EFFECT MINIMUM TILLAGE, CROP ROTATION AND CROP RESIDUES AS MANAGEMENT PRACTICES ON SOIL HEALTH

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ABSTRACT

Two field experiments were conducted at the research station of College of Agricultural Engineering Sciences - University of Baghdad at Aljadriya, Baghdad –Iraq during two seasons 2021-2022, to evaluate effect of minimum tillage, crop rotation and crop residues on soil health. The 1st one was with split-plot arrangement with two factors: crop residues (0% Residues (0%R) and 100% Residues (100%R)) and tillage (minimum (MT) and conventional (CT)) with four replicates. The 2nd one was with split-split plot arrangement with three factors: the same tillage and residues in 1st trail coupled with crop rotation (clover – maize and clover – mung bean). Soil organic carbon (SOC), organic matter (SOM), active carbon (SAC), aggregate stability, EC, total bacteria and fungi count, available N, P, K, Fe, Zn were evaluated as a soil health indicators. Results of both trails indicated that the best results were (12.78 g SOC Kg^{-1}, 22.03 g SOM Kg^{-1}, 178.92 mg SAC Kg^{-1}, 44.72%, 1.11 dS m^{-1}, 425.0*10^8 CFU g^{-1} soil, 357.5*10^3 CFU g^{-1} soil, 50.75 mg N, 17.12 mg P, 279.9 mg K, 4.68 mg Fe Kg^{-1}, 2.79 mg Zn Kg^{-1} soil for the treatment (100%R+MT+ clover – mung bean crop rotation) compared with results of (8.96 g SOC Kg^{-1}, 15.45 g SOM Kg^{-1}, 109.3 mg SAC Kg^{-1}, 31.42% , 1.66 dS m^{-1}, 33.5*10^8 CFU bacteria g^{-1} soil, 16.5*10^3 CFU fungi g^{-1} soil , 30.62 mg N, 11.75 mg P, 133.5 mg K, 2.95 mg Fe Kg^{-1}, 1.73 mg Zn Kg^{-1} soil) for treatment (0%R+ CT+ without crop rotation) respectively.

Keywords: Soil quality, aggregate stability, saturated hydraulic conductivity, total carbonate, calcareous soil, alkaline phosphatase enzyme activity.

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تأثير الحراثة الدنيا وتعاقب المحاصيل وبقايا المحصول كممارسات إدارية في صحة التربة

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المستخلص

تم إجراء تجربتين حقليتين في محطة أبحاث كلية علوم الهندسة الزراعية – جامعة بغداد في الجادرية ، بغداد – العراق خلال موسمين 2021–2022 ، لتقييم تأثير ممارسات الحد الأدنى من الحراثة وتناوب المحاصيل وإدارة مخلفات المحاصيل في صحة التربة. كانت التجربة الأولى بترتيب الألواح المنشقة بعاملين: مخلفات المحاصيل (0٪ و 100٪ مخلفات) والحراثة (الحد الأدنى (MT) والتقليدية ((CT)بأربعة مكررات. التجربة الثانية كانت بترتيب الألواح المنشقة–المنشقة واشتملت على ثلاثة عوامل: عاملي المخلفات والحراثة نفسها مصحوبة بتعاقب المحاصيل (برسيم – ذرة صفراء) و(برسيم – ماش). تم تقدير الكاربون العضوي(SOC) و المادة العضوية (SOM) والكاربون النشط (SAC) وثباتية التجمعات وEC والعدد الكلي للبكتيريا والفطريات والجاهز بالتربة من N و P و K وFe وZn كمؤشرات لصحة التربة. أظهرت نتائج التجربتين أن أفضل النتائج كانت (12.78 غم SOCكغم$^{-1}$ و 22.03 غم SOM كغم $^{-1}$و 178.92 ملغم SAC كغم$^{-1}$ و 44.72% و 1.11دسي سيمنز م$^{-1}$ والبكتريا 425.0 *10 CFU ^{8}غم$^{-1}$ تربة والفطريات 357.5 *10CFU^{3} غم$^{-1}$ تربة و 50.75 ملغم N و 17.12 ملغم P و 279.9 ملغم K و4.68 ملغم Fe كغم$^{-1}$ و2.79 ملغم Zn كغم$^{-1}$ تربة لمعاملة (حراثة الحد الأدنى + 100% مخلفات + دورة زراعية برسيم –ماش) مقارنة بالنتائج (8.96 غم SOC كغم$^{-1}$ و15.45 غم SOM كغم$^{-1}$ و 109.3 ملغم SAC كغم$^{-1}$ تربة و 31.42٪ و 1.66 دسي سيمنز م$^{-1}$ والبكتريا 33.5* CFU 10^{8}غم$^{-1}$ تربة والفطريات 16.5 *10CFU ^{3} غم$^{-1}$ تربة و 30.26 ملغم N و 11.75 ملغم P و 133.5 ملغم K و 2.95 ملغم Fe و1.73 ملغم Zn كغم $^{-1}$تربة لمعاملة (حراثة تقليدية + 0% مخلفات + بدون دورة زراعية) على الترتيب.

