Plant Archives Volume 20 No. 2, 2020 pp. 9265-9276 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECTS OF DIFFERENT TILLAGE METHODS AND FERTILIZER ON SOIL CARBON, EMISSION OF CO2, AND MAIZE YIELD

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Abstract

The agricultural sector contributed to the increase of the greenhouse gases (GHGs) concentrations into the atmosphere. Soil management and the use of high amounts of energy (direct and indirect) contribute significantly to these emissions. This work aims to study the soil organic matter and carbon transformation affected by four tillage practices (Minimum tillage performed via rotary plough, Minimum tillage performed via chisel plough seven blades, Minimum tillage performed via disk plowing and no-tillage with using three types of fertilizer (urea, manure and compost). The study was carried out during 2017 and 2018, at Faculty of Agriculture, Cairo University-Egypt. the experiment laid out in strip block design and three replicated. Maximum total biomass production and grain yield were recorded in case of minimum tillage performed via rotary plough with manure fertilization. No tillage increased C content of soil, which led to reduce the emission of carbon dioxide. The Collected data revealed that, The No tillage system recorded higher soil organic carbon over all the minimum tillage systems at 0-15 cm depth.

Keywords: Conservation tillage, CO2 emission, Maize, soil organic carbon; crop rotation; soil tillage; fertilization; agricultural management.

Introduction

Maize is the third most important crop in Egypt. It plays an important role in agriculture-based economy of the country. It has a high nutritional value; maize seed contains many by-products like glucose, fatty acid, amino acid, along with 72% starch, 10% protein, 4.8% oil and 8.5% fiber (Ministry of Food and Agriculture, 2015).

Sustainable agriculture demands to be environmentally responsible, consequency we must give priority to the impact of agriculture on soil quality and on the environment rather than agricultural and economic factors (Robertson et al., 2000; Tilman et al., 2011). Therefore increasing carbon sequestration is essential to achieving environmental development as well as helping to reduce global warming. It can also increase soil organic carbon storage and improve soil fertility (Dawson and Smith, 2007; Lal, 2004).

Only a small portion of the crop biomass is converted into organic carbon, but the conversion rate is not highly equivalent to the rate of mineralization. That is why adopting conservation tillage practices is an effective approach to reduce the mineralization and increase the concentration of organic carbon in the soil and reduce emissions of carbon dioxide (Zhao et al., 2018).

Tillage regulates soil structure and is also important factor affecting soil carbon storage and emissions (Abdalla et al., 2013). The main form of soil carbon loss in dry lands is carbon dioxide, which comes from mineralization of soil organic carbon, while disturbing the soil in agricultural production by plowing is the main way to increase the emission of carbon dioxide (Lu and Liao, 2017; Silva-Olaya et al., 2013). The emission of CO2 is the main contributor to increase global warming due to its greater radiative effect because it has a long time to adapt to any new balance. If the sources change, it could reach 200 years (IPCC, 2007).

Soils store about three times as much carbon as the terrestrial vegetation. Soil Carbon pool comprises soil organic carbon (SOC) and soil inorganic carbon (SIC) pool (Lal, 2004). Thus, agricultural soils contain 25-75% less organic carbon compared to natural or non-disturbed ecosystems (Lal et al., 2015).

The benefits of reduced tillage are reducing soil erosion, agrochemical leaching, improved soil structure, increased organic carbon concentration, and reduced carbon dioxide emissions (Aguilera et al., 2013; Alvaro-Fuentes et al., 2009)

Most studies confirm that no-till increases the concentration of soil organic carbon in the topsoil layers, especially the highest concentration of it to a depth of 10 cm (Angers and Eriksen-Hamel, 2008; Luo et al., 2010). Only a few studies have considered deeper soil layers below 30 cm and there the positive effect of no-tillage was highly variable (Govaerts et al., 2009). The adoption of no-till-based agriculture has the global potential to sequester 62–350 kg C· ha- 1 per year (West and Post, 2002).

This work aims to study the effect of four tillage practices with application of three types of fertilizer on the soil organic matter and on carbon transformation under maize crop.

Material and Method

2.1. Experimental site

Field experiments were carried out at in the experimental field - Faculty of Agriculture, Cairo University, Egypt during the 2017-2018 year to study the effect of four tillage practices with using three types of fertilizer on the soil organic matter and carbon transformation under maize crop (Giza 2).

Table (1) shows the tested experimental treatments. They were four tillage systems (no tillage, rotary plough, chisel plough and disk plough) with Appling three types of fertilizer (manure, compost and urea). The tillage was performed via rotary plough and the tillage performed via chisel plough seven blades at 20 cm depth. But, the tillage was performed via disk plowing at 30 cm depth. No tillage consisted of sowing by direct hand cultivation. There were three replicates. The experimental plot area was 30 m2 (5m×6m).

The experimental design was laid out in strip block design with three replications, where four soil tillage systems (minimum with three different plows, and no tillage) acted as vertical treatments and three fertilizers applications (manure , compost and urea) as horizontal one.

Table1. The experimental Treatments.

Tillage	Fertilizer	Symbol	Tillage	Fertilizer	Symbol
No tillage	Manure	NT1	Chisel plough	Manure	MT2-1
	Compost	NT2		Compost	MT2-2
	Urea	NT3		Urea	MT2-3
Rotary plough	Urea	MT1-1	Disk plough	Urea	MT3-1
	Manure	MT1-2		Compost	MT3-2
	Compost	MT1-3		Manure	MT3-3

During the summer, the seeds of the four treatments were prepared, planning and dividing the land, and taking the first sample. The first treatment consisted of NT in which the crop was directly planted on the standing residues of the previous crop. As for the treatment using a rotary plow width of 120 cm, the soil was turned over and the crop residues were buried and mixed with the soil, the treatment with disc plow includes a complete inversion of the soil and burying crop residues to a depth of 30 cm, the last treatment used chisel plough seven blades at 20 cm tillage.

