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(Research Article)

Role of composted organic material in reducing hazardous effect of salinity stress on biological nitrogen fixation and plant growth in salt affected soils of arid region

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Abstract

Application of organic matter (OM) has shown positive effects on growth and yield of crop grown under soil salinity stress. The present study was conducted to estimate effectiveness of OM in enhancing Biological Nitrogen Fixation (BNF) in soil and in return improving growth and yield of cowpea. Therefore, role of (OM) in alleviating impact of salinity stress on (BNF) in soils of arid region was evaluated in medium textured soils of different content of salts content. Experiment was conducted in pots under greenhouse conditions. Salinity range studied was 3.5, 8.2 and 12.4 dSm-1 in J1, J2, and J3 soil respectively. Compost as OM was added at 15, 25 and 50 g Kg-1 soil. Cowpea local variety was used as a test crop. Total nitrogen in soils without the addition of organic matter after harvesting was the least at the highest salinity level and the highest was in the soil of the least salinity level. Number of root nodules reduced by 27.0% and 49.0% when soil salinity increased to 8.2 and 12.4 dSm-1, respectively, compared to that in soil of 3.5 dSm-1. Total N in Cowpea plant linearly increase with the increase of level of (OM) addition. Rate of Increase in total N was the highest at the lowest salinity level soil and was the least at the highest salinity level soil. Weight of root nodules decreased by 45% when soil salinity increased by 42%. Addition of OM at a rate of 25 g OM Kg-1 soil to J1 soil of (3.5 dSm-1) and soil J3 of 12.4 dSm-1 weight of root nodules increased by 47.0%. and 21.7%, respectively. Dry weight of Cowpea plant grown in the three soils received different levels of OM decreased with the increase of soil salinity irrespective of level of OM addition. Addition of OM at a rate of 15, 25, and 50 g kg-1 soil of 3.5 dSm-1 seed yield increased by 65%,130%, and 136% respectively. These results had confirmed the role of OM in alleviating salinity stress on BNF process in soil.

Keywords: Rhizobia Bacteria; Nodule; Nitrogen Percentage in Soil; Cowpea

1. Introduction

Drought with low precipitation and high temperature are the main features of the climate of Iraq as a part of arid and semi-arid regions. Drought with low precipitation and high temperature are the main features of the climate of Iraq as a part of arid and semi-arid regions. Elevated high temperature with low relative humidity increases rate of water evaporation from soil surface leaving excess salts to accumulate in the rooting zoon of the soil. Consequently, arable land gradually converted with time into salt affected soils [1]. Farmers under these conditions start to use low quality to irrigate their land. Brackish ground water is the water resource usually used for cropping which usually leads to increase salinity problem and reducing crop yield. Soil salinity is the main factor in reducing soil productivity. Also, salinity poses a negative impact on the abundance and distribution of soil microbes and soil-dwelling organisms [2].

There is a high demand on mineral nitrogen fertilizers by farmers to increase their land productivity [3]. Relatively high price of mineral nitrogen fertilizers coupled with their adverse environmental impact on water through the high increase in phyto-autotrophic [4] and soil necessitate intensive work for alternative source of nitrogen. According, to [5] there is high increase in demand on N fertilizer by farmers.

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Biofertilizers may be the promising safe and affordable nitrogen fertilizer in Iraq. In this regard the process of biological nitrogen fixation (BNF) is of considerable importance in term of providing crops with adequate level of N. Studies by [6] had showed that 90 ton of N were annually added per hectare by BNF process which markedly improve soil fertility and increase crop yield. Symbiotic relation of Rhizobia bacteria and legume plants is of considerable importance in term of plant available N.

It has been reported that this important association between Rhizobia and legume crop is highly affected by soil salinity stress [7]. Nodule on the root of legume crop was measurably reduced under salinity stress. [8] Found a considerable decrease in the yield of legume crop under salt stress in soil. [9] Reported that that legume crops are varied in their effect by salinity stress. They found that dry weight of cowpea root nodules, grown in salt affected soil, decreased by 75%. They also found that activity of Nitrogenase enzyme was reduced by 40%.

Adding organic farm waste in compost form to soil was found to alleviate hazardous effect of salts on BNF [10]. Organic matter was also found to reduce the adverse effect of Na^{+} ions, exchangeable sodium percentage (ESP) and the ECe of the soil. This positive effect of organic matter was attributed to organic acids result from continuous decomposition of organic matter in soil [11]. [12] Suggested that organic acids in soils improve balance of nutrient elements in soil. [13] Found that organic acids improve soil aeration which in return increase microbial activity in soils.