كلمات مفتاحية: جودة التربة, ثباتية التجمعات، الإيصالية المائية المشبعة, الكاربونات الكلية، تربة كلسية، فعالية إنزيم الفوسفاتيز القاعدي.

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INTRODUCTION

Soil health can be defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. Soil organic matter (SOM) is very important in determining soil fertility 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. Identifying agricultural management practices that minimize loss or even enhance SOM stores, is very important for sustaining soils and food production systems, and improving the environment by minimizing global warming (8). Integrating good soil's physical, chemical, fertility and biological properties can improve soil health and increasingly become a common management practice. Several studies have reported greater SOC under minimum or no tillage compared to conventional tillage (7, 14 and 21). Numerous studies have indicated that crop rotation, minimum tillage, and crop residues improved physical, chemical, biological, and fertility properties and enhanced soil health and quality, (4, 5, 15, 16, 17, 20, 22 and 25). Furthermore, enriching the soil enhances life on our planet. The effects of tillage systems (minimum tillage, conventional tillage and deep tillage) and crop residues retention on soil properties. Minimum tillage and crop residues improved soil properties and increased yield. (23). Reducing Tillage and using crop rotation with legume and crop residues effected on soil carbon and soil physical properties. It increases organic carbon and improves bulk density, porosity and water content (19). This study was aimed to evaluate the effect of soil management practices (reducing tillage, using crops rotation with legume crop in the rotation system and using previous crop residues) on soil properties as affected on soil health and fertility.

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). Results of soil analysis pre-planting test for the studied field soil show in Table 1. The trial was conducted in a randomized complete block design (RCBD) with four replicates, to investigate the effect of tillage, crop residues, and crop rotation management practices on clover, maize, and mung bean productivities. In the 1st experiment, two factors were used: the first was the residue 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 1st experiment started in 20th of November 2021 and finished in 1st of March 2022). 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 radiata* L.), Productivities. Both crops were sown at the same plots of the previous clover crop, (the 2nd experiment started in 22th of March 2022 and finished in 1st of August 2022) in a split-split plot arrangement. Plants were fertilized in the two trails according to Ali (6). Soil samples were collected before and after each trial to test the soil's chemical, physical, fertility and biological properties. At the end, of every experiment samples of soils were collected for measuring SOC, SOM, AC, aggregate stability, soil saturated hydraulic conductivity, EC, pH, total carbonates, the total count of bacteria and fungi, alkaline phosphatase enzyme, soil available N, P, K, Fe, and Zn. It should be noted that although the two experiments are differ in design and had different statistical analyses they will be presented together for the sake of simple comparisons**.**

Table 1. Chemical , Physical , Biological and Fertility properties of the Soil before planting*

Property		Value	Unit
Hydrogen potential (pH) (1:1)		8.25	-
Electrical conductivity (EC) (1:1)		1.85	dS m^{-1}
Available nitrogen		28.00	
Available phosphorus		13.25	
Available potassium		174.01	mg kg^{-1} soil
Available iron		3.55	
Available zinc		2.10	
Carbonate minerals		345.0	
Soil organic carbon		9.35	g kg^{-1} soil
Soil organic matter		16.13	
Active carbon		128.44	mg kg^{-1} soil
Dissolved cations	Ca^{2+}	8.95	
	Mg^{2+}	4.55	
	K^{1+}	2.35	
	Na^{1+}	3.47	m mol L^{-1}
Dissolved anions	SO_4^{2-}	5.10	
	Cl^{1-}	19.5	
	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}
Sand		353.0	
Silt		519.0	g kg^{-1}
Clay		128.0	
Soil texture class			Silty loam
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} 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 methods mentioned by (9, 10 and 24)**

RESULTS AND DISSCUSION

The effect of crop residues, tillage, and crop rotation on soil health and quality indicators were presented in (Tables 2 – 6). Results of SOC, SOM, and AC were presented in Table 2. The results indicated that all carbon parameters were improved by applying such practices. The treatment (100%R + MT + crop rotation clover – mung bean) gave the values of (12.78 g kg^{-1}, 22.03g kg^{-1}, 178.92 mg kg^{-1} Soil) with an increasing percent (42.63, 42.59, 63.70,)% compared with treatment (0% R + CT) of the first season (without crop rotation) which were (8.96 g kg^{-1}, 15.45 g kg^{-1}, 109.3 mg kg^{-1}) respectively. The effect of treatments on some soil physical properties mostly related to soil quality and health were presented in table 3. Results indicated that aggregate stability and saturated hydraulic conductivity were improved with such practices with an increment of 42.32 and 22.91% for 100%R+MT+crop rotation (especially where legumes follow each other). Table 4 shows the results of the effect of management practices on some soil chemical properties. Results indicated a decrease in EC and total carbonates. The Effect of management practices on some soil biological properties show in Table 5. Table (4) indicates a significant reduction in (EC, pH, and total carbonates) which were (1.11 dS m^{-1}, 7.90, 322.5 g kg^{-1}) with decreases of (33.13, 3.54, 11.93)% for treatment (100%R+ MT + crop rotation clover – mung bean) compared with values (1.66 dSm^{-1}, 8.19, 366.2 g kg^{-1}) for treatment (0%R + CT) for 1st season (without crop rotation), respectively