The seeds were sown manually, leaving a distance of 70 cm between the rows of the corn and 30 cm between the plants, at the beginning of the cultivation the manure fertilizer was added early at a rate of 20 m3.fed-1 because the nitrogen component was slowly decomposing from it. The soil was irrigated at a rate of 500-800 mm. After 20 days from planting, urea and compost fertilizer were added at a rate of 300 kg urea per fed as a compaction at the bottom of the plants and a short distance from them.

2.2. Soil parameters

Soil samples were collected and analyzed for soil properties after the harvest of crops. Three samples were collected from each plot. The collected soil samples were air dried, grinded, passed through 2mm sieve and stored in polythene bags for analysis. Fresh soil samples at 30 cm depth were collected and kept under refrigeration for estimation of soil organic carbon (SOC) and Soil organic carbon sequestration (SOCS).

Table 2 : Soil physiochemical characteristics in the first 30 cm depth under both tillage systems at the beginning of the experiment.

Tillage system	BD g.cm−3	Texture (%)			pH	OC g.kg−1	Total C	Total N	P Mg.kg−1	K
		Sand	Silt	Clay						
MT	1.38	32.1	50.7	19.3	8.2	5.0	9.8	0.8	26	226
NT	1.39	29.8	48.6	19.5	8.4	5.6	10.8	0.8	18	227

Soil Organic carbon

At the beginning of the cultivation, soil samples were taken at depths 0-15 and 15-30 cm and over the course of cultivation, 5 samples were taken from each treatment, and also after harvesting the corn. These samples were taken using a hand drill and then taken to the laboratory where they were analyzed to determine the soil organic carbon content, nitrogen content and bulk density.

Soil organic C was determined by dry combustion by Walkley and Black's wet oxidation method (Jackson, 1967). The soil organic C and bulk density were measured at the end of crop season by collecting undisturbed soil cores at depths of 0–15 and 15–30 cm. CO_2 mitigation related to C sequestration in the soil (sequestrated CO_2[soil]) was calculated as in Borin et al. (1997). Using Walkley and Black's method, soil organic C concentration was determined. From soil organic C and bulk density, the soil organic C content in 0–15 cm per hectare was calculated using equation (1):

$$SOC = 100 \text{ ‘SOC’ } \rho b \, d \qquad (1)$$

Where

SOC: soil organic C content (Mg ha^{-1})

'SOC': is soil organic C concentration (g Kg^{-1})

ρb : bulk density (Mg m^{-3})

D : depth (m).

The stored CO_2 in the soil was determined as:

$$\text{sequestrated } CO_2[\text{soil}] = \frac{44}{12} \, SOC$$

Where 44 and 12 are the molecular weights of CO_2 and C, respectively.

To determine germination percentage and the total biomass of the maize crop, plants samples were picked in one-meter area from four rows and were weighed. Furthermore, in every plot, two strips of 12 m x 1.5 m were harvested and grains were weighed separately to estimate the crop yield.

Statistical analysis

Combined analysis of variance of a RCBD across the two seasons was computed after carrying out Bartelet test according to Steel et al. (1980). Snedecor and Cochran (1994) calculated LSD estimates to evaluate the mean variations, by using MSTAT C software package.

Results and Discussion

3-1 Soil organic carbon (SOC)

The SOC of soil during cultivation and after harvest of maize crop as influenced by tillage practices is presented in Figure (1). The SOC was significantly influenced by tillage systems at 0-15 and 15-30 cm depths.

At 0-15 cm depth, the results showed that highest values for soil organic carbon were with no tillage (NT) treatments practices. No tillage with urea fertilization recorded significantly higher SOC (0.73 %) comparing with minimum tillage with rotary plough (MT1), chisel plough (MT2) and disk plowing (MT3) (0.65 ,0.60 and 0.64 %, respectively). With no tillage with manure fertilization, The SOC **was** 0.71% and minimum tillage with rotary plough (MT1), chisel plough (MT2) and disk plowing (MT3) were 0.63, 0.62 and 0.65 %, respectively ,also it was on par with no tillage with compost fertilization (0.70%) and Minimum tillage with rotary plough (MT1), with chisel plough (MT2) and disk plowing (MT3) (0.62 , 0.63 and 0.62 % , respectively).

However, no significant difference in SOC at 15 to 30 cm is observed when no tillage compared with minimum tillage. The results generally suggest that reducing tillage intensity can enhance SOC at the 0 – 30 cm soil depth (Figure 2).

The higher amount of SOC in surface soil layer under conservation till might be due to higher accumulation of crop residue that derived carbon and lesser exposure of previous crop roots even after the crop harvest that reduced the oxidative losses of roots, this phenomena agrees with West and Post (2002).

