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المجلة العراقية لبحوث السوق
وحماية المستهلك

SOIL ORGANIC CARBON AND AGGREGATE STABILITY AS AFFECTED BY SOIL MANAGEMENT PRACTICES

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ABSTRACT

A field experiment was in research station Aljadriya at the College of Agricultural Engineering Sciences - University of Baghdad– Iraq (33̊ 16́ 02̋ N. 44̊ 22́ 33̋ E) during spring season - 2022. The purpose of the investigation was to evaluate the effect of Tillage, Crop Rotation and Crop Residues Management Practices on soil organic carbon (SOC) and active soil carbon (ASC), Aggregate stability and saturated hydraulic conductivity. The experiment was laid out on Randomized Complete Block Design (RCBD), with Split –Split Plot Arrangement. Factors were: Crop Residues (0% Residues (0%R) and 100% Residues (100%R)), Tillage (Minimum Tillage (MT) and Conventional Tillage (CT)) and Crop Rotation (Clover – Maize and Clover – Mung Bean) with four replicates. Results of the trial indicated that the best results were with the treatment (100% R + MT + Crop Rotation Clover – Mung Bean) giving (12.78 g SOC Kg^{-1} Soil , 178.92 mg AC Kg^{-1} Soil, 44.72% Aggregate stability, and 2.79 cm h^{-1} for Saturated hydraulic conductivity) compared with results of the Treatment (0% R+ CT + Crop Rotation Clover - Maize) giving (8.08 g SOC Kg^{-1} Soil, 88.88 mg AC Kg^{-1} Soil, Aggregate stability 39.05%, Saturated hydraulic conductivity 2.32 cm h^{-1}). So, it can be concluded that adopting good management practices can improve many soil properties like Organic Carbon and Soil aggregate Stability leading to healthy and productive soil.

Keywords: Soil health indicators, Minimum Tillage, Conventional Tillage, Saturated hydraulic conductivity , SOM.

كاربون التربة العضوي وثباتية التجمعات وتأثرهما بعمليات إدارة التربة

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الخلاصة

نُفذت تجربة حقلية في المحطة البحثية التابعة لكلية علوم الهندسة الزراعية– جامعة بغداد في الجادرية، بغداد– العراق (33̊ 16́ 02̋ N . 44̊ 22́ 33̋ E) خلال الموسم الربيعي ٢٠٢٢ لتقييم تأثير الحراثة والتعاقب المحصولي وبقايا المحصول في كاربون التربة العضوي والإيصالية المائية المشبعة للتربة. نفذت التجربة بتصميم القطاعات الكاملة المعشاة وبترتيب الألواح المنشقة– المنشقة. تضمنت التجربة ثلاثة عوامل هي: بقايا المحصول السابق (٠٪ بقايا و ١٠٠٪ بقايا) والحراثة (حراثة دنيا وحراثة تقليدية) اما العامل الثالث فهو التعاقب المحصولي (برسيم– ذرة صفراء) و (برسيم– ماش) بأربعة مكررات لتقييم تأثير هذه العوامل في كاربون التربة العضوي (الكاربون العضوي والكاربون النشط (الفعال) وبعض

[*] The research is extracted from the doctoral thesis of the first researcher.

الصفات الفيزيائية (ثباتية تجمعات التربة والإيصالية المائية المشبعة). كانت افضل النتائج (١٢,٧٨ غم كاربون عضوي كغم-١ تربة و ١٧٨,٩٢ ملغم كاربون نشط (فعال) كغم-١ تربة) و ثباتية تجمعات التربة ٤٤,٧٢٪ وإيصالية مائية مشبعة ٢,٧٩ سم ساعة-١) للمعاملة (١٠٠٪ بقايا المحصول+ حراثة دنيا+ تعاقب محصولي برسيم- ماش) بالقياس الى معاملة (٠٪ بقايا+ حراثة تقليدية+ تعاقب محصولي برسيم- ذرة صفراء) التي حققت (٨,٠٨ غم كاربون عضوي كغم-١ تربة و ٨٨,٨٨ ملغم كاربون نشط (فعال) كغم-١ تربة) و ثباتية تجمعات التربة ٣٩,٠٥٪ وإيصالية مائية مشبعة ٢,٣٢ سم ساعة-١). لذا يمكن الاستنتاج ان تبني ممارسات إدارية جيدة يمكن ان تحسِّن، من كاربون التربة العضوي وثباتية تجمعات التربة مما تؤدي الى تكوين تربة صحية ومنتجة.

