Conclusion:

Building soil organic carbon by adding organic amendments can induce soil capacity to sequestrate carbon dioxide from the atmosphere, increase soil capacity in storing better amounts of water available to plant absorption, and improving the soil – air condition at mixing depth.

All these positive impacts of organic amendments can help in building a sustainable agriculture with increased efficiency of used water and fertilizers. Yet the most important result of this research is: the importance of using suitable amounts in proper and effective schedule to help soil in keeping the positive and desirable changes. Adding organic matter with more than 80 ton (dry weight)/ha on average is recommended with yearly repetition that ensure compensating the lost amounts via decomposition.

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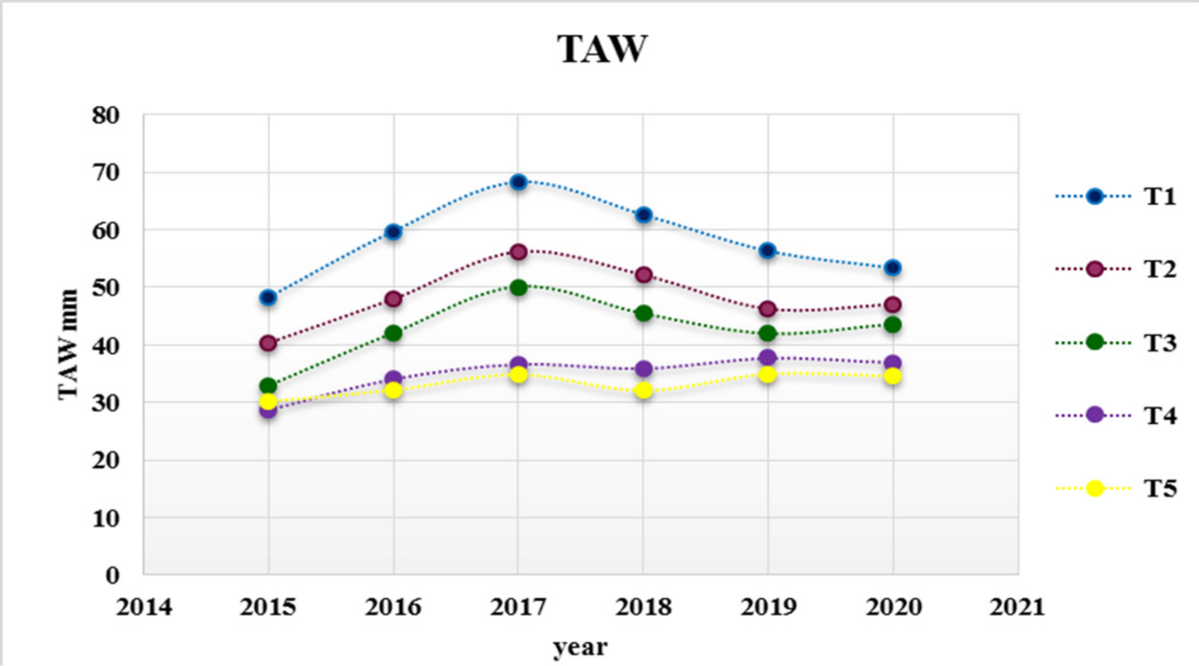

Fig. 9. Soil content of total available water (mm).

Fig. 10. Shows a strong relation between soil OC and soil TAW (R2= 0.86). This strong effect of OC is derived from its positive effect on building soil aggregates and then altering the soil pores system (number and size). Where soil water usually saved and moved. In addition to the capacity of organic compost in absorbing water then losing it to plants easier than soil particles. By using the resulted equation, an increase of 1% in soil content of OC could increase the soil TAW by (16 to 18 mm). This increase means a better water use efficiency and saving good amounts of water requirements. These saved amounts could be used to irrigate extra lands or other crops.