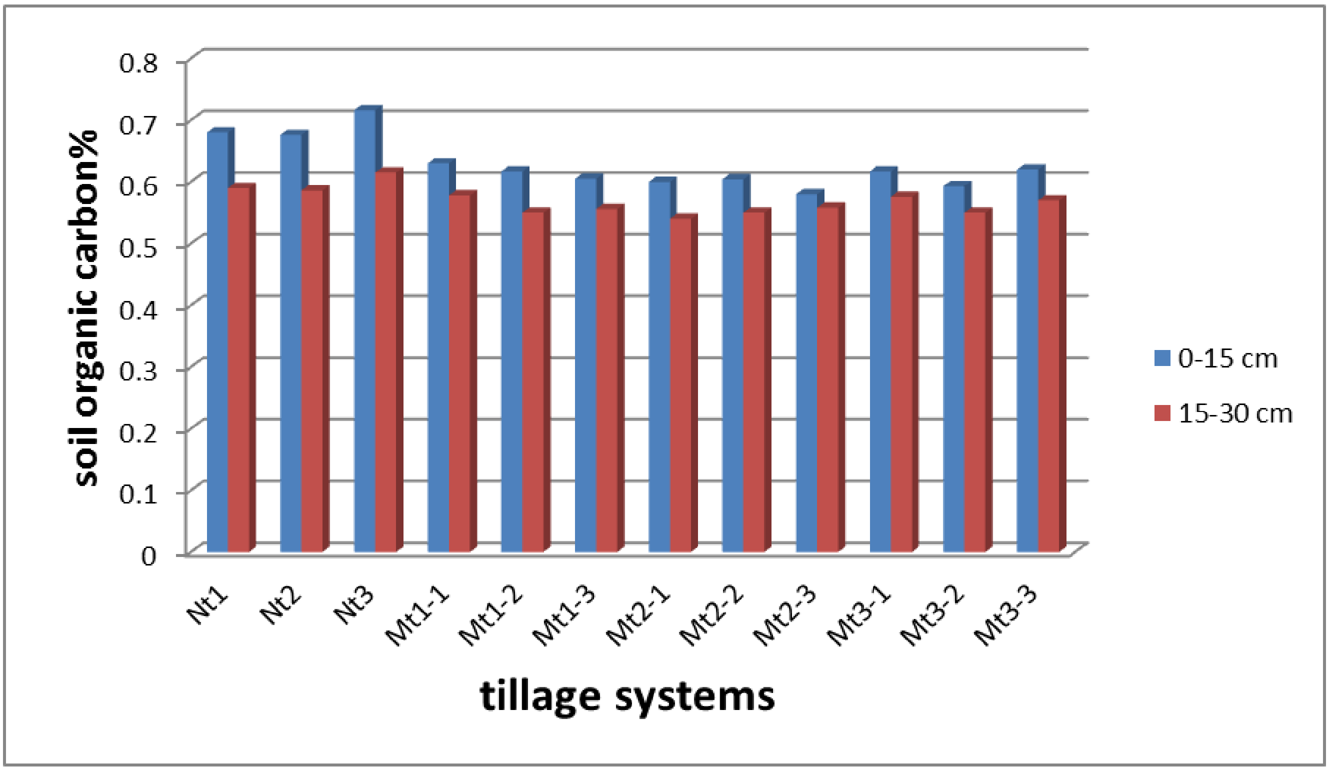

Fig.1. Soil organic carbon as influenced by different tillage systems at the beginning of cultivation at different depths.

