water-stable aggregates (large macroaggregates >2000 µm, small macroaggregates 250-2000 µm and microaggregates 53-250 µm), soil organic carbon, moisture content and soil microbial activity in clay loam soil. Soil samples were collected at two depths (0-10 cm and 10-20 cm) from Almhanawiya farms in the Babylon province in September of 2013. Overall, NT had more stable aggregates accompanied by higher soil organic carbon, moisture content and microbial activity as compared to CT soils. For the 0-10 cm depth, a higher percentage of water stable large macroaggregates >2000 µm (45.48%) were found in no-tillage (NT) soils compared with conventional tillage (CT) (16.49%). Furthermore, NT retained more organic carbon (72.13 $g.kg^{-1}$) than conventional tillage (59.11 $g.kg^{-1}$). Similarly, NT reduced the evaporation of water (18.77%) compared with conventional tillage (CT) (5.45%). Likewise, microbial activity increased in no-tillage (NT) soil (2.66 $mg.g^{-1}$) in a comparison with conventional tillage (CT) (2.10 $mg.g^{-1}$). These findings suggest that no-tillage (NT) soil increased soil aggregate stability and caused a higher protection of organic carbon and retention of water as an indicator of water use efficiency and soil quality. More importantly, large macroaggregates (>2000 µm) were distinctively governed by tillage system whereas other sizes tended less likely to be affected by tillage system.

التغيرات في محتوى المادة العضوية ، ثباتية تجمعات التربة ونشاط احياء التربة المجهرية في الحقول المحروثة وغير المحروثة لبعض ترب محافظة بابل

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الخلاصة :
اجريت هذه الدراسة لغرض معرفة تاثير الحراثة وعدم الحراثة في ثباتية تجمعات التربة ضمن احجام مختلفة-53 (250 و 250-2000 و اكبر من 2000 ميكرون) وعلى كمية الكاربون العضوي ونسبة الرطوبة وعلى نشاط احياء التربة المجهرية . تم اخذ عينات التربة من عمقين مختلفين (0-10 و 10-20 سم) من مزارع منطقة المهناوية شمال مدينة الحلة في شهر ايلول 2013. بينت النتائج زيادة معنوية في ثباتية تجمعات التربة في التربة الغير محروثة مقارنة مع التربة المحروثة. لقد رافقت هذه الزيادة زيادة معنوية في كمية الكاربون العضوي و نسبة الرطوبة ونشاط

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احياء التربة المجهرية في التربة الغير محروثة. ادت الحراثة الى خفض ثباتية تجمعات التربة (16.49%) في الطبقة السطحية والطبقة السفلى مقارنة مع الترب الغير محروثة (45.48%) ضمن احجام تجمعات التربة الكبيرة (اكبر من 2000 ميكرون) بينما لم يسجل تاثيرات سلبية واضحة للحراثة في الاحجام المختلفة الاخرى. كما ادت الحراثة الى زيادة معنوية في احجام تجمعات التربة الصغيرة (250-53) ميكرون مقارنة مع التربة غير المحروثة . ادى عدم حراثة التربة الى زيادة في كمية الكاربون العضوي ($72.13\ g.kg^{-1}$) ونسبة الرطوبة (18.77%) ونشاط احياء التربة المجهرية ($2.66\ mg.g^{-1}$) مقارنة مع كمية الكاربون العضوي ($59.11\ g.kg^{-1}$) ونسبة الرطوبة (5.45%) ونشاط احياء التربة المجهرية ($2.10\ mg.g^{-1}$) في الترب المحروثة بالتعاقب. لقد اقترحت الدراسة اولا باهمية عدم الحراثة في زيادة ثباتية تجمعات التربة وحماية الكاربون العضوي وزيادة نشاط الاحياء المجهرية في التربة فضلا عن تقليل خسارة المياه كمؤشر لكفاءة التربة على حفظ الرطوبة. اقترحت الدراسة ايضا بان ثباتية تجمعات التربة (اكبر من 2000 ميكرون) هي الاكثر تاثرا بعملية الحراثة .

