International Journal of Multidisciplinary and Current Research ISSN: 2321-3124
Research Article Available at: http://ijmcr.com

Role of different types of organic matter in barley growth and Building up organic carbon in soil under saline stress

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Received 20 July 2017, Accepted 25 Sept 2017, Available online 11 Oct 2017, **Vol.5 (Sept/Oct 2017 issue)**

Abstract

Pot experiment was conducted to evaluate effect of type of organic matter addition on barley growth and development and level of organic carbon (OC) left in the soil. Alternate irrigation with saline and fresh water was also evaluated to explore the extent of using saline ground water in irrigation. The results showed an increase in dry matter weight with addition of partially decomposed barley straw and peat of barley straw by 11.12 and 30.67% respectively, while in case of addition of barley straw, the dry matter decreased by 3.42% compared to the control treatment. Addition of Nitrogen fertilizer as urea at a rate of 200 kg N .h^{-1} increased bio mass yield of barley by 27.5% compared to zero N addition. Bio-mass production of barley irrigated with saline ground water compared to that irrigated with fresh water was reduced by 13.25%, 12.95% and 24.5% upon addition of straw of barley, partially decomposed straw of barley and well decomposed straw of barley (Peat), respectively. The addition of organic matter significantly reduced the concentration of proline in plants, compared to the control treatment, with a decrease rate of 35.5%, 38.8% and 20.8% for Barley straw, partially decomposed straw of barley and Peat of barley straw respectively. Residual organic carbon in soil after harvesting was increased compared to control treatment by 221.8%, 192.9% and 170.8% under barley straw, partially decomposed barley straw and peat of barley straw, respectively.

Keywords: *Organic matter, C/N, O.C Built up, saline stress*

1. Introduction

Organic matter is one of the most important constituents of arable soil. It represents the most complex part because it is composed of different organic compounds and in varying stages of decomposition (Havlin *et al*., 2005). It consists of humus, glomalin, charred (plant material resulting from incomplete burning), Litter and detritus, finally a small but biologically active portion of SOM consists of easily oxidized, often relatively soluble compounds derived from litter, such as sugars and amino acids, as well as a wide array of biochemical synthesized by microorganisms or contributed by plant roots (Weil 2001). Its content in soil is generally range from 2 g. kg^{-1} in desert soils to 800 g. kg^{-1} in organic soils. Organic matter content in arable soil is usually in a range of 10-40 g. kg^{-1} (Magdoff and Weil 2004). Over most of the earth's land surface, the quantity of C as SOM ranges from 1.4 to 1.5 MMTCE (Million metric tons of carbon equivalent). The contribution of agricultural land to CO_2 released to atmosphere was estimated to be 20–25% of the total amount released due to human activity (Reicosky *et al*, 2000). However, addition of organic matter increases soil fertility and improves its physical, chemical and biological properties (Weil 2001).

Addition of different types of organic matter to soil was found to increase efficiency of reclamation of salt-affected soils (Dwenee 2003). Significant relationship was found between addition of organic materials and enhanced soil aggregation, improved infiltration, retention of water and nutrient recycle enrichment (Greenland and Szabo1cs, 1994).

The amount of organic carbon in soils depends on balance between inputs of photo synthetically fixed carbon that go into plant biomass and loss of carbon through microbial decomposition. Agricultural practices can modify the organic matter inputs from crop residues and their decomposition, thereby resulting in a net change in flux of CO_2 to or from soils (Reicosky *et al*, 2000).

Some agricultural practices after harvesting contribute to loss of a huge amount of organic carbon in plant residues. Burning crop residues, leave the entire field area exposed to sunlight which may contributes to loss of organic carbon and converting it to carbon dioxide. This process is definitely contribute global warming. On the

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contrary, incorporating plant residues with soil or collecting plant residues and converting them into well decomposed crop peat would contribute to measurable increase of organic carbon in soil and reducing the emission of carbon dioxide into the atmosphere. This article aimed to explain the relationship between added plant residue and organic carbon accumulation in related to saline stress and C/N of plant residue as well as plant productivity.

Materials and methods

The experiment was carried out on 25/10/2015 at Soil and Water Resources Center of the Agricultural Research Directorate in Al- Zaafarania site in Baghdad to evaluate role of different types of organic material in accumulation of organic carbon and growth of barley when irrigated with fresh water (1.0 dS m^{-1}) and saline water (4.0 dS m^{-1}). Table 1. shows chemical properties of irrigation water.