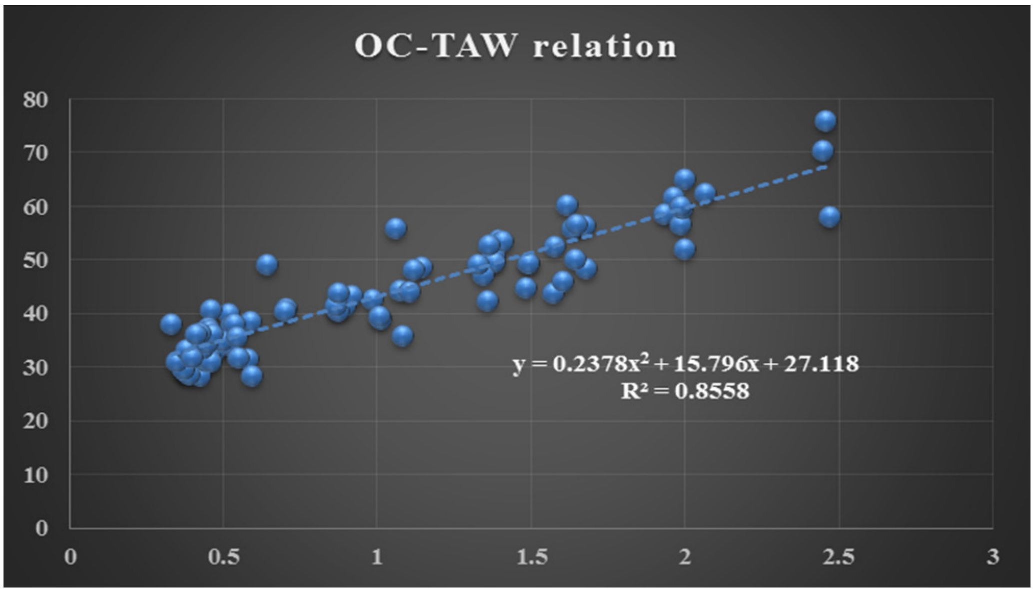

Figure 10. Relation between soil organic matter (%) and total available water (mm).

From Fig. 8,the correlation value between soil OC and FC is 0.64. Which reflect the real relation between those indicators. The result of this long-term experiment approve the non-liner relation between level of organic additions and soil FC. This result in consistent with (Khaleel et al., 1981) who mentioned a small changes in soil moisture at FC level and almost minor at wilting point level in heavy clay soil.

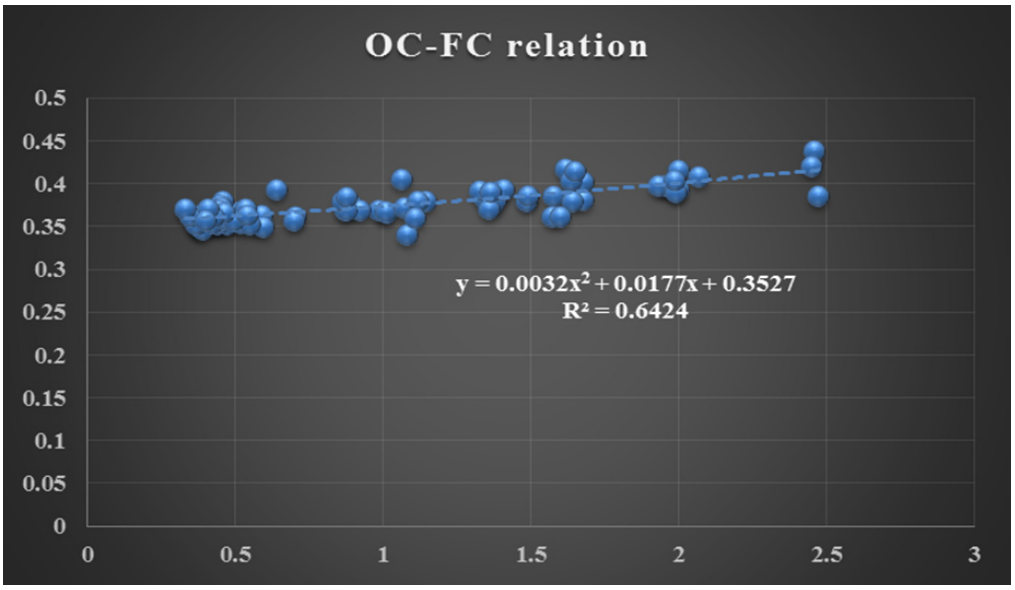

Figure 8. Relation between Soil field capacity (m^3/m^3) and Soil content of organic carbon (%).

Because, not only soil content of OM and OC would determine soil capacity to save moisture, but also the soil structure, pores size and their consistence on the other hand. Organic carbon alter the formation of better soil aggregates (Adugna , 2016), which in heavy soils (rich of micro-pores) has a positive effect on increasing the macro-pores and improve the water movement within soil profile (Krull et al., 2004). Although all the values of FC over six years of study were significantly higher than both: mineral treatment and control.

5- Soil content of total available water- TAW (mm):

Studying soil content of total available water can give a better estimation of soil condition related to its capacity in providing water to plants without stress or spending extra energy to absorb water instead of depending only on soil FC.

From Fig. 9. It is obvious that all levels of compost increased soil content of TAW significantly, since the early beginning of the trial. Although, T1 treatment could increase TAW with (20- 25- 22)% higher than T2 which increased TAW with (2312-14-)% comparing with T3 respectively during the years of additions (20152017-). On the other hand, T1 was better than T2 and T3 in saving the positive changes after cutting compost additions. This due to compost effect on soil Bd (R^2= 0.93) and soil FC (R^2= 0.94). Changes in T4 and control Treatments was merely 12% in the year 2018 - as best recorded value- and is due to the grass residues and reduced tillage (Oliveira et al., 2020). This result agrees with results of (Brown and Cotton, 2011).