Introduction :

Soil structure plays a key role in soil fertility (AL-Maliki and Scullion, 2013). Soil aggregates are the arrangement of soil particles (sand, silt and clay) linked by organic materials (Six et al, 2004). The aggregate stability can be used as an index of soil structure (Amezketa, 1999). Soil aggregates can physically protect organic carbon from the degradation process (Tisdall and Oades, 1982; Beare et al, 1994a; AL-Maliki, 2012).

There is a rising interest in determining the effect of conservation tillage on carbon sequestration (Deen et al, 2003). Conservation tillage is a widely used practice to improve sustainability of agricultural ecosystems and minimise input costs. No-tillage (NT) can increase carbon and nitrogen storage and improves biological properties (Feng et al, 2003). In addition, no-tillage (NT) can enhance soil aggregation and leading to retention of soil organic matter (Beare et al, 1994b; Carter, 1992). In contrast, tillage is assumed to have a major impact on soil carbon loss. Conventional tillage (CT) induces soil degradation by disrupting soil aggregates and depleting soil organic carbon content (Kay, 1990). Conventional tillage can expose the soil to the wind forces and water erosion and causing a reduction in soil organic carbon (Drury et al, 1998). The reduction of organic matter can cause deterioration in aggregate stability.

It is well recognized that NT soil can result in the physical stabilization of organic carbon within soil aggregates (Six et al, 1999). Plant roots and fungal hyphae play an important role as binding agents throughout the stabilization of organic carbon within soil aggregates (AL-Maliki and Scullion, 2013). Six et al, (2000) 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, 2004). Soil biological activity under NT showed increases (Madejon et al, 2009). Likewise, microbial biomass was found to be higher in no tillage (NT) than conventional tillage (CT) (Alvear et al, 2005; Feng et al, 2003). The higher microbial activity can promote the production of organic binding agents which contribute to stabilization of soil aggregates.

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Improving water use efficiency appears to be a promising goal in agriculture because of the water shortages. Mitchell, (2012) concluded that No-tillage soil was retained more water (0.89 and 0.97 inches) than the tilled soil. Furthermore, the availability of crop residues can reduce the evaporation of water from soil by shading leading to a lower soil temperature and reducing wind influences (Klocke et al, 2009; van Donk et al, 2010). Crop systems play an important factor on soil aggregation. The extensive roots system from grasses has the greatest effect on the aggregation resulting in a high aggregate stability (Harris et al, 1966). Besides, the alfalfa rooting system can release exudates and increase carbon in soil (Angers, 1992). Similarly, Su et al, (2009) proved that the alfalfa plant can increase organic carbon and enhance soil structure.

There are no studies in Iraq from the field that describe the effect of no-tillage (NT) and conventional tillage (CT) on microbial activity, organic carbon, moisture content and the distribution of soil aggregates. The objectives of this study were (1) to evaluate soil aggregate stability (large macroaggregates >2000 µm, small macroaggregates 250-2000 µm and microaggregates 53-250 µm) in a no-tillage and conventional tillage (CT) under a depth of 0-10 and 10-20 cm (2) to investigate the effects of no-tillage (NT) and conventional tillage (CT) on organic carbon (3) to determine the effects of no-tillage (NT) and conventional tillage (CT) on moisture content (4) to perform the effects of no-tillage (NT) and conventional tillage (CT) on microbial activity.

Methods and materials :

1- **Experiential site**

Soil samples were collected from Almhanawiya farms which are located north of the Hillah city in Babylon province. Soil samples were obtained from two depths 0-10 cm and 10-20 cm using a hand spade and cores with a height of 10 cm 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. Moldboard plowing technique was used as a conventional tillage. Soil had a clay loam texture (25 % sand, 40 % silt, and 35 % clay). PH of the soil is 6.5. The electric conductivity is 4 ds/m.

2- **Soil measurements**

a- **Aggregate stability**

Aggregate stability was performed using a wet sieving machine technique (AL-Maliki and Scullion, 2013) which investigated rainfall by dripping water onto aggregates. Aggregate materials were gently sieved through a set of sieves (2 and 4 mm) of sieve apertures to recover aggregate of 2-4 mm. Aggregate materials which remained on the 2 mm sieve were used in measuring aggregate stability. 50 g aggregate materials were transferred to a wet sieving machine with a 2000, 250 and 53 µm sieves aperture. The

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wet sieving machine was switched on for two minutes at a water flow rate of 6.8 litres per minute. After which, the aggregate materials which remained on the sieves were transferred to beakers. These materials were considered as the percentage of stable aggregates (Large macroaggregates >2000 µm, small macroaggregates 250-2000 µm and microaggregates 53-250 µm) which were used for calculating the final result of aggregate stability. All beakers were transferred to an oven at 105 C° for 24 hours.