Table 1 Some chemical properties of irrigation water

Water dS m^{-1}	pH	Na	Ca	Mg	Cl	SO_4	HCO_3	SAR	Class
		Soluble ions mmole.L^{-1}							
1.00	**7.38**	3.27	1.40	1.67	4.15	**1.62**	0.44	2.64	C3-S1
4.00	**7.16**	14.5	4.68	5.51	15.2	11.0	0.48	6.40	C4-S1

Table 2 Chemical properties of the organic matter used in the study

Organic material	EC 1:5 dS m^{-1}	pH 1:5	Cations (gm Kg^{-1})		Anions (gm Kg^{-1})		Total N (gm Kg^{-1})	O.C (gm Kg^{-1})	Ava. P ppm	C/N
Barley straw	**1.35**	**7.35**	Na	**0.42**	SO_4	**0.40**	**5.22**	**445.2**	**6.89**	**85.3**
			Ca	**0.79**						
			Mg	**0.51**	Cl	**0.32**				
			K	**1.25**						
Partially decomposed straw of Barley	**1.64**	**7.21**	Na	**0.39**	SO_4	**0.48**	**8.65**	**423.8**	**15.62**	**48.9**
			Ca	**0.94**						
			Mg	**0.65**	Cl	**0.33**				
			K	**1.54**						
Peat of barley straw	**1.86**	**6.85**	Na	**0.38**	SO_4	**0.53**	**19.52**	**402.6**	**20.31**	**20.6**
			Ca	**0.81**						
			Mg	**0.66**	Cl	**0.41**				
			K	**1.95**						

Organic matter

Three types of organic materials were used. They were:

1. Barley straw (O.M 1): Collected from the harvesting process. Straw was dried at 65 °C temperature and was grinded to pass through a 1.0 cm opening sieve.
2. Partially decomposed straw of barley (O.M 2): It is the remains of barley plants after harvest and then was subjected to aerobic decomposition according to method of Razaq *et al*., (2005) by providing an appropriate level of moisture for the plant residues as well as adding soil suspension as a source of microorganisms in presence of adequate O_2 level. Nitrogen and phosphorus was added to enhance decomposition process. Material was considered as partially decomposed upon temperature was dropped to ambient temperature, material assume dark color and some plant tissues are still existed to identify its source. Partially decomposed material dried at 65 °C for 72 hours and grinded to pass 1 cm opening sieve.
3. Barley straw peat (O.M 3): Barley straw was subjected to aerobic decomposition process in presence of adequate moisture level and all necessary supplements as described by Razaq et. al., (2005).

Chemical properties of the organic materials used in this study are given in Table 2. Organic matter of various types was included in this study. Amount added of each type was 2.0% on OC content. Required amount of organic matter was added to 10 kg soil, thoroughly mixed and transferred to the pot. Consequently, weights of organic substances added to 10 kg soil were as follows:

1- 449.2 (gm) Barley straw
2- 471.9 (gm) Partially decomposed straw of barley
3- 496.7 (gm) Peat of barley straw

Loamy soil, was used in this study. Some physical and chemical characteristics of the soil were shown in table (3). Barley seeds were planted according to treatments at a rate of 6 plants per pot and reduced after germination to 2 plants. Nitrogen, as urea, at a rate of 200 kg N .h^{-1} only for the treatments which included the addition of nitrogen. The addition of nitrogen was given label N+ code and distributed according to the treatments and mixed with soil homogeneously. Potassium sulphate was added at rate of 100 kg K. h^{-1} and TSP fertilizer at rate of 25 kg P.h^{-1} were added to all treatments.

Table 3 Some physical and chemical properties of the soil used in the experiment

Properties	Units		Value
ECe	$dS\ m^{-1}$		3.21
pH	-		7.75
O.M	$gm\ kg^{-1}$		8.53
$CaCO_3$			210.5
$N\text{-}NH_4$	Ppm		37.2
$N\text{-}NO_3$			**28.9**
Ava. K			42.1
Ava. P			7.65
Soluble cations	Ca^{2+}	$mmol.\ L^{-1}$	0.53
	Mg^{2+}		0.41
	Na^{+}		1.53
Soluble anions	Cl^{-}		1.41
	$SO_4^{=}$		0.69
	HCO_3^{-}		0.04
	$CO_3^{=}$		Nil
SAR	-		1.57
Texture**	Sand	$gm\ kg^{-1}$	292.01
	Silt		467.85
	Clay		240.14
Soil texture			Loam

* Chemical analyses were conducted according to Page (1982)
** Texture analyses were conducted according to Gee and Bauder (1986)