A strong correlation ($R2= 0.81$) was found between both (fig. 6). This is because of the role of organic carbon in inducing specific changes in soil structure, soil pores phase and soil weight (mixing soil with lighter organic materials –table3). Depending on this strong relation and with taking the reduction of soil organic carbon content after the year 2017 into consideration, the later increase in soil bulk density values becomes understood. Although soil bulk density in all treatments received, compost additions were better than mineral and control treatment both at the same year 2020 and at comparing with the base year 2015 after six year of study.

This trend of changes indicates to the reason of changes with time: at beginning the decrease of clay soil density with compost addition is mainly due to the difference in densities between soil and compost, therefore it is a weight matter. Yet after six years of study and with losing a part of added compost, the changes at 2020 was mainly due to changes of soil structure and the pore part alteration.

4-Soil Field capacity –FC (m^3/m^3):

The values of soil FC in Fig. 7. Is the volumetric values resulted from multiplying soil moisture at field capacity (weight content) with soil bulk density. Therefore, the values from 2015 to 2017 were increased drastically with the increase of compost level, and that goes along with the findings of (Khaleel et al., 1981) and due to the capacity of organic matter to absorb higher amounts of moisture (Table 3) . Yet the most important result is the soil behavior after stopping the additions. It is obvious from figure 7. That T3 treatment faced a decline in soil moisture content at FC in 2018 directly after the last addition in 2017. While T2 could achieved a more stable moisture content tell 2018- two year after cutting the additions-. The best result was obtained in T1, where the larger compost additions helped to achieve almost stable moisture content for 3 years and only declined by the year 2020. This result is very crucial and could approve the difference in suitable amounts of organic amendments for physical changes from those used as organic fertilizers. As well, ensure the possibility of building a soil with better capacity to obtain and save moisture from precipitation and irrigation water by increasing soil organic carbon.

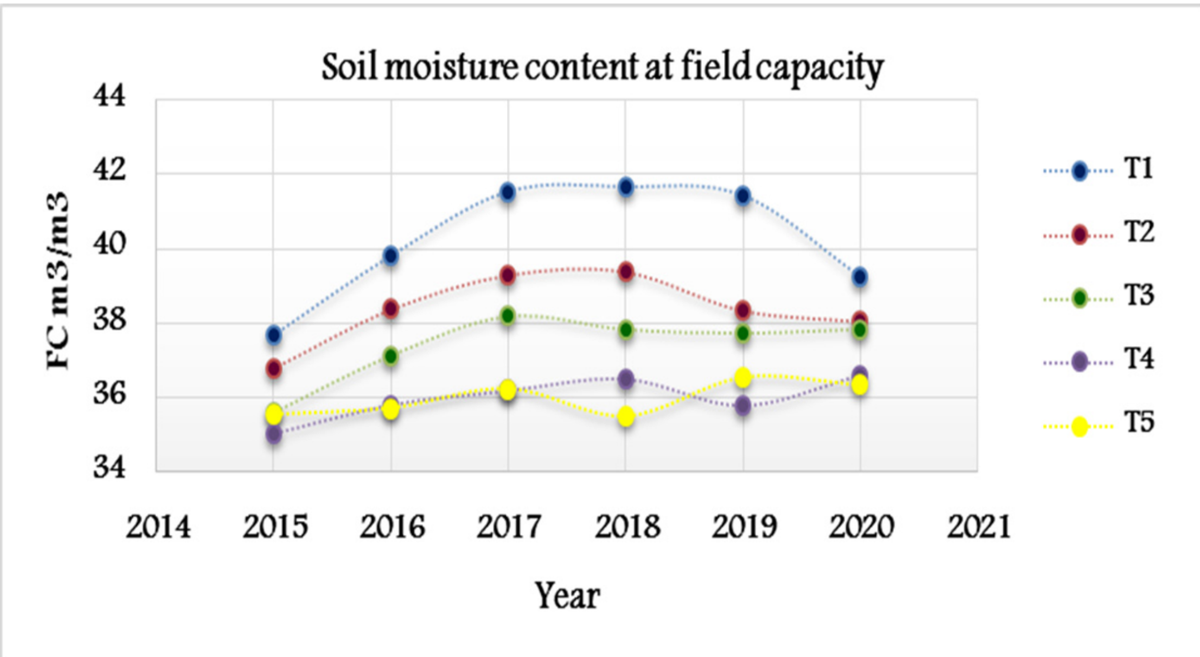

Fig.7. Soil moisture content at field capacity (m^3/m^3).

soil capacity of sequestering carbon increased with 167%-131%-42% in T1-T2-T3 respectively in 2020 comparing with control, although the organic additions stopped since 2017. While mineral additions in T4 led only to a minor increase of 5% comparing with control.