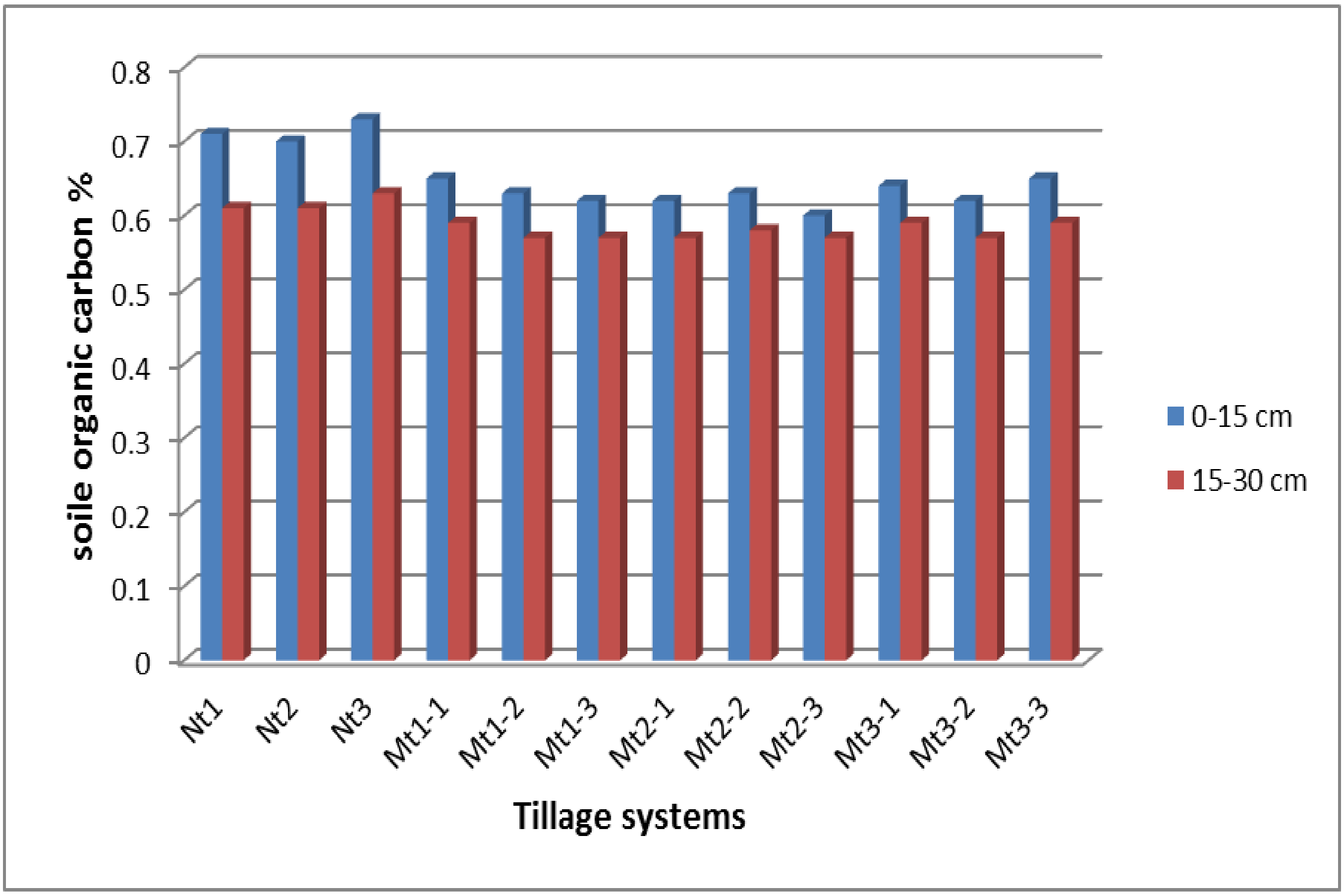

Fig.2. Soil organic carbon as influenced by different tillage systems After harvest at different depths.

Table.3: Soil organic carbon as influenced by different agricultural practices

Tillage systems		Soil organic carbon (%)			
		0-15 cm		15-30 cm	
		Beginning of cultivation	After harvest	Beginning of cultivation	After harvest
No tillage with manure fertilization		0.68	0.71	0.59	0.61
No tillage with compost fertilization		0.676	0.70	0.586	0.61
No tillage with urea fertilization		0.716	0.73	0.615	0.63
Minimum tillage performed via rotary plough with urea fertilization .		0.63	0.65	0.578	0.59
Minimum tillage performed via rotary plough with manure fertilization .		0.617	0.63	0.55	0.57
Minimum tillage performed via rotary plough with compost fertilization .		0.605	0.62	0.556	0.57
Minimum tillage performed via chisel plough with manure fertilization .		0.60	0.62	0.54	0.57
Minimum tillage performed via chisel plough with compost fertilization .		0.604	0.63	0.55	0.58
Minimum tillage performed via chisel plough with urea fertilization.		0.58	0.60	0.558	0.57
Minimum tillage performed via disk plowing with urea fertilization		0.617	0.64	0.576	0.59
Minimum tillage performed via disk plowing with compost fertilization		0.593	0.62	0.55	0.57
Minimum tillage performed via disk plowing with manure fertilization		0.62	0.65	0.57	0.59
F test	5%	*	*	*	*

*: Significant at 5%.

3-2 Soil bulk density

At 0-15 cm depth ,after harvesting of maize crop, soil bulk density was recorded and highest values for bulk density (Mg m-3) was recorded from those plots where MT1 (Minimum tillage performed via rotary plough) practices were done followed by MT2 (Minimum tillage performed via chisel plough) treatment. Lowest bulk density was recorded from NT (No tillage) practiced plots. So MT treatment represented increased bulk density than NT treatment (Fig. 3).