The calculation of aggregate stability was as follow:

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

b- Organic carbon

Soil organic carbon was estimated by the muffle furnace method (Ball, 1964). Soil was passed through 2 mm sieve. 10 g of soil was placed into a crucible after recording its weight. Crucibles placed into 105 C° oven over-night. All crucibles then were reweighed after taking them from the oven. Crucibles were placed into a muffle furnace and ignited at 400 C° for 16 hours. After 16 hours, crucibles were taken out and reweighed again.

The percentage of loss ignition was calculated as follow:

$$\%\ \text{loss ignition} = \frac{(\text{oven dry soil weight} - \text{ignited soil weight})}{(\text{oven dry soil weight})} \times 100$$

Soil organic matter which was calculated from the above equation was divided by 1.724 to obtain the percentages of soil organic carbon (Howard and Howard, 1990). This Van Bemmelen factor is based on the assumption that organic matter is 58% of carbon (100/58= 1.724) (Pansu and Gautheyrou, 2006).

c- Basal Respiration by static alkali method

20 g of soil was placed inside a flask corked with a stopper to which a 10 ml glass bottle was attached. The bottle was filled with 5 ml solution of 0.62M NaOH. The NaOH solution captured any CO_2 that was respired from the soil.

0.5 M HCl was used to neutralize 5 ml of NaOH containing a phenolphthalein indicator; the addition of three drops of the indicator into the NaOH solution caused a colour change to pink. The endpoint of the titration was when the pink colour was changed to pale. The amount of carbon dioxide evolved in soil respiration was estimated based on Sonnenholzner and Boyd, (2000).

$$CO_2\left(\frac{mg}{g}\right) = \frac{(B - V)N22}{w}$$

where B = standard HCl used to titrate NaOH in the blank (mL); V =standard HCl used to titrate NaOH in the treatment (mL); N = normality of HCl (1.00 N); 22 = equivalent weight of CO_2; W = dry weight of soil in the chamber (g).

3- Statistical analysis

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The data were analysed using Minitab version 14. ANOVA analyses (two-way ANOVA) tested for depths (0-10 cm and 10-20 cm) and type of tillage (no-tillage regime (NT) and conventional tillage (CT)) effects. Results for the aggregate stability were analysed by three ways ANOVA with three factors of a depth, type of tillage and size of aggregates. Aggregate stability findings were further analysed by two ways ANOVA including type of tillage and size of aggregates to obtain the significant differences between values within the same depth. Differences between means were further evaluated where significant treatment effects were obtained using Tukey's Studentized range (HSD) test with a significance level of $P < 0.05$.

Results and discussion :

1- **Effect of tillage (no-tillage (NT) and conventional tillage (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 a no-tillage (NT). Organic carbon is an important factor contributing to linked soil particles leading to a great stability (AL-Maliki, 2012). In addition, the availability of alfalfa plant in a no-tillage (NT) can provide the organic materials in soil. The alfalfa rooting system can release exudates and increase carbon in soil (Angers, 1992). Some studies have proved that the alfalfa plant can significantly increase SOC and N stocks, and improve soil structure (Su et al, 2009). 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; Elliott, 1986). Previous studies of 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, 1994b). The larger increase in aggregate stability in NT can also be related to the microbial activity which was higher in NT than CT. NT promoted soil microbial activity in soil surface (Madejon et al, 2009; Staley et al, 1988) 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 overall that aggregate stability was significantly higher at a depth of 0-10 cm compared to that of 10-20 cm (Figure 2). The highest significant amount of organic carbon at a depth of 0-10 cm could have played an important parameter in maximising aggregate stability. Increases in organic carbon content in soil can improve aggregation status and decrease dispersion ratio (Singh et al, 2007).