3- Soil Bulk density –Bd (g/cm^3):

Differences in soil organic carbon content was directly reflected in soil bulk density values. The higher increase of OC in T1-2017 resulted in a degrease of 31% in soil Bd. Which was the highest percent over the six years. A similar behavior was found for other treatments and years. Large number of previous researches approved this result (Brown and Cotton, 2011; Kowaljow et al., 2017), that's why a relationship was studied between soil content of OC and soil Bd (fig. 6).

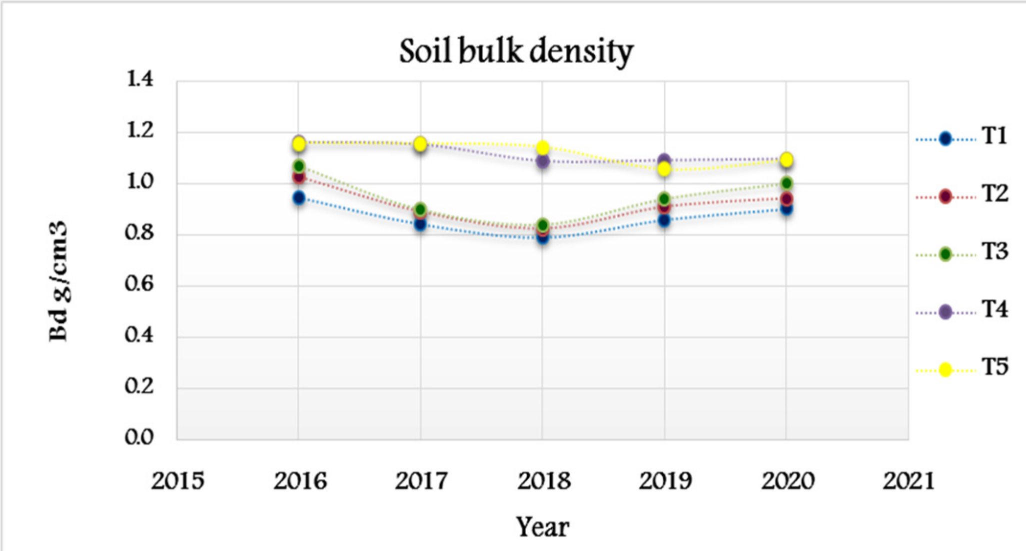

Figure 5. Soil Bulk density (g/cm3).

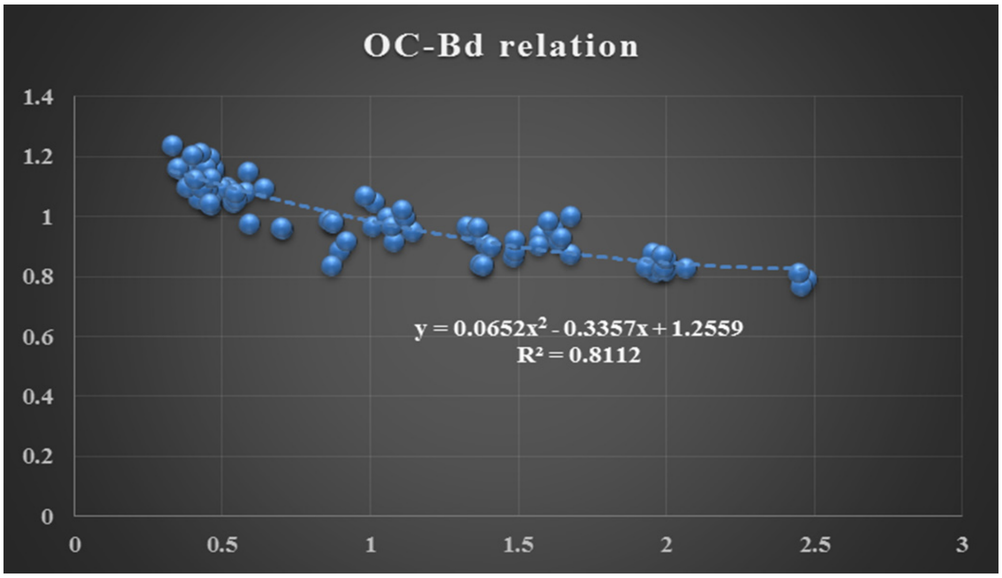

Fig. 6. Relation between Soil Bulk density (g/cm3) and Soil content of organic carbon (%).

Soil in the mineral treatment as well as the control-T5 showed unstable behavior, increased content from 2015 to 2018 then declined with time during the next years.

Despite of the fact that: 28% (0.54% OC) was the maximum increase in T4 comparing with control over six years of study. This increase was due to the organic residues from the grass cover, and the fluctuation is a natural result to the differences in growth rate and dense of grass over years of the study.

The maximum peak of increase was in 2017, and in spite of the following decrease, T1 was 24%- 104%-210%-243% higher than (T2-T3-T4-T5) respectively at the end of the trial.