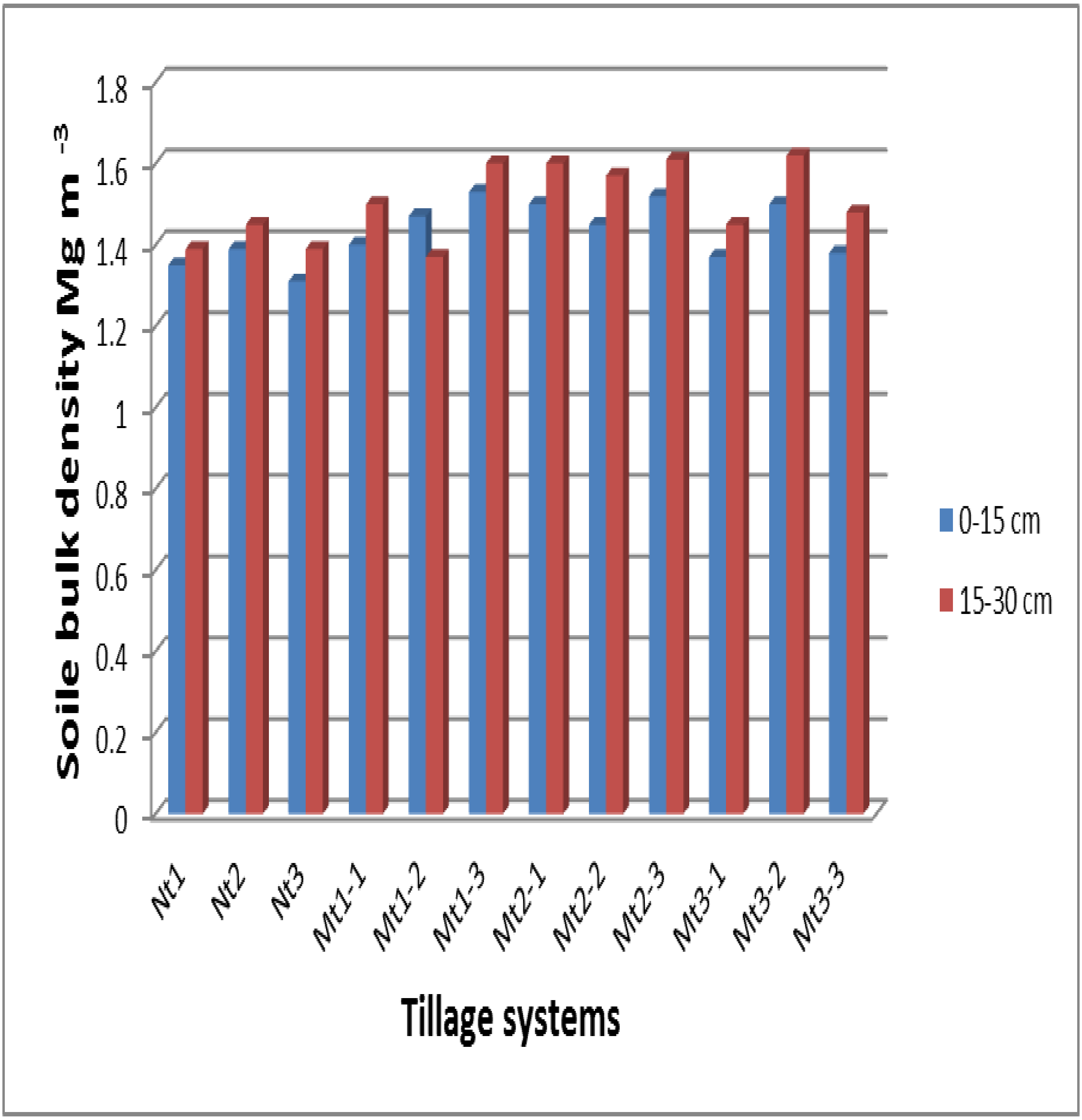

Fig.3. Mean bulk density (Mg m^{-3}) at different depths.

3-3 Soil organic carbon sequestration (SOCS)

The different cultivation practices had a significant effect on SOCS after harvest of maize crop. At 0-15 cm depth, The Collected data revealed that, all the no tillage practices NT1, NT2 and NT3 recorded significantly higher SOCS (14.3, 14.59 and 14.344 t ha-1, respectively) as compared with different minimum tillage (Fig. 4). However, there is no significant difference in SOC at 15 to 30 cm when no-till compared with minimum-till.

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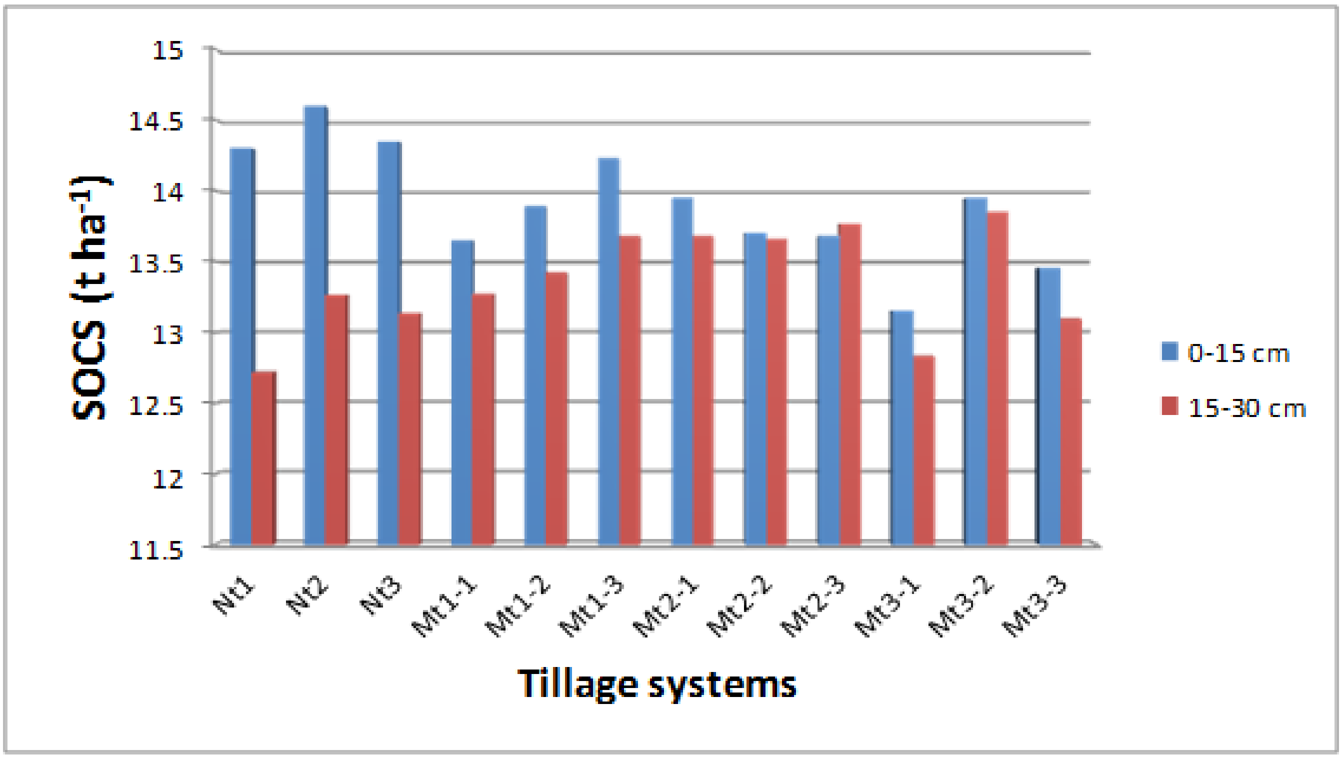

Fig.4 Soil carbon sequestration (t ha^{-1}) as influenced by different tillage systems after harvest

3-4 CO2 emission related to different agricultural practices

CO2 emission due to farming operations are the second largest contributor of total carbon emissions to the atmosphere in the agricultural sector. Significant treatment effects on soil CO2 emission is observed at almost all measuring times although CO2 emission varied tremendously with time regardless of treatment.