Aggregate size distributions were significantly ($P < 0.05$) influenced by tillage regime at a depth of 0-10 cm (Table 1). Large macroaggregates (>2000 µm) in no-tillage (NT) were significantly higher (45.48%) than conventional tillage (CT) (16.49%). It seems that conventional tillage (CT) had degraded the largest aggregates due to probably the physical effect of mouldboard plow and depletion of organic matter from soils because of

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the lack of plant cover. At a depth of 10-20 cm; large macroaggregates (>2000 µm) in the no-tillage regime (NT) were also significantly higher (16.64%) than conventional tillage (CT) (7.11%). However, the reverse was true in the conventional tillage at a depth of 10-20 cm (CT), which tended to have more stable microaggregates (53-250 µm) compared to the microaggregates (53-250 µm) of the no-tillage soil. This status can confirm that conventional tillage (CT) more likely disintegrated the largest macraggregates 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 (Tisdall and Oades, 1982). The microaggregates can be more persistent against the field conditions (Tisdall and Oades, 1982). The highly stable aggregates are microaggregates (<250µm) because they consist of clay–polyvalent metal–organic matter complexes. Microaggregates are formed by bonding of C–P–OM clay sized units, where C: clay particle, P: polyvalent metal (Fe, Al, Ca) and OM: organo-metal complex (Six et al, 2004).

There was an interaction plot ($p< 0.05$) between type of tillage (NT, CT) and sizes of aggregate at a depth of 0-10 cm (Figure 1). This can declare that the large macroaggregates (>2000 µm) in the no-tillage regime (NT) performed more pronounced increase in aggregate stability compared to the rest of the sizes. Whilst in the conventional tillage (CT); large macroaggregates (>2000 µm) showed a substantial decline but no changes were recorded in small macroaggregates (250-2000 µm) and microaggregates (53-250 µm) in a comparison to the no-tillage regime (NT) confirming that most changes in aggregates stability were markedly happened in the large macroaggregates (>2000 µm) in the conventional tillage (CT) at a depth of 0-10 cm. These findings can signal that the large macroaggregates (>2000 µm) were badly deteriorated by the conventional tillage (CT). This can be evident that the largest aggregates can easily be exposed to the field stress such as excessive cultivation and tillage. Tisdall and Oades, (1982) noted that macroaggregation was controlled by soil management whereas; the water-stability of micro-aggregates depends on the persistent organic binding agents and appears to be a characteristic of the soil, independent of management.

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Table 1. Effect of tillage (no-tillage (NT) and conventional tillage (CT)) on water stable aggregates with different sizes (Large macroaggregates >2000 µm, small macroaggregates 250-2000 µm and microaggregates 53-250 µm) in two depths (0-10 and 10-20 cm).

		Water- stable aggregate (%)	
Depth (cm)	**Aggregate size(µm)**	**No -tillage**	**Conventional tillage**
	>2000	**45.48 ± 1.32 [a*]**	**16.49 ± 1.95 [a]**
0-10 cm	**250-2000**	**3.513 ± 0.753**	**4.213 ± 0.428**
	53-250	**8.81 ± 1.95**	**5.833 ± 0.383**
	>2000	**16.64 ± 2.62***	**7.11 ± 1.10**
10-20 cm	**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 (NOVA/LSD; *P* < 0.05) compared to the lower depth within the column. (*) Main effects of the type of tillage on aggregate stability within row.

There was also an interaction plot ($p < 0.05$) between type of tillage (no-tillage (NT), conventional tillage (CT)) and depths of soil (Figure 2); emphasising the aggregate stability in the no-tillage 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.

There was an interaction plot ($p < 0.05$) between type of tillage (NT, CT) and sizes of aggregate at a depth of 10-20 cm (Figure 3). These results pointed out that conventional tillage (CT) degraded preferentially the large macroaggregates (>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) can be due to disintegrations of the large aggregate by the physical effect of mouldboard leading to finer aggregates consequently; most of the large aggregates were broken down into small units received entirely within the smaller sieve leading to a higher amount of microaggregates (53-250 µm). Macroaggregates consist of microaggregates and once they are exposed to the disruptive forces, they disintegrated into microaggregates (Tisdall and Oades, 1982).