This trend of decrease is predicted after stopping the additions, in addition to the high temperature degrees during the years of study, which accelerated the decomposition of soil organic matter , this agree with that mentioned by (FAO, 2017).

2-Soil carbon sequestration potential –Cseq (ton/ha):

Soil carbon sequestration was calculated for the upper (030- cm) soil layer.

From a mathematical sight, soil carbon sequestration potential would increase with every increase of soil content of OC (Equation 2). Figure 3. is a clear evidence of this relation, Cseq increased during years of additions in treatments of compost, then directly decreased with cutting the additions. A natural trend with decreased soil OC and increased soil Bd (the main factors of Equation 2 for a fixed soil layer).

Climate change side by side to unsustainable agricultural practices translated into SOC loss and releasing considerable amounts of CO_2 into the atmosphere. For this reason the resulted strong relation R2=0.99 that found (OC-Cseq) (fig. 4) should be activated and functioned to increase the soil capacity to sequester carbon and mitigate Carbon dioxide emissions(FAO, 2019).

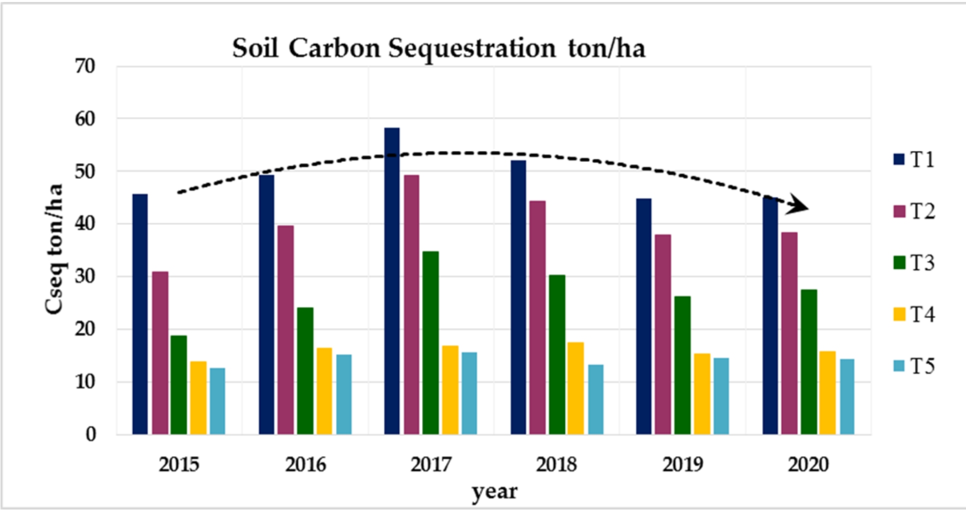

Fig. 3. Soil carbon sequestration potential (ton/ha) over six years of study.

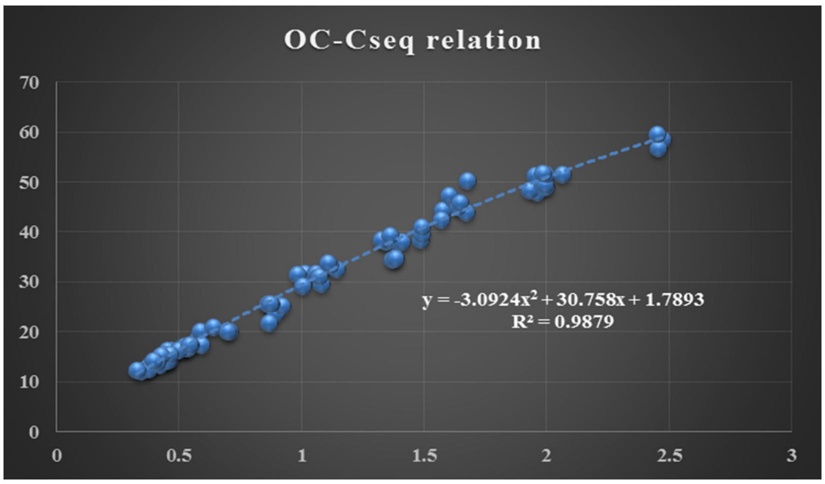

Fig.4. Relation between soil content of organic carbon (%) and carbon sequestration potential (ton/ha).

6- Studied parameters:

This research concentrated on studying the behavior of some soil physical properties with the organic additions.

I. Soil content of organic carbon-OC (%): as 58% of the soil total content of organic matter determined by Walkley-Black method (1934).