Table 2. Effect of minimum tillage, crop rotation and crop residues management on some soil carbon parameters

Treatments	Carbon parameters 1st Season (without crop rotation) (clover) SOC (g Kg^{-1} soil)	 SOM (g Kg^{-1} soil)	 SAC (mg Kg^{-1} soil)
0%R+CT	8.96	15.45	109.3
0%R+MT	10.27	17.71	132.1
100%R+CT	11.29	19.47	154.2
100%R+MT	12.08	20.82	173.6
LSD 0.05	0.462	0.797	8.07
	Second season (crop rotation) clover - maize		
0%R+CT	8.08	13.93	88.88
0%R+MT	9.29	16.01	111.45
100%R+CT	10.95	18.88	145.09
100%R+MT	11.74	20.24	161.39
LSD 0.05	0.382	0.661	4.926
	Clover – mung bean		
0%R+CT	9.20	15.86	105.80
0%R+MT	10.43	17.97	130.32
100%R+CT	11.50	19.82	155.19
100%R+MT	12.78	22.03	178.92
LSD0.05	0.382	0.661	4.926

Table 3. Effect of minimum tillage, crop rotation and crop residues management on some soil physical parameters

Treatments	Physical properties Aggregate stability (%)	 Saturated hydraulic conductivity (cm h^{-1})
	1st season (without crop rotation) (clover)	
0%R+CT	31.42	2.27
0%R+MT	38.20	2.32
100%R+CT	37.73	2.56
100%R+MT	41.84	2.65
LSD 0.05	0.427	0.174
	2nd season (crop rotation) clover - maize	
0%R+CT	39.05	2.32
0%R+MT	40.41	2.34
100%R+CT	42.08	2.51
100%R+MT	43.81	2.72
LSD 0.05	0.974	0.098
	clover –mung bean	
0%R+CT	39.82	2.37
0%R+MT	40.62	2.38
100%R+CT	42.54	2.67
100%R+MT	44.72	2.79
LSD0.05	0.974	0.098

Table 4. Effect of minimum tillage, crop rotation and crop residues management practices on some chemical properties .

Treatments	EC (1:1) (dS m^{-1})	pH	Total carbonate (TC) (g Kg^{-1} soil)
	Chemical properties		
First season (without crop rotation) (clover)			
0% R + CT	1.66	8.19	366.2
0% R + MT	1.60	8.15	361.9
100% R + CT	1.50	7.93	342.6
100% R + MT	1.48	7.81	338.1
LSD 0.05	NS	0.208	14.4
Second season (crop rotation) clover - maize			
0% R + CT	1.69	8.41	362.5
0% R + MT	1.53	8.34	360.0
100% R + CT	1.49	8.02	346.9
100% R + MT	1.18	7.99	330.6
LSD 0.05	0.168	0.087	7.971
clover – mung bean			
0% R + CT	1.59	8.36	361.3
0% R + MT	1.42	8.28	351.9
100% R + CT	1.24	8.09	332.5
100% R + MT	1.11	7.90	322.5
LSD 0.05	0.168	0.087	7.971

Table 5 indicates the effect of crop residues, tillage and crop rotation on biological properties in the soil as indicators of soil health and quality. It shows a significant increase in (total bacteria count, total fungi count, alkaline phosphatase enzyme activity) with treatment (100% residues + minimum tillage + crop rotation clover – mung bean) which values were ($425.0*10^8$ CFU, 357.5 * 10^3 CFU, 170.11 µg P-nitro phenol g^{-1} dry soil h^{-1}) comparing with treatment (0% residues + conventional tillage) in the first season (without crop rotation) which were (33.5* 10^8 CFU, 16.5* 10^3 CFU, 136.38 Microgram P-nitro phenol g^{-1} dry soil h^{-1}), respectively.