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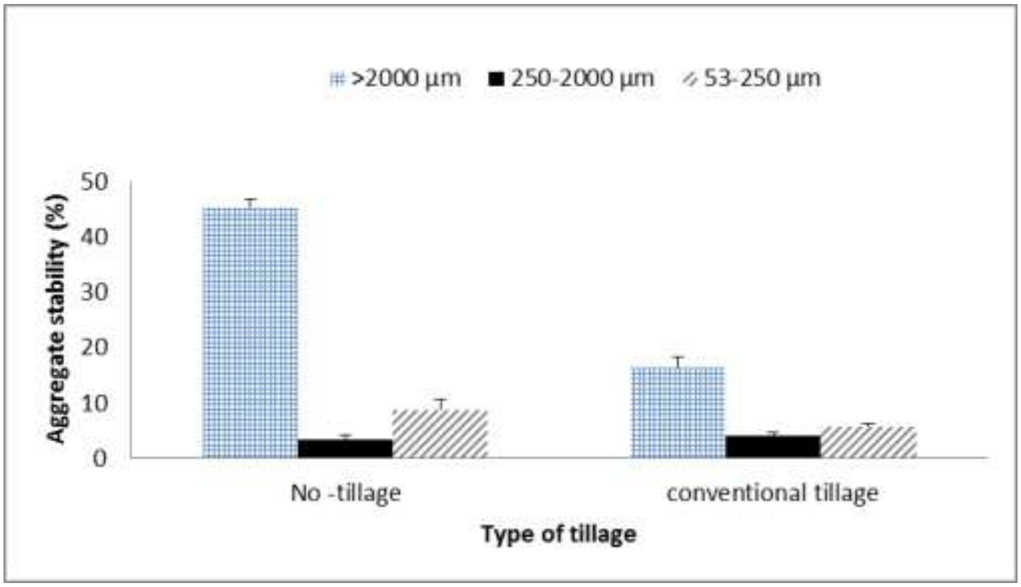

Figure 1. Interaction (p<0.001) plot between type of tillage (no-tillage (NT), conventional tillage (CT)) and size of aggregates (Large macroaggregates >2000 µm, small macroaggregates 250-2000 µm and microaggregates 53-250 µm) for the aggregate stability % at a depth of 0-10 cm. Bars represent standard errors.

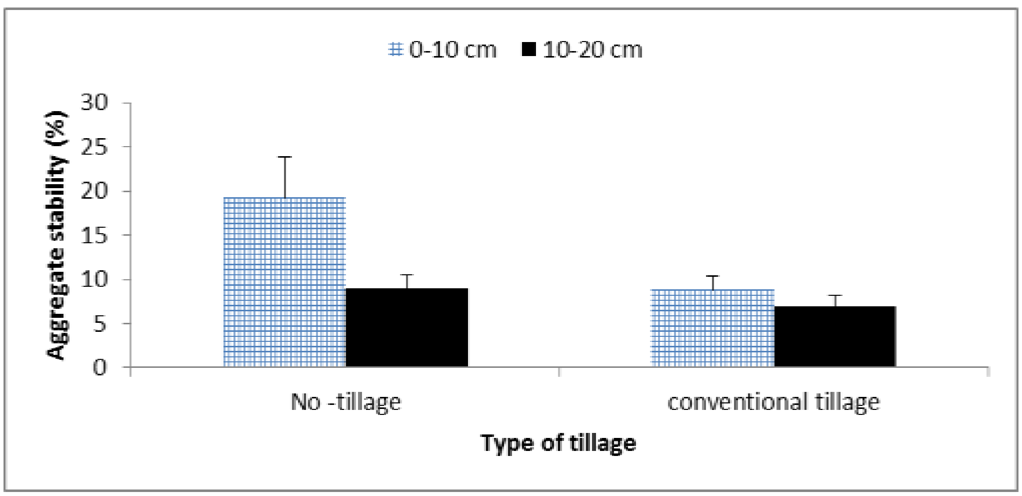

Figure 2. Interaction (p<0.001) plot between type of tillage (no-tillage (NT), conventional tillage (CT)) and depths (0-10 and 10-20 cm) for the aggregate stability %. Bars represent standard errors.