CO2 emission reductions with less intensive tillage alternatives are statistically significant, the greatest reductions in CO2 emission are associated with those tillage systems having less soil disturbance, such as the no tillage treatments (Fig. 5).

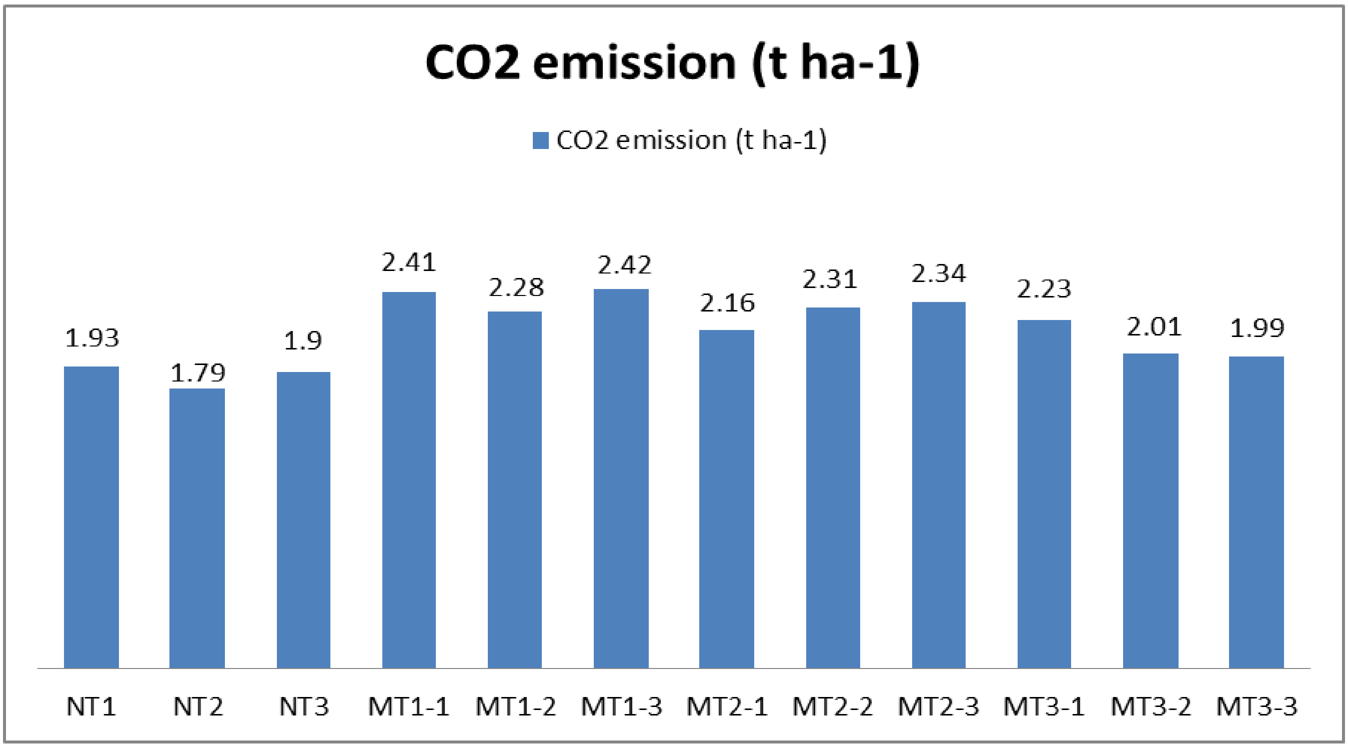

Fig. 5. CO2 emission (t ha-1) related to different agricultural practices.

3-5 Germination percentage

Collected data showed that highest values for germination percentage were recorded from those plots where the minimum tillage treatment practices were done. Minimum tillage performed via rotary plough with manure fertilization (MT1-2) recorded significantly higher germination percentage (84.9 %) as compared to no tillage. (Fig. 6)