Table 4 Effect of different types of organic matter on barley dry matter (g. pot^{-1}) when irrigated with fresh water, saline water, with and without nitrogen fertilizer

Treatments	Fresh water N -	Fresh water N +	Saline water N -	Saline water N +	O.M Mean
Control	^{g}**64.20**	^{b}**84.64**	^{l}**38.06**	^{k}**47.52**	^{d}**58.61**
O.M 1	^{j}**53.49**	^{f}**68.07**	^{k}**46.75**	^{i}**58.70**	^{c}**56.60**
O.M 2	^{h}**60.76**	^{c}**78.53**	^{j}**52.42**	^{f}**68.82**	^{b}**65.13**
O.M 3	^{d}**76.16**	^{a}**98.70**	^{ih}**60.16**	^{e}**71.36**	^{a}**76.59**
LSD. 0.01			**2.0562**		**1.0281**
Mean of water	^{a}**73.07**		^{b}**55.47**		
LSD. 0.01	**0.727**				
Mean of N fertilizer	N -	^{b}**56.50**	LSD. 0.01		
	N +	^{a}**72.04**	**0.825**		

The experiment was carried out with three replicates and included 48 experimental units according to complete randomized block design (factorial) and data were analyzed with SAS program. The plants were irrigated with two type of water according to experiment design. The amount of irrigation water applied was calculated regarding to 75% of field capacity. The experiment continued till harvest and grains were obtained. Experimental measurements were included:

1- Dry weight of shoot and grains.
2- Proline content of barley leaves was estimated according to Bates 1973
3- Organic Carbonate in Soil was estimated according to page 1982.

Results and discussion

Shoot dry weight

Results showed (Table 4) that dry weight of shoots upon irrigation with either fresh or saline water was 73.1 and 55.5 g. pot^{-1} respectively. In other word, dry weight upon irrigation with saline water was reduced by 24.1% compared to that irrigated with fresh water. This result is in agreement with those of Shannon (1997), Munns and Tester (2008).

Results also showed that the addition of nitrogen increased dry matter yield of barley by 72.0 g. pot^{-1} compared to 56.5 g. pot^{-1} without nitrogen addition, which represent an increase by 27.5%. Dry matter, on the other hand, increased by 11.1% and 30.7% for the treatments received partially decomposed straw and peat straw respectively.

However, in case of addition of barley straw treatment, productivity of dry matter relatively decreased by 3.42% compared to that of zero organic matter addition. This variation in productivity may be attributed to high C/N ratio of barley straw which was 85.3 compare to 48.9, 20.6 for partially decomposed straw and peat of barley straw, respectively. This result is in agreement with those of Ming Nie *et al*., (2015) and ; Lodhi *et al*., (2006).

The results showed that dry matter yield was 53.5 g. pot^{-1} for treatment barley straw irrigated with fresh water and received no nitrogen. This much of dry yield was 16.65% less than that of control treatment at which neither straw nor nitrogen was added. This can be explained on basis of competition for nitrogen in the soil between plants and microorganisms for nitrogen (Bünemann *et al*., 2006). Dry matter yield was 68.07 g. pot^{-1} and increased by 27.3% under addition of nitrogen fertilizer. However, dry matter yield collected in control treatment was 84.6 g. pot^{-1} , which is markedly higher than the yield obtained for treatment received straw and nitrogen fertilizer. This result may be attributed to the fact that part of nitrogen fertilizer was utilized by microorganism participated in decomposition process of straw.

In case of irrigation by saline water without adding nitrogen fertilizer, the results showed that dry matter of barley straw treatment with high C / N ratio, was 46.75 g. pot^{-1} and for control was 38.06 g. pot^{-1} with an increase by 22.83%. Addition of nitrogen fertilizer for control and barley straw treatment showed a significant superiority of barley straw over the control treatment from 47.52 to 58.70 g. pot^{-1} with an increase by 23.52%.

This result is in contrast of what was found in case of fresh water, which may be explained on the basis that saline water reduced the effectiveness of microorganisms participating in decomposition of organic matter. In return, left more nitrogen for plant uptake. Addition of organic matter is expected to improve movement in root zone which may reduce salt stress resulting from addition of saline water. This finding is corresponding with results concerning the role of organic matter in increase of bio mass of plant (Dwenee 2003, Shortall and Libharfit 1975, Walling *et al*., 1975, Herron and Erthat 1965), as well as with the results of relationship between organic matter decomposition and nitrogen content in soil and their effect on availability of nitrogen to plant (Vyas And Montiramani 1971, Thompson *et al*., 1954). It is found that the rate of decomposition of organic matter in case of irrigation with saline water is slower than in case of irrigation with fresh water. This may be explained on basis of the role of salts in reducing the activity of soil microorganisms (McCormic and Walf 1980).