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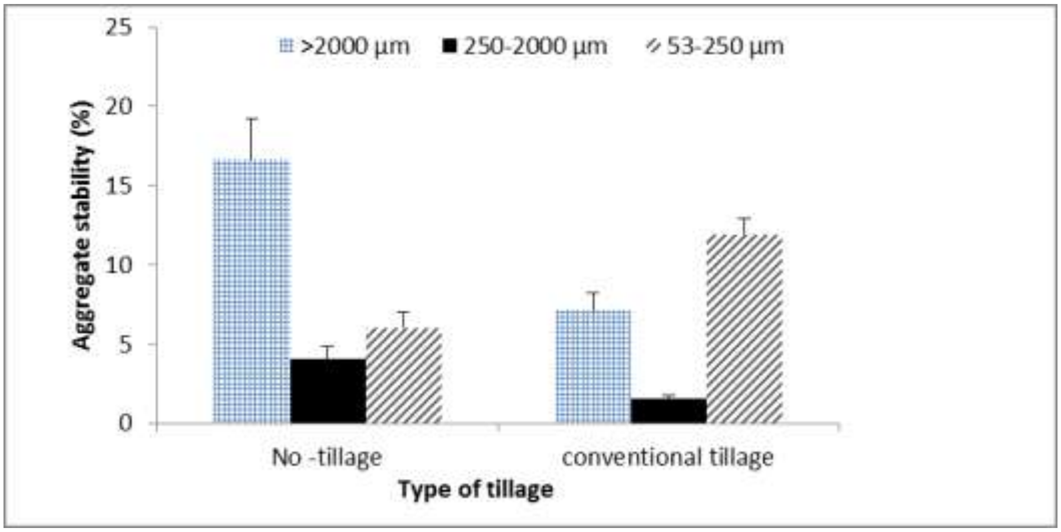

Figure 3. Interaction (p<0.001) plot between type of tillage (no-tillage (NT), conventional tillage (CT)) and size of aggregates (Large macroaggregates >2000 µm, small macroaggregates 250-2000 µm and microaggregates 53-250 µm) for the aggregate stability % at a depth of 10-20 cm. Bars represent standard errors.

2- **Effect of tillage (no-tillage (NT) and conventional tillage (CT)) on moisture content**

It was observed that the no-tillage regime (NT) preserved significantly much moisture content compared to the conventional tillage (CT) (Figure 3). No significant differences were noted between the two depths. Conventional tillage (CT) can turn up soil thoroughly allowing an entrance of air to the soil causing less moisture content by drying process whereas the no-tillage regime (NT) had retained much more moisture due to less air mobility throughout soil. This can be evident that the no-tillage regime (NT) could improve the water use efficiency by reducing the water evaporation from soil. In addition, no-tillage regime (NT) can eventually increase the soil's water-holding characteristics. These results are similar to Mitchell et al, (2012) who found that more water was retained in the no-tillage soil than in the tilled soil. Similarly, Drury et al, (1998) found that no-tillage (with and without red clover) increased soil water content by 2 to 5% and reduced soil temperatures by 1 to 2°C.

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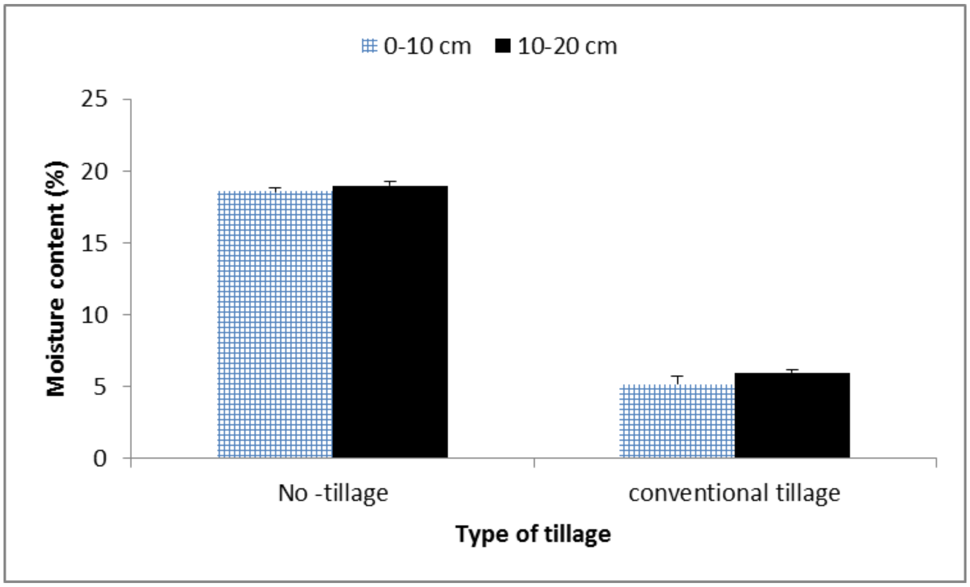