Table 5. Effect of minimum tillage, crop rotation and crop residues management practices on some biological properties as an indicators of soil health and quality

Treatments	Total bacteria count ($*10^8$ CFU g^{-1} soil)	Total fungi count ($*10^3$ CFU g^{-1} soil)	Phosphatase activity (µ g para nitro phenol g^{-1} dry soil h^{-1})
	Biological properties		
First season (without crop rotation)			
0% R + CT	33.5	16.5	136.38
0% R + MT	93.2	35.2	141.24
100% R + CT	205.0	75.0	159.46
100% R + MT	237.5	122.5	167.22
LSD 0.05	29.95	25.76	6.558
Second season (crop rotation) clover - maize			
0% R + CT	17.0	10.0	105.99
0% R + MT	66.2	24.5	117.30
100% R + CT	162.5	85.0	139.25
100% R + MT	207.5	130.0	152.79
LSD 0.05	16.30	18.68	9.61
clover – mung bean			
0% R + CT	49.2	22.0	116.28
0% R + MT	81.5	37.8	127.49
100% R + CT	187.5	95.0	143.92
100% R + MT	425.0	357.5	170.11
LSD 0.05	16.30	18.68	9.61

Table 6 indicates the effect of crop residues, tillage and crop rotation on available nutrients in the soil as indicators of soil health and quality. It shows a significant increases of (available nitrogen, phosphorus, potassium, iron, and zinc)) with treatment (100% residues + minimum tillage + crop rotation clover – mung bean) which values were (50.75 mg N

kg^{-1}, 17.12 mg P kg^{-1}, 279.9 mg K kg^{-1}, 4.68 mg Fe kg^{-1}, 2.79 mg Zn kg^{-1}) with increasing percent (65.74, 45.70, 109.66, 58.64, 61.27)% comparing with treatment (0%R + CT) in the first season (without crop rotation) which were (30.62 mg N kg^{-1}, 11.75 mg P kg^{-1}, 133.5 mg K kg^{-1}, 2.95 mg Fe kg^{-1}, 1.73 mg Zn kg^{-1}), respectively, It should mention that Zn in 1st trail (100%R+MT) (2.98 mg Zn kg^{-1}soil) was higher than Zn in 2nd trail (100%R+MT+crop rotation clover-mung bean) (2.79 mg Zn kg^{-1} soil).

Table 6. Effect of minimum tillage, crop rotation and crop residues management practices on some fertility properties as an indicators of soil health and quality

Treatments	Fertility index Available nitrogen (mg N Kg^{-1} soil)	Available phosphorus (mg P Kg^{-1} soil)	Available potassium (mg K Kg^{-1} soil)	Available iron (mg Fe Kg^{-1} soil)	Available zinc (mg Zn Kg^{-1} soil)
First season (without crop rotation) (clover)					
0% R + CT	30.62	11.75	133.5	2.95	1.73
0% R + MT	32.38	13.12	150.4	3.20	2.03
100%R + CT	42.00	14.66	189.8	3.90	2.39
100%R+ MT	45.50	16.88	212.3	3.99	2.98
LSD 0.05	1.457	0.819	34.26	0.213	0.137
Second season (crop rotation)					
clover - maize					
0% R + CT	22.75	10.39	144.7	3.05	1.65
0% R + MT	28.00	12.42	168.9	3.38	1.98
100%R + CT	35.88	14.16	216.2	4.18	2.30
100%R+ MT	44.50	15.39	248.4	4.46	2.51
LSD 0.05	4.889	0.374	16.77	0.156	0.097
clover – mung bean					
0% R + CT	26.25	11.96	158.8	3.13	1.83
0% R + MT	29.75	13.73	195.4	3.54	2.08
100%R + CT	40.12	15.01	243.3	4.25	2.39
100%R + MT	50.75	17.12	279.9	4.68	2.79
LSD 0.05	4.889	0.374	16.77	0.156	0.097

Tables 2, 3, 4, 5 and 6 show 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 some chemical, physical, biological, and soil fertility properties as affected by such treatments. The increments in soil carbon, soil aggregate stability, soil saturated hydraulic conductivity, and biological and soil nutrient availability were very clear. on the contrary, the decrease in some soil chemical properties were clear as well (1 , 2 and 18). These results reflect the role of crop residues (alfalfa and clover) in increasing soil organic carbon parameters (Table 2). Soil organic carbon and organic matter can be considered the best indicators for soil health and quality (11 and 14) due to the carbon role in biodiversity especially soil microorganisms and enzymes (Table 5). These microorganisms have a very important role in nutrient cycling (7) 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 and saturated hydraulic conductivity (Table 3) 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 (1and 2). 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 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 (14). The results of these two experiments confirmed the results of (13) and the results of (16 and 17), and results of (15). Results of these two experiments showed the first experiment indicated enhanced soil properties and soil health and quality. 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 (3, 4, 12, 18 and 26)

CONCLUSION

Using integrated management practices: crop rotation, residues of previous crop and minimum tillage can have a very clear impact on soil health, so using such practices could be recommended.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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