الكلمات المفتاحية: دلائل صحة التربة، الحراثة الدنيا، الحراثة التقليدية، الإيصالية المائية المشبعة، مادة التربة العضوية.

INTRODUCTION

Soil Organic Carbon (SOC) can be considered one of the most soil criteria that affect other soil properties, crop production, soil health, and the environment. Soil organic carbon is the part that soil Microorganisms depend it in their growth. At the same time, Soil microorganisms can play an important role in organic carbon formation, preservation, and loss **(Tao *et al*., 2023)**. Soil Organic carbon is very important in determining soil fertility, increasing biodiversity and productivity, and soil health. A lot of SOM can be lost due to soil and environmental effects, especially in arid and semi-arid regions. Soil organic carbon can play a very important role in carbon dioxide (CO_2) sequestration and decreasing Global warming **(Magdoff & Es, 2021; Ali *et al*., 2022; Al-Halfi & Al-Azzawi, 2022a,b)** So soil health institute considered soil organic carbon as the main indicator for soil health **(Soil Health Institute, 2023)**. Identifying agricultural management practices that minimize loss or even enhance SOC stores, is very important for sustaining soils and food production and security systems, and improving the environment by minimizing global warming **(Amelung *et al.*, 2020)**. Soil aggregates, and their stability (i.e. soil structure) is other important criteria for good and healthy soil. Soil with good soil structure can hold more water, good aeration, drain extra water, and have good crop production **(Ali, 2015; Magdoff & Es, 2021; Ali, *et al.*, 2022; Masood & Ali, 2022; Jassim & Hamied, 2022).**

Integrating good soil's physical, chemical, and biological properties can improve soil health and productivity **(Van Eerd *et al*., 2021)**. Several studies reported greater formation SOC under minimum or no tillage compared to conventional tillage **(Magdoff & Es, 2021; Nyambo *et al*., 2021; Ali *et al*., 2022).** Many studies indicated that good Soil Management Practices such as using crop rotation, minimum tillage, and crop residues improved physical, chemical, biological, and fertility of soil and enhanced soil health and quality, **(Nath *et al*. 2021; Riahinia & Emami, 2021; Saurabh *et al*, 2021; Al-Halfi, & Alazzawi, 2022a,b; Mohammed & Hasan, 2022a,b; Masood & Ali, 2023; Morrisville, 2023; Jasim & Hamid, 2023)**, besides, enriching the soil, they enhance life on our planet **(Morrisville, 2023)**. Zero tillage was better than minimum and conventional tillage in maize grain yield and other yield components, **(Al-Rubaie & Al-Ubaidi, 2018)**. **Nafawaah, & Mageed, (2019)** mentioned that different harrowing systems affected soil organic matter decomposition as well as some soil and plant properties. **Othman *et al.*, (2020)** indicated that conservation agriculture in the presence of crop rotation. Using the optimum crop combination (crop rotation) together with conservation agriculture can maximize the profits and the agricultural income of farms **(Alnassr, 2019)**.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Research Station of the College of Agricultural Engineering Sciences - University of Baghdad in Aljadriya, Baghdad – Iraq (33° 16′ 02″ N. 44° 22′ 33″ E) during two seasons Fall and Spring of 2021-2022. Trial were conducted in a randomized complete block design with four replicates, to investigate the effect of Tillage, Crop Residues, and crop rotation Management Practices on organic carbon and aggregate stability. In the 1st experiment, two factors were used: the first was the residues of the previous crop (Alfalfa) (*Medicago sativa* L.), 100% residues (100% R) and 0% residues (0%R), the 2nd factor was tillage (minimum tillage MT and conventional tillage CT) in split-plot arrangement planted with Clover (*Trifolium repens* L.). The 2nd experiment followed the 1st one in the spring season using Tillage, Crop Residues, and crop rotation Clover - Maize (*Zea mays* L.) and Clover - Mung bean (*Vigna radiate* L.) on Maize and Mung bean Productivities. Both crops were sawn at the same plots of the previous Clover crop, in a split – split plot arrangement. Soil samples were collected before and after each trial to estimate some chemical, physical and fertility properties of soil. At the end, of every experiment samples of soils were collected for measuring SOC, SAC, Aggregate stability, and Soil hydraulic conductivity, The estimation results for the studied field soil pre-planting are shown in table (1).