Mitigate adverse effects of salinity

Salinity in irrigation water reduced plant growth dry matter of plants as a response to salt stress. The rate of decrease in productivity when watering with saline water compared to irrigation of fresh water are estimated according to equation below:

% Reduction = ((D.Mf – D.Ms) /D.Mf)*100

where:
D.Mf= dry matter when irrigated with fresh water
D.Ms= dry matter when irrigated with saline water

Figure 1. shows that the decrease in productivity of dry matter of barley as a result of irrigation by saline water compared to irrigation by fresh water was changed according to type of added organic matter. Figure 1 also shows that all kinds of added organic matter have reduced proportion of reduction in productivity. Addition of organic matter with high C/N ratio resulted in lowest reduction in dry matter which is amounted to 13.25, 12.95% for the treatment of barley straw, partially decomposed barley straw respectively. Reduction in dry matter yield under treatment of peat of barley straw treatment which is of low C/N ratio was 24.78%. These results show that organic matter with higher C/N, ratio although it was negatively affected productivity as shown in Table 4, is highly efficient in reducing salt stress on plants due to its ability to improve water relationships within root zone. It may contribute to increase the salts movement as well as non-accumulation of salts in the root zone that would contributes to reduction of salt stress on plants (Bünemann *et al*., 2006, Dwenee 2003). These results are corresponding with the values of proline content in leaves of plants as shown in Table 5. That may indicate low values of proline content by 5.64, 5.11 mg. g^{-1} DW for Barley straw and Partially decomposed straw of barley treatments respectively compared to values of proline content for control and Peat of barley straw treatments by 8.36, 6.62 mg. g^{-1} DW respectively.

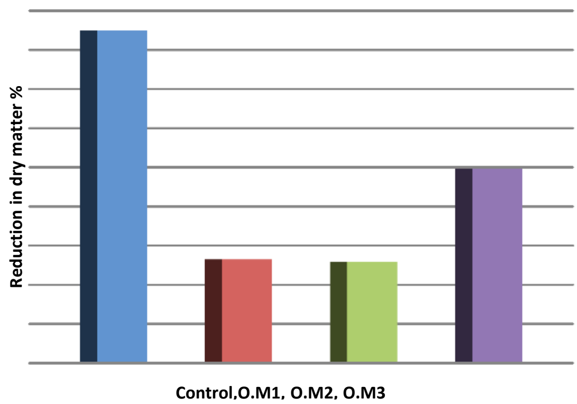

Figure 1 Effect of irrigation with saline water and addition different type of organic matter on reduction of dry matter yield of barley

Proline Content

Table 5. shows an increase in the concentration of amino acid proline when irrigating with saline water by a mean of 8.49 mg. g^{-1} DW. Watering in fresh water, however, proline concentration was 4.37 mg. g^{-1} DW with an increase by 94.27%. This is corresponding to what many researchers have previously reported that increase the accumulation of amino acid like a proline in plant leaves as a mechanism for resistance to salt stress (Heidari 2009, Suriyan and Kirdmanee 2009, Sheng *et al*., 2011).

The addition of nitrogen led to a significant decrease in concentration of proline in plant leaves with 5.99 mg. g^{-1} DW while it was 6.88 mg. g^{-1} DW at non-addition of nitrogen with a percentage of decrease by 12.93%.

Table 5 Effect of different types of organic matter on proline content (mg. g^{-1} DW) when irrigated with fresh water, saline water, with and without nitrogen fertilizer

Treatments	Fresh water		Saline water		O.M
	N -	N +	N -	N +	Mean
Control	5.48fg	4.46hi	12.33a	11.17b	8.36a
O.M 1	4.62h	3.59j	7.60d	6.75e	5.64c
O.M 2	4.11jhi	3.83jhi	6.80e	5.69f	5.11d
O.M 3	4.79hg	4.11jhi	9.28c	8.29d	6.62b
LSD. 0.01			**0.7029**		0.3015
Mean of water	4.37b		8.49a		
LSD. 0.01	0.3561				
Mean of N fertilizer	N -	6.87a	LSD. 0.01		

Table 6 Effect of different types of organic matter on organic carbon content (%) when irrigated with fresh water, saline water, with and without nitrogen fertilizer