Figure 3. Effect of tillage (no-tillage (NT) and conventional tillage (CT)) on moisture content (%) under two depths (0-10 and 10-20) cm. Bars represent standard errors.

3- Effect of tillage (no-tillage (NT) and conventional tillage (CT)) on organic carbon content

These results revealed that the no-tillage regime (NT) protected significantly more organic carbon than the conventional tillage (CT) (Figure 4); declaring that conventional tillage (CT) caused losses of organic carbon. The disruption of aggregates under conventional tillage (CT) might have released the organic carbon to the mineralisation process. Moreover, conventional tillage (CT) brings subsurface soil to the surface where it is exposed to wet-dry cycles (Beare et al, 1994a) and increases the decomposition of SOC. Furthermore, the importance of alfalfa plant in no-tillage regime (NT) can increase soil organic carbon (Su et al. 2009) by releasing exudates from roots system (Angers, 1992). No-tillage regime (NT) 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 no- tillage soils (Denef et al, 2004).

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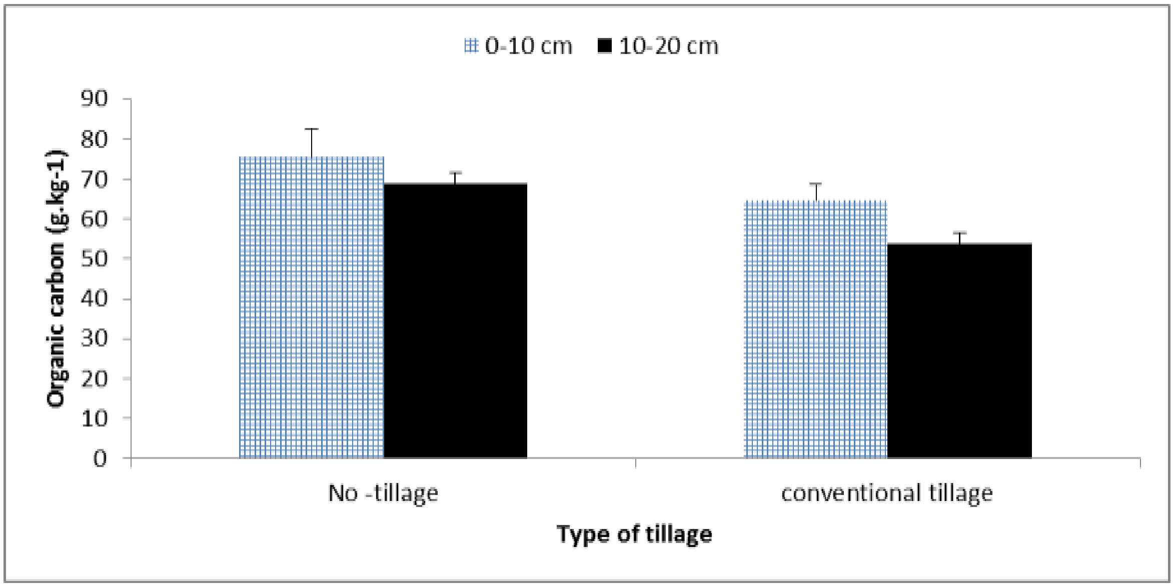

Figure 4. Effect of tillage (no-tillage (NT) and conventional tillage (CT)) on organic carbon content (g. Kg^{-1}) under two depths (0-10 and 10-20) cm. Bars represent standard errors.