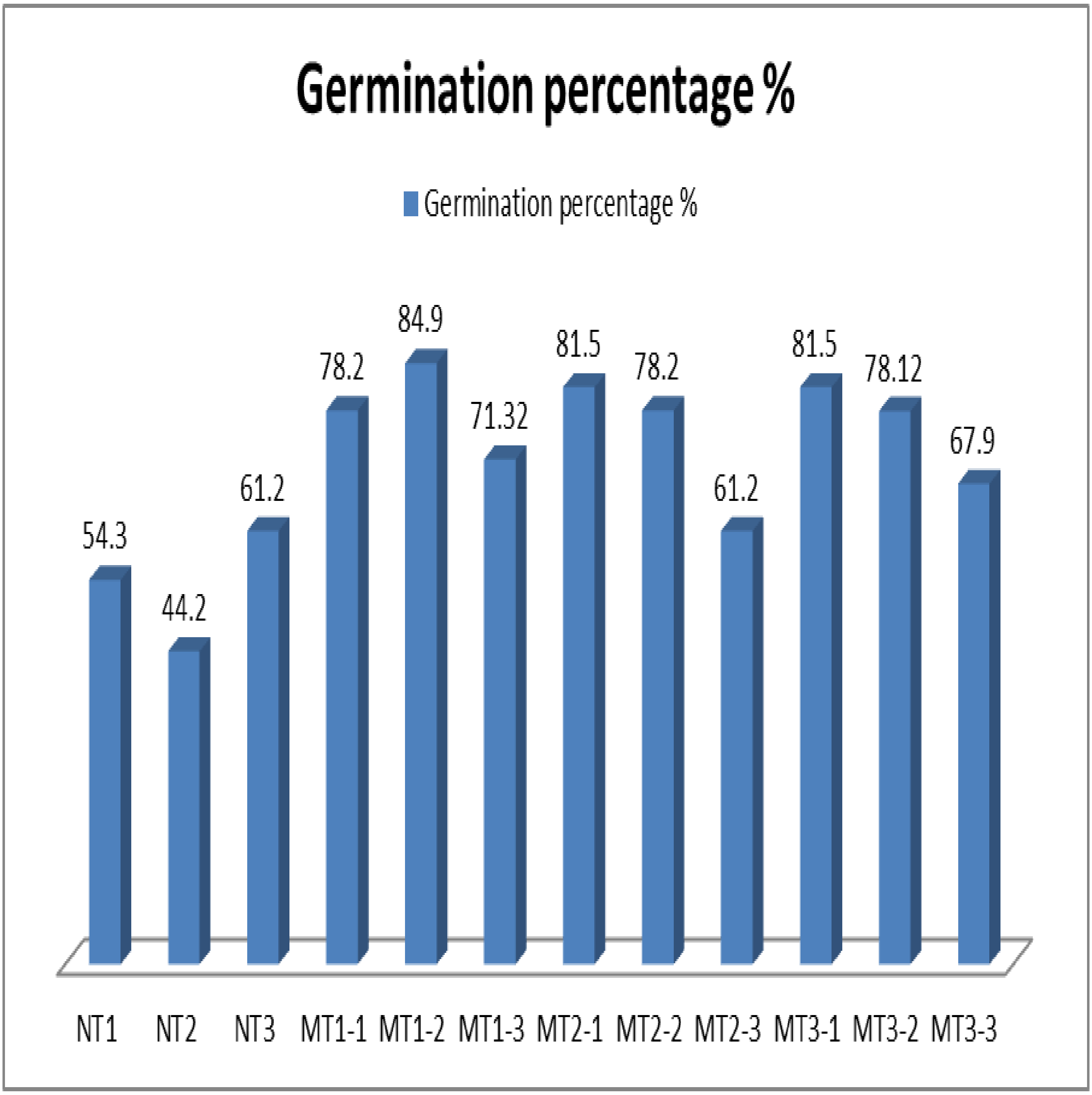

Fig.6 Germination percentage % as influenced by different tillage practices.

3-6 Total grain yield

After harvesting of maize, Average specifications of five plants were taken in each block, total grain yield was recorded and highest grain yield was obtained from minimum tillage performed via rotary plough with manure fertilization (MT_{1-2}). Minimum grain yield was noted where No tillage with compost fertilization (NT_2) was practiced. (**Fig. 7**)