II. soil bulk density – Bd (g/cm3): by using the cylinder method (Blak and Hartge, 1986).

III. soil field capacity –FC (m3/m3): by cylinder method (Klute, 1986).

IV. soil content of total available water –TAW: by using the following equation from (Allen et al., 1998).

$$TAW\ (mm) = 1000\times(\theta FC - \theta Wp)\times Ze \quad \text{........Equation (1)}$$

where:

- θFC :soil water content at field capacity level (m3/m3).
- θ Wp :soil water content at wilting point level (m3/m3).
- Ze: depth of amended soil layer (m).

soil carbon sequestration potential –Cseq (ton/ha): by using the following equation from (Baldock, 2009).

$$Cseq\ (ton/ha) = Ze \times Bd \times OM \quad \text{........Equation (2)}$$

Where:

Ze: studied layer depth (cm).

Bd: soil bulk density (g/cm3).

OM: soil content of organic matter (%).

7- Statistical analysis:

After collecting data from six years for all studied parameters, GenStat12 edition was used to calculate the least significance difference- LSD at 5% significance level (One-way ANOVA in randomized blocks).

Results and discussion:

1- Soil content of organic carbon –OC (%):

Soil content of organic matter and then organic carbon is the result of input/output balance of organic sources. Therefore, directly affected by compost addition, (Fig 2)The increase was higher -as predicted- with high levels of additions (T1&T2 treatments), this result agree with the findings of (Chatterjee et al., 2017). As well as increased with the repeating of the organic additions from 2015 to 2017. After stopping the additions, there was an obvious decline of (18 -19- 22%) in T1-T2-T3 respectively. This decreasing trend continue during the next years, although it was clearer in 2019 comparing to 2020.

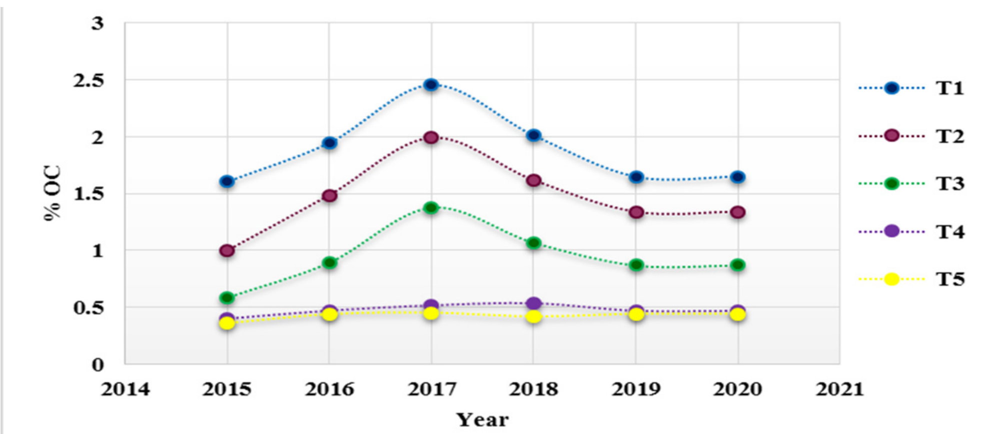

Fig.2. Soil content of organic carbon %.

Table 4. Added amounts of compost during the years (2015 - 2017)- compost content of nitrogen (%).

Year of study/ Treatment	Added amount (dry weight) kg / plot			Added amount (fresh weight) kg / plot		
	T1	T2	T3	T1	T2	T3
2015	80	40	20	93	46.5	23.2
2016	60	30	15	69.8	29	17.5
2017	50	25	12	58	32.5	14.5

The first additions (additions of treatment T1 as a base treatment) were calculated according to soil & compost analysis and the required amount of compost was 80 ton/ha. Treatment. T2 received only organic fertilizers equals to half the amounts of T1, and T3 received half the amounts of compost add toT2 treatment and the other half as mineral nitrogen (Urea 46%) .(table 4) While the mineral treatment received the nitrogen amounts as Urea 46%, and control treatment without any addition T5

4- Experimental design:

The experiment was designed as complete randomized blocks. And figure (1) shows the locations of each treatment. Four treatments were applied, in addition to a control treatment, in order to compare the changes. By replicating each treatment for three times, 15 plots were resulted in total. Each plot was 9 m2 and 2 m was left as interval distance between adjacent plots from all sides.

5- Agricultural management:

After calculating the right amounts of compost, the additions were prepared according to the plot area and compost moisture content, then mixed within the upper 025- cm of the soil of each plot. No crop was planted and grass was left to grow then mixed into the soil with tillage. Tillage was applied once a year and in a way that ensure a good compost incorporation, reduce the soil disturbance and the possibility of moving out of the plot. Soil samples were taken in August of each year, from three different places of each plot far from the sides.