Table (1): Chemical, Physical, Biological and Fertility properties of the Soil before planting*

Characteristics		Value	Unit
Potential Hydrogen (pH) (1:1)		8.25	-
Electrical Conductivity (EC) (1:1)		1.85	dS m^{-1}
Available Nitrogen		28.00	mg kg^{-1} Soil
Available Phosphorus		13.25	
Available Potassium		174.01	
Available Iron		5.65	
Available Zinc		3.75	
Carbonate minerals		345.0	g kg^{-1}Soil
Soil Organic matter		16.13	
Soil Organic Carbon		9.35	
Active Carbon		128.44	mg kg^{-1}Soil
Cations	Ca^{2+}	8.95	m mol L^{-1}
	Mg^{2+}	4.55	
	K^{1+}	2.35	
	Na^{1+}	3.47	
Anions	SO_4^{2-}	5.1	
	Cl^{1-}	21.5	
	HCO_3^{1-}	2.95	
	CO_3^{2-}	Nill	
CEC		19.45	C mol_+ kg^{-1} soil
Soil Aggregate Stability		26.45	%
Saturated Hydraulic Conductivity		1.96	cm h^{-1}
SPD		g kg^{-1}	Soil texture Class
Sand		٣٥٣,٠	Silty Loam

Silt	٥١٩,٠	
Clay	١٢٨,٠	
water content		
at 33 kPa	23.4	%
at 1500 kPa	12.0	
Available Water	11.4	
Biological Properties		
Total Bacteria Count	$4.5 * 10^9$	CFU g^{-1} dry Soil
Total Fungi Count	$3 * 10^3$	
Alkaline Phosphatase Enzyme Activity	108.49	Microgram p-nitro phenol g^{-1}dry soil h^{-1}
*Measurements done according to method mentioned (Black *et al.*, 1965 ; Aoda & Mahdi , 2017; Salim & Ali, 2017)		

It should be noted that Although there are two experiments but the 2nd experiment represented the collective effect of both trials, so the results of the 2nd trial will be presented and discussed in this paper.

RESULTS AND DISSCUSION

1- SOIL ORGANIC CARBON (SOC) (SOC g kg^{-1} Soil)

Table 2 showed the effect of crop residues, tillage and crop rotation on soil organic carbon, results emphasized the best value of SOC was 12.78 g SOC kg^{-1} soil for treatment (100% R + MT + Crop Rotation Clover – Mung bean) with increasing of 58.17% compared with 8.08 g SOC kg^{-1} soil for treatment (0% R + CT + Crop Rotation Clover – Maize). Results indicated the best values were with 100% R, minimum tillage and crop rotation clover – mung bean individually and double interaction with (100% R + MT) , (100% R + crop rotation clover – mung bean) and (MT + crop rotation clover – mung bean),with significant differences .

Table (2): Effect of crop residues, two tillage systems and crop rotation on Soil Organic Carbon (SOC g kg^{-1} Soil).