4- Effect of tillage (no-tillage (NT) and conventional tillage (CT)) on respiration rate

The measurement of microbial activity is an indicator of soil quality. A high quality soil can be biologically active and contains enormous population of microorganisms. Data on the respiration rate confirmed that the microbial activity was significantly greater in the no-tillage regime (NT) compared to the conventional tillage (CT) (Figure 5). The organic carbon content was more in no-tillage soil than conventional tillage. This suggests the importance of carbon as energy source for maximising microbial activity. In the current study, the no-tillage soil (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 to increasing microbial populations. Alfalfa had a capacity to produce greater root exudates and enrich the soil with nitrogen (Angers, 1992). In addition, soil moisture content was higher in no-tillage soil. Moisture content can encourage the microbial population leading to greater respiration rate. Conventional tillage (CT) 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 conventional tillage (CT) soil. These results are similar to Hendrix et al, (1988) who reported that CO_2 fluxes were slightly greater in no-tillage plots than in conventional tilled plots in Georgia. Likewise, Franzluebbers et al, (1995) reported that annual soil CO_2 fluxes from various cropping systems in Texas were up to 23% greater in no-tillage compared to conventionally disked systems. Similarly,

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Karlen et al, (1994) proved also that the respiration rate in no tillage soil was higher (352 mg C kg^{-1}) than mouldboard plow (74 mg C kg^{-1}).

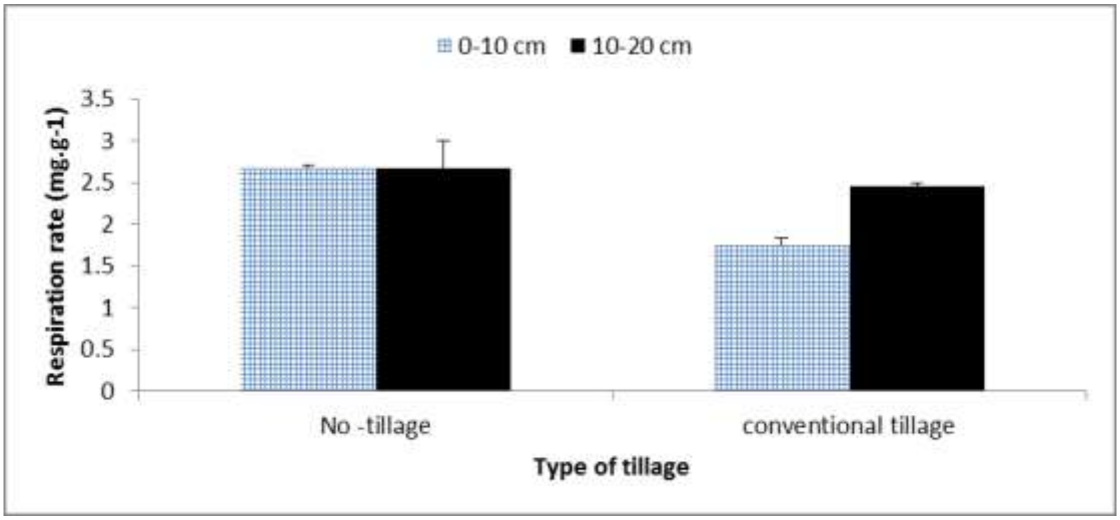

Figure 5. Effect of tillage (no-tillage (NT) and conventional tillage (CT)) on respiration rate (mg g^{-1}) under two depths (0-10 and 10-20) cm. Bars represent standard errors.

Experimental results suggest 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 (NT) were higher than conventional tillage (CT) at both depths. However, conventional tillage (CT) increased microaggregates (53-250 µm) at a depth of 10-20 cm compared to the microaggregates (53-250 µm) of the no-tillage soil. This can approach that conventional tillage (CT) disintegrated most likely the large macraggregates into microaggregates which were more resistant to the wetting method. More importantly, large macroaggregates (>2000 µm) were governed by tillage regime whereas other sizes tended to be less likely affected by tillage regime. No-tillage (NT) 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 (NT) in improving the agricultural agroecosystem and soil health.

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