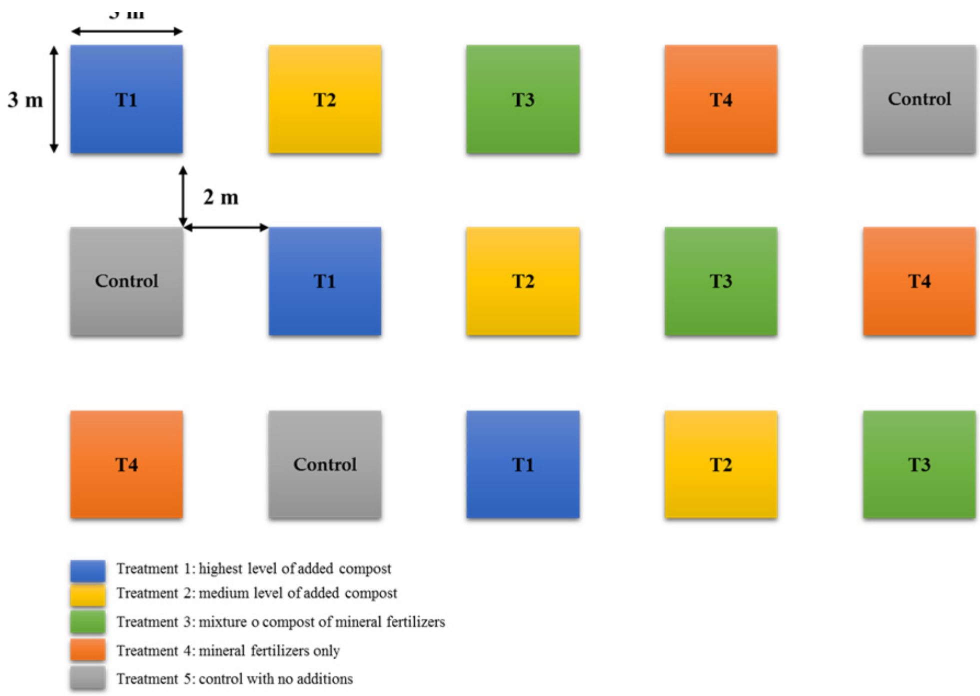

Figure 1. distribution of experimental plots in the field

additions?

Literature researches can answer that question: a great number of those studies used organic matter as an organic fertilizer to reduce the use of mineral fertilizers with natural alternatives -low in cost-. The added amounts were only enough to affect the chemical properties but not the physical ones. Only few studies discussed the additions of organic fertilizers as soil amendments not only nutrients.

Results of Khaleel et al.(1981) were the first to mention the importance of additions' size on the produced effects, and found that bigger and repeated amounts are needed to induce any physical changes.

Therefore, this research aimed to study the effects of large levels of organic compost on heavy clay soil, and their capacity to save the changes after cutting the organic additions.

Material and Methods

1- Site of experiment:

the research was conducted in Hout research station (32.47 lat., 36.60 long., 1050 Alt.), which located in the south of Syria (Al-Swaida governorate). The annual precipitation is 250 mm, although it was declined remarkably during the recent years. The average temperature vary in average from 35 C° in hot summer to about 13 C° or less in cold season.

2- Soil characteristics:

the chemical and physical characteristics of studied soil are shown in tables (1 and 2) and analyzed according to the methods mentioned in (Al-Zoubi et al., 2013) , the tested soil was a heavy clay soil, poor in organic matter content (≥ 0.5%)

Table 1. Soil chemical properties.

Sample depth (cm0	N (%)	P (mg/kg)	K (mg/kg)	OM (%)	pH	EC(dS/m)	$CaCO_3$ (%)
					Saturated paste		
30-0	0.02	3.5	350	0.5	7.5	0.4	0.8

Table 2. Soil physical properties.

Sample depth(cm)	Clay (%)	Silt (%)	Sand (%)	Bd	Rd	FC (m^3/m^3)	PO (%)	Infilt (cm/h)
				(g/cm^3)				
30-0	58	23	19	1.15	2.76	0.36	58.15	1.5

3- Compost characteristics and the added amounts:

The used compost was derived from the recycling factory of Damascus governorate. Which, went under several analyses to ensure its validation to be incorporated in agricultural land (content of heavy metals in particular).

The physical properties of the compost were estimated according to the methods mentioned in (Khater, 2012) as shown in table 3.

Table 3. Compost physical properties.

Compost sample	Bulk density- Bd g/cm^3	Saturation Capacity- SC g water/ g compost	Total Porosity-Po %	Organic Matter -OM %	C/N	MOISTURE
2015	0.58	3.3	64.5	37	17:1	16.4
2016	0.58	3.4	65.1	38	16:1	16.4
2017	0.58	3.2	64.3	37	17:1	16.1

Abstract

A field experiment was conducted in Hout research station- The General Commission for Scientific Agricultural Research-, located in the south of Syria (Al-Swaida Governorate) over the period from 2015 to 2020 -and still on going- to study the effect of adding different levels of organic amendment- Compost of town refuse- on some soil physical properties (2015-2017). Then studying the soil capacity to preserve changes after stop adding the organic additions (2018- 2020) to a heavy clay soil.