Crop Residues	**Tillage System**	**Crop Rotation**		**Crop Residues and Tillage**
		Clover - Maize	**Clover – Mung bean**	
0% Residues	Conventional T.	8.08	9.20	8.64
	Minimum T.	9.29	10.43	9.86
100% Residues	Conventional T.	10.95	11.50	11.22
	Minimum T.	11.74	12.78	12.26
LSD 0.05		0.382		0.395
Crop Residues		Crop Rotation		Residues Mean
		Clover - Maize	Clover – Mung bean	
0% Residues		8.68	9.81	9.25
100% Residues		11.34	12.14	11.74
LSD 0.05		0.397		0.414
Tillage Systems		Clover - Maize	Clover – Mung bean	Tillage Systems Mean
Conventional T.		9.52	10.35	9.93
Minimum T.		10.51	11.60	11.06
LSD 0.05		0.122		0.103

Crop Rotation Mean	10.01	10.98	
LSD 0.05	0.084		

2- ACTIVE SOIL CARBON (ASC) (ASC mg kg^{-1} Soil)

Table 3 showed the significant effect of using crop residues, tillage and crop rotation in ASC. The best value of ASC was 178.92 mg ASC kg^{-1} Soil with triple interaction treatment (100% R + MT + Crop Rotation Clover – Mung bean) with increment of 101.31% compared with 88.88 mg ASC kg^{-1} Soil for treatment (0% R + CT + Crop rotation Clover – Maize). The double interactions and the individual treatment all were significant.

Table (3): Effect of crop residues, two tillage systems and crop rotation on Active Soil Carbon (ASC mg kg^{-1} Soil).

Crop Residues	**Tillage System**	**Crop Rotation**		**Crop Residues and Tillage**
		Clover - Maize	**Clover – Mung bean**	
0% Residues	Conventional T.	88.88	105.80	97.34
	Minimum T.	111.45	130.32	120.88
100% Residues	Conventional T.	145.09	155.19	150.14
	Minimum T.	161.39	178.92	170.16
LSD 0.05		4.926		5.080
Crop Residues		Crop Rotation		Residues Mean
		Clover - Maize	Clover – Mung bean	
0% Residues		100.17	118.06	109.11
100% Residues		153.24	167.06	160.15
LSD 0.05		5.120		5.344
Tillage Systems		Clover - Maize	Clover – Mung bean	Tillage Systems Mean
Conventional T.		116.99	130.50	123.74
Minimum T.		136.42	154.62	145.52
LSD 0.05		1.621		1.398
Crop Rotation Mean		126.70	142.56	
LSD 0.05		1.085		

3- SOIL AGGREGATE STABILITY (%)

Table (4): Effect of crop residues, two tillage systems and crop rotation on Soil Aggregate Stability (%).

Crop Residues	**Tillage System**	**Crop Rotation**		**Crop Residues and Tillage**
		Clover - Maize	**Clover – Mung bean**	
0% Residues	Conventional T.	39.05	39.82	39.43
	Minimum T.	40.41	40.62	40.52
100% Residues	Conventional T.	42.08	42.54	42.31
	Minimum T.	43.81	44.72	44.26
LSD 0.05		0.974		0.916
Crop Residues		Crop Rotation		Residues Mean
		Clover - Maize	Clover – Mung bean	
0% Residues		39.73	40.22	39.97
100% Residues		42.95	43.63	43.29
LSD 0.05		0.909		0.985
Tillage Systems		Clover - Maize	Clover – Mung bean	Tillage Systems Mean
Conventional T.		40.56	41.18	40.87
Minimum T.		42.11	42.67	42.39
LSD 0.05		0.540		0.442

Crop Rotation Mean	41.34	41.93	
LSD 0.05	0.391		

Table 4 showed the significant effect of using crop residues, tillage systems and crop rotation as a soil management practices in soil aggregate stability. The best value was 44.72% for treatment (100% R + MT + Crop Rotation Clover – Mung bean) with increment of 14.52% compared with 39.05% for treatment (0% R + CT + Crop rotation Clover – Maize). The double and individual interactions treatments all were significant.