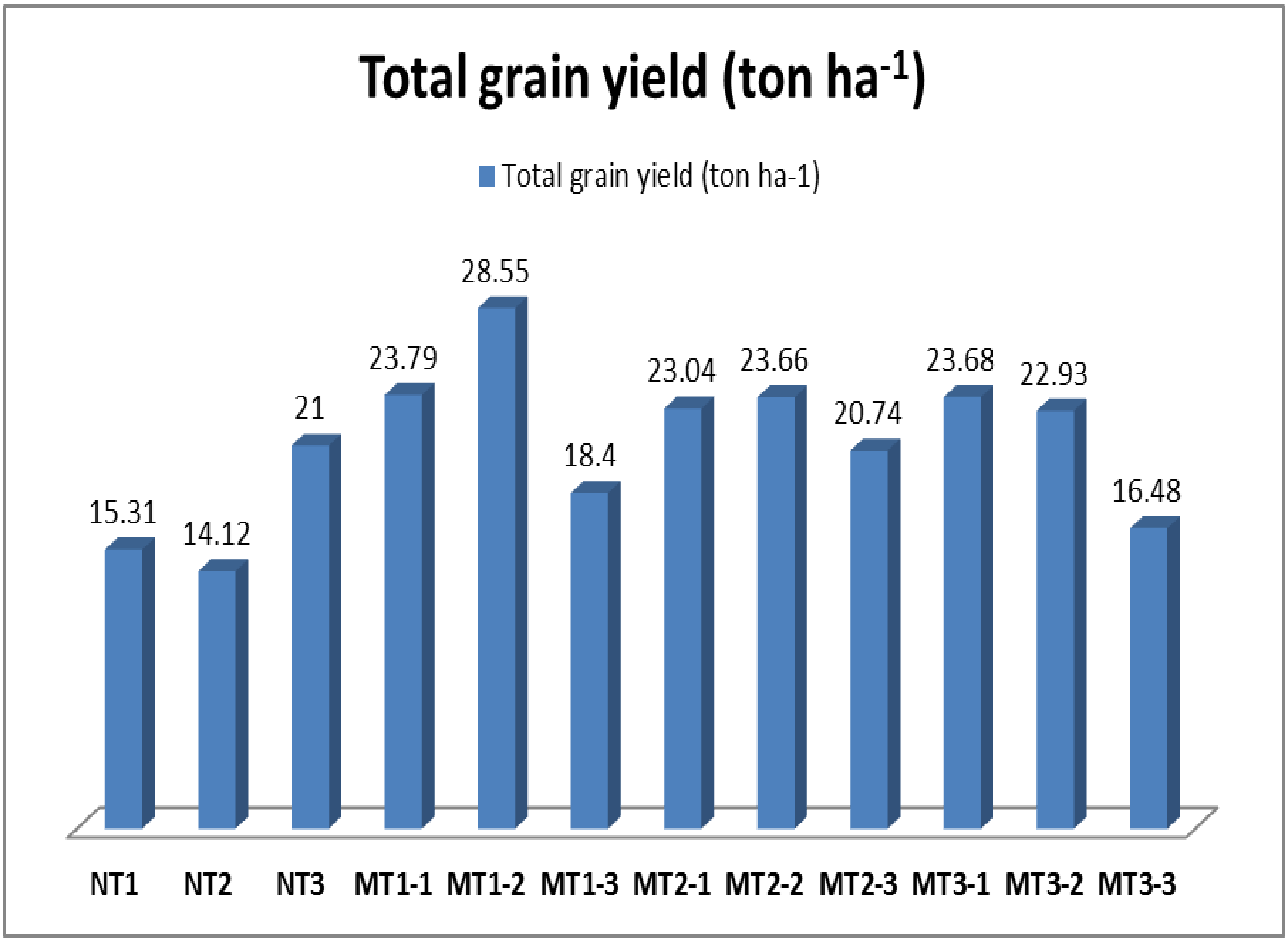

Fig.7. Total grain yield as influenced by different tillage systems.

4. Discussion

In this study, we assessed the effect of minimum and no tillage with different fertilization on maize yield, soil organic carbon, Soil organic carbon sequestration, CO2 emissions from soil. This allowed the identification of the best tillage techniques in terms of the tradeoff between the mitigation of soil CO2 emissions and maize grain production. Moreover, potential differences in mean CO2 flux during the maize growing were examined.

It is believed that tillage practices are the main cause of loss of soil organic matter due to its disturbance, and this problem can be solved by changing to no-till which has less destructive effects. Therefore, the higher organic carbon content in the no-tillage compared to the minimum-till areas is due to the reduced disturbance of the soil structure, these conclusion and recommendation of charging the current soil preparation practices to no tillage agree with Bahadar et al., (2007) and Das et al.,(2013).

Tillage processes integrate the wastes and fertilizers into the soil, but it leads to its physical breakdown, soil inversion, and increased ventilation leads to oxidation of organic matter in the soil and erosion, which reduces the organic carbon content of the soil in the surface soil, this result accords with the findings of other studies Roldan et al., 2003; Halvorson et al., 2002.

Our results may be discordant with the results of other studies, as there has been an increase in soil organic carbon in soils fertilized with urea fertilizer than previous crop residues, as crop residues were said to be the most effective way to convert carbon residues into organic carbon for storage in the soil (Tang et al., 2019; Wu et al., 2017).

The significant fraction of SOC under no-tillage was accumulated in surface soil with 25.8% greater SOC content in 0–15 15 cm depth of no-tillage system than that in the conservation tillage system, this result accords with the findings of other studies which revealed that 9.89% greater SOC in 0–50 cm soil profile under no-tillage than under conservation tillage (Ghimire et al. 2017).

With no tillage, the residues are kept at the surface of the soil and partially incorporated into the soil from minimum tillage, so the emissions of CO2 in the atmosphere also become slow. Thus in the total balance, net fixation or sequestration of carbon takes place and the soil becomes a net sink of carbon as Bot and Benites, 2005 and Naveen Kumar and Babalad. 2018 found.

In this study, during no-tillage, it is possible that the carbon residue did not have a higher utilization rate compared to minimum tillage. Therefore, the decrease in the emission of CO2 and the increase in SOC may be related to the carbon cycle in the soil and the ability to sequester microbial carbon, Schmidt et al., 2011; Six et al., 2002 and Zachos et al., 2008 concluded the role of CO2 and SOC and the whole carbon cycle.

On the other hand in agreement with Castanheira and Freire, 2013 explanation, the minimum tillage practices increase in CO2 emissions may be due to loosening the soil. Therefore, the transfer of CO2 from the soil surface to the air increased. Also, the remains of decomposing crops are often unstable and loose soil can increase its mineralization rate.

In this study, the highest grain yield was obtained through minimum tillage treatments, as tillage practices improved the availability of nutrients and water for efficient absorption, which led to a higher grain yield accords with Gomma et al., 2002.

significantly highest biological yield was obtained by practicing minimum tillage as compared to no tillage practices. This may be due to availability of nutrients and more production of root hairs because of well tilth soil favorable for root proliferation and it may also have facilitated nutrient uptake this result accords with the findings of other studies (Gul et al., 2009). It is also reported that tillage practices are also involved in retention of moisture in the soil and residues management on the soil surface, which ultimately cause increase in maize yield, the same effect was found by Habtegebrial et al., 2007 and Shahbaz Khan et al., 2017.

Conclusions

Our study systematically evaluated the storage of SOC and CO2emissions under different tillage practices. The results indicated that no tillage increased soil organic carbon by 5.2 t ha-1, as well as decreased soil CO2 emission flux by 14.2% compared with the minimum tillage. This results show that the adoption of no-till methods helped reduce emissions of CO2 in the soil as well as increase the storage of SOC in the soil, and this leads to improving soil fertility and mitigating the greenhouse effect of agriculture. The results also help to better manage the soil and achieve sustainable agricultural and environmental development. However, the highest yield of corn grains was obtained through minimum tillage practices compared to no-till practices due to improved availability of nutrients and water as a result of plowing.

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