The results showed several positive changes of all tested organic levels, although the treatment (T1; the highest level of compost 80 ton/h) of adding dry compost was the best on all studied indicators, and improved soil content of organic carbon by 442% in 2017 and with 243% at 2020 after three years of stopping the amending procedure. A desirable decline in soil bulk density of 31% and 22%. In addition to a positive increase in soil moisture content at field capacity with 15% and 8% , in soil content of total available water with 96% and 54% . And raising the capacity of soil carbon sequestration potential with 275% and 167% at the same dates respectively. While insignificant changes were detected with mineral fertilizer in T4 treatment in compare with the control.

Key words: Bulk density, Carbon sequestration, Field capacity, Mineral fertilizer, Organic carbon.

Introduction

The recent researches addressed huge challenges facing the conventional agriculture, which has been depending on mineral fertilizers, with many negative impacts on the environment and low capacity to build a sustainable agriculture (Voltr et al., 2021). At the same time, the term “ soil health” has become among the most used and discussed issues during the last decades, after the dangerous threats emerged from the unwise human , industrial and agricultural use of soil all over the world.

The global soil partnership-FAO has adopted this term and specified a group of soil properties, which are strongly related to soil health, and consider them the most important and the ones to start working on. In addition to start raising the awareness of soil health in order to achieve a sustainable use of our soil. SOC was on the head of that list due to its importance and effect on soil properties and finally the soil productive capacity as a source of human food and life for a great deal of population.

Nevertheless, what is the soil organic carbon- SOC? Why it is important to build the soil content of organic carbon-OC?

SOC is a composite of different materials with different extent of decomposition, wide range of different chemical, physical properties, size, composition and type SOC importance is derived from playing a major role in soil functions, from chemical (CEC- pH buffering..etc), physical (water retention capacity – soil structure and aggregate stability.. etc) to biological properties (source of energy- nutrient..etc) (Baldock, 2009)..

Soil content of OC is not stable, but a process of balance between the inputs and the outputs, yet the detected values of the Syrian agricultural lands cannot meet the desired levels for an ideal soil health.

Increased temperature side by side with the decreased precipitations because of the recent climate change, have increased the threat and potential of losing the SOC by accelerating the Soil organic matter- SOM decomposition. According to FAO (2017) soils from various agro-ecosystems have lost 2575%-of their SOC pool. Therefore, the urgent need and importance of building the SOC must be highlighted.

Building strategies vary according to site-specific factors. However, increasing the inputs by adding organic amendments considered among the basics. Organic fertilizers can directly increase the pool of soil organic carbon, and indirectly through increasing the soil content of nutrients (N-P-K and other micro-elements) (Voltr et al., 2021????),and inducing a better plant growth with a higher crop residues which, come back to soil after harvesting.

Nevertheless, why this function did not lead to save SOC and achieve a sufficient level of OC over years of

دور المحسنات العضوية في بناء كربون التربة العضوي
Role of Organic Amendments in Building Soil Organic Carbon

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الملخّص

أجريت تجربة حقلية في محطة بحوث حوط التابعة للهيئة العامة للبحوث العلمية الزراعية السورية، والتي تقع في محافظة السويداء جنوبي سورية، خلال الفترة من عام 2015 لغاية عام 2020 ولا زالت مستمرة - بهدف دراسة تأثير إضافة مستويات مختلفة من كومبوست قمامة المدينة في بعض الخواص الفيزيائية (2015-2017)، ثم دراسة قدرة التربة على الاحتفاظ بتلك التغيرات بعد قطع الإضافات العضوية (2018-2020) في تربة طينية ثقيلة القوام.

بينت النتائج تغيرات إيجابية عدة في كل المستويات العضوية المختبرة، رغم أن المعاملة T1 ذات الإضافة الأعلى (80 طن/ه) كانت الأفضل في كل المؤشرات المدروسة، وحسنت محتوى التربة من الكربون العضوي بنسبة 442 % في العام 2017، وبنسبة 243 % في العام 2020 بعد ثلاث سنوات من توقف عملية التحسين، مع انخفاض مرغوب في الكثافة الظاهرية للتربة بنسبة بلغت 31 % و22 % على التوالي، بالإضافة لزيادة إيجابية في محتوى التربة الرطوبي عند حد السعة الحقلية بنسبة بلغت 15 % و8 %، وفي محتوى التربة من الماء الكلي المتاح بنسبة قدرها 96 % و 54 % على التوالي، ورفع قدرة التربة على احتجاز الكربون بنسبة بلغت 275 % و167 % للمواعيد ذاتها على التوالي، بينما وجدت تغيرات غير معنوية للسماد المعدني في المعاملة T4 مقارنة بالشاهد.

الكلمات المفتاحية : الكثافة الظاهرية، احتجاز الكربون، السعة الحقلية، السماد المعدني، الكربون العضوي.

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