4- SOIL SATURATED HYDRAULIC CONDUCTIVITY (cm h^{-1})

Table 5 showed the significant effect of using crop residues, tillage systems and crop rotation as a soil management practices in soil saturated hydraulic conductivity. The best value was 2.79 (cm h^{-1}) for triple interaction treatment (100% R + MT + Crop Rotation Clover – Mung bean) with increasing of 20.26% comparing with 2.32 (cm h^{-1}) for treatment (0% R + CT + Crop rotation Clover – Maize). The double and individual interactions treatments all were significant.

Table (5): Effect of crop residues, two systems tillage and crop rotation on Soil Saturated Hydraulic Conductivity (cm h^{-1}).

Crop Residues	**Tillage System**	**Crop Rotation**		**Crop Residues and Tillage**
		Clover - Maize	**Clover – Mung bean**	
0% Residues	Conventional T.	2.32	2.37	2.34
	Minimum T.	2.34	2.38	2.36
100% Residues	Conventional T.	2.51	2.67	2.59
	Minimum T.	2.72	2.79	2.75
LSD 0.05		0.098		0.076
Crop Residues		Crop Rotation		Residues Mean
		Clover - Maize	Clover – Mung bean	
0% Residues		2.33	2.37	2.35
100% Residues		2.61	2.73	2.67
LSD 0.05		0.076		0.076
Tillage Systems		Clover - Maize	Clover – Mung bean	Tillage Systems Mean
Conventional T.		2.41	2.52	2.47
Minimum T.		2.53	2.58	2.56
LSD 0.05		0.068		0.054
Crop Rotation Mean		2.47	2.55	
LSD 0.05		0.051		

Tables (2, 3, 4, 5) showed the Effect of Tillage, Crop Rotation and Crop Residues Management Practices on some soil properties as an indicator of Soil Health and Quality. These tables presented the differences in Organic Carbon Sources and Some Physical Properties as affected by such treatments. The increments in soil carbon, soil aggregate stability, soil hydraulic conductivity were very clear as well **(Abbasi *et al.*, 2009; Alam *et al.*, 2014; Ali & Albayati, 2018)**. These results reflect the role of residues of the last crop (clover) in increasing soil organic carbon parameters (Table 2). Soil organic carbon can be considered one of the best indicators for soil health **(Magdoff, & Es 2021; Morrisville, 2023; Higashi *et al.., 2014*)** due to the carbon role in biodiversity especially soil microorganisms. These Microorganisms have a very important role in nutrient cycling **(Ali, *et al*., 2022)** Besides, soil organic matter has a very important role in nutrient availability. Crop residues at the same time enhance physical soil properties like soil aggregate stability (table 4) and saturated hydraulic conductivity (Table 5) through the activity of bacteria which secrete or provide soil polysaccharides that keep particles of soil together and that lead to creating new soil aggregates and keep another aggregate and resistance of soil degradation, so that leads to enhance physical soil properties like aggregate stability and saturated hydraulic conductivity and soil structure. Fungi have a very important function represented by gathering particles of soil by hyphae so it helps to form new aggregates of soil and increasing of aggregates stability.

Minimum tillage leads to the same result due to reducing oxidation of organic matter and conserves organic carbon from being lost especially in an arid-semi arid climate of Iraq. At the same time, minimum tillage can reduce broken colonies of bacteria and fungi and keep them healthy .

Crop rotation especially one containing legumes in sequences is very important in providing nutrients, especially nitrogen (**Magdoff & Es, 2021**). The results of this experiment confirmed the results of **Jeghata & Muhawish (2021**) and the results of **Mohammed & Hasan (2022 a, b**), and results of **Jasim & Hamid (2023)**; **Masood & Ali (2023**).

It can be concluded that adopting best management practices can improve soil properties and soil health. Healthy soil will produce better yield with good quality as have been seen from the results of **(Alhalfi & Alazzawi, 2022a; Al-Furaiji & Ali, 2023; ITPS, 2015; Mooleki *et al*., 2016; Sommer *et al*., 2014)**.

CONCLUSION

Using integrated management practices: crop rotation, residues of previous crop and minimum tillage can have a very clear impact on Soil Organic Carbon and Soil Aggregate Stability and can lead to soil health, so using such practices can be recommend.

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