Treatments	Fresh water		Saline water		O.M
	N -	N +	N -	N +	Mean
Control	0.523k	0.580k	0.513k	0.531k	0.536d
O.M 1	1.743e	1.463hg	1.983a	1.713cd	1.725a
O.M 2	1.653ed	1.350ji	1.863b	1.413ih	1.570b
O.M 3	1.590ef	1.310j	1.523fg	1.383jih	1.452c
LSD. 0.01			**0.0872**		0.0436
Mean of water	1.277b		1.365a		
LSD. 0.01	0.0308				
Mean of N fertilizer	N -	1.424a	LSD. 0.01		
	N +	1.218b	0.0405		

This may be due to role of nitrogen in increasing vegetative growth that is led to diluted proline concentration in plant leaves, also due to contribution of nitrogen in synthesis of many antioxidants that assist the plant resist salt stress (Havlin *et al*., 2005).

The addition of organic matter significantly reduced the concentration of proline in the leaves of plants and in different percentages according to the type of added organic matter compared to the control treatment, with a proportional decrease of 35.5%, 38.8% and 20.8% for Barley straw, Partially decomposed straw of barley and Peat of barley straw respectively.

These results show that highest decrease in proline concentration occurred in treatment of relatively high C/N of organic materials. Although high C/N ratio showed a significant superiority in reducing the concentration of proline in leaves, which indicates its effectiveness in reducing salt stress in root zone. This positive effect may be attributed to state of organic matter itself because it is being partially decomposed or non-decomposing and difficult to decompose at the same time that is would contributing to increase the efficiency of water movement in root zone and relatively reduce the accumulation of salts around the roots, which reduces salt stress that is exposed as a result of irrigation with saline water.

Results showed that the highest concentration of proline was in saline water treatment when non-nitrogen fertilizer was added by 12.32 mg. g^{-1} DW, while lowest concentration of proline was when watering with fresh water and adding nitrogen fertilizer to partially decomposed straw of barley treatment by 3.59 mg. g^{-1} DW. This may be attributed to increase of nitrogen concentration in soil that is would reduced C/N in added organic matter as well as improves soil fertility. Sequentially, reduces abiotic stresses and improves water relationships in root zone, which greatly increases growth and reduces the concentration of proline in plant leaves (Havlin *et al*., 2005).

Soil organic carbon

Table 6 shows the values of organic carbon content remaining in soil after harvesting of plants. The results showed that the addition of different organic materials contributed to a significant increase in soil organic carbon content compared to control treatment by 221.8%, 192.9% and 170.8% for barley straw, partially decomposed straw of barley and peat of barley straw respectively. These results show superiority of barley straw with higher C/ N ratio in soil content of organic carbon. Barley straw with high C/N ratio have a negative effect on plant growth as shown in Table 1. The high organic carbon in soil for treatment with high C/N is due to its relatively low degradation in soil and its resistance to microorganism attack due to relatively low nitrogen content, which microorganisms need to build biomass (Moore *et al*., 2000). Reducing degradation would decrease CO_2 emissions into atmosphere and conserving organic carbon in soil, which will later contribute to improving soil fertility properties.

The addition of nitrogen fertilizer contributed to reduction of organic carbon content in soil by 14.46%, which can be attributed to role of added nitrogen in reducing the ratio of C/N, which in turn leads to increase in decay and degradation of added organic matter (Bünemann *et al*., 2006, Graham *et al*., 2002). This action would contribute to release of CO_2 into the atmosphere as a result of microbial activity degradation, leading to a decrease in proportion of organic carbon in soil (Bown *et al*., 2011).

The irrigation by saline water increased the concentration and content of organic carbon in soil by 6.97%, indicating the role of saline water in reducing the effectiveness of microorganisms that attack organic matter would led to increasing their organic carbon content in soil. The results showed that highest value of organic carbon content was when irrigated with salty water and added barley straw without adding nitrogen fertilizer. It reached 1.983% while the lowest value of organic carbon content when watering salt water for control treatment without adding nitrogen fertilizer by 0.513%.

Conclusion

These results show that organic substances with high C/N Although it has negatively affected productivity, it is highly efficient in reducing salt stress on plants. These results show that highest decrease in proline concentration occurred in treatment of relatively high C/N of organic materials. Although high C/N ratio showed a significant superiority in reducing the concentration of proline in leaves, which indicates its effectiveness in reducing salt stress in root zone. Although barley straw with higher C/N ratio have a negative effect on plant growth as shown in Table 1. The high organic carbon in soil for treatment with high C/N is due to its relatively low degradation in soil and its resistance to microorganism attack due to relatively low nitrogen content.

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