The objective of this study is to evaluate effect of soil salinity on BNF process and the role of organic matter added to soil in alleviating the hazardous effect of salts on BNF process under arid conditions of Iraq.

2. Material and methods

Pot experiment was conducted under greenhouse conditions to determine the role of well decomposed organic material in alleviating hazardous effect of soil salinity to BNF process. Soils of 3.5, 8.2 and 12.4 dSm^{-1} salinity levels were selected for this study. Enough soil sample was obtained from 0 to 30 cm depth of each soil. Samples were air dried and crushed to pass 4 mm sieve for cropping. Subsamples crushed to pass 2mm sieve of each soil were extracted to be used for soil characterization. Ten kg of each soil were transferred into 10 kg plastic pots. Soils were collected from Jadria Area south of Baghdad. These soils are Jadria 1 (J1) Jadria 2 (J2) and Jadria 3 (J3).

pH and EC of 1:1, was determined using pH and EC electrode, respectively. Water soluble cations (Na, K, Ca, Mg) were determined, in clear water extract of the soils, using Atomic Absorption spectrophotometry (Nov 400 Analytica Jenna). Chloride was determined by titrating against Sliver nitrate as indicated by [14]. Sulphate was determined by precipitation with barium chloride as described by [15]. Organic matter was determined according to Walkley and Black method as it found in [16].

A range of organic compost was added to the soils in the pots in 0.0%, 1.5%, 2.5%, 5.0% of soil which is equivalent to 0, 150, 250, 500 gram OM per 10 kg soil in the pot. These levels were designated as OM_0, OM_1, OM_2, and OM_3 respectively. The experiment was conducted as randomized complete block design with 4 replicates and statistically analysis by SAS System.

All pots were cropped to Cowpea local verities. Plants were harvested at maturity stage. Fresh weight, dry weight for root part was determined. Root nodules were determined for each crop. Fresh and dry weight of the above ground were determined. Plant and soil samples were obtained for determining total N content as it suggested by Bremner and Mulveney as found in [17].

3. Results and discussion

Soil Characteristics are given in table 1.

Textural class of the three soils introduced to the current study are of loam textured class. This means that these soils are of good aeration which in return support active BNF process. Soil pH is slightly alkali to neutral which is a typical soil pH for the most of soils of mid and southern part of Iraq. All three soils are of low nitrogen content which may suggest that under low N content BNF is expected to be at maximum if other soil and environmental condition fairly adequate for good Rhizobia growth and activity. All three soils are of different salinity level being 3.5 dSm-1 for J1. However, salinity of J2 and J3 soils are 8.2 and 12.4 dSm-1, respectively. This may indicate that salinity stress was the least at J1 soil and being the highest at J3, which in return BNF is expected to be the highest at J1 and the least at J3.

Apparently, this wide range of salinity may serve as excellent indicator to show the role of added OM in alleviating the salt stress. Characteristic of Organic matter, as a compost, are given in table 2.

Table 1 Physical and chemical properties of the soils used in the study

Soil Type	pH	EC 1:1	N%	Na	Ca^{+2}	Mg	K	Cl	SO_4	Soil particles distribution		
			mg. kg^{-1}	mg. kg^{-1}	mg. kg^{-1}	mg. kg^{-1}	mg. kg^{-1}	meq.l^{-1}	meq.l^{-1}	Sand	Silt	Clay
S1	7.0	4.4	0.06	67.0	103.4	45.0	1.2	46.4	169	50.6	26.1	23.3
S2	7.3	16.6	0.03	176.0	471.0	129.2	2.3	27.1	388	50.6	22.1	27.3
S3	8.1	28.8	0.04	6180	585.3	1177.0	30.9	4186	9425	50.7	24.0	25.3

Table 2 Characteristics of the organic material used in the study

EC1;1 ds.m-1	pH	N%	C%	K g.kg-1	P2O2 g.kg-1	Na g.kg-1	C:Nrat	Mg g.kg-1	Ca g.kg-1
1	7.2	0.1	80	20	70	36.6	40-1	13	213

Compost is of low salinity level and low nitrogen content as well. However, the compost used in this study is of high K, P and Ca content. Therefore, the compost is a good source of organic carbon which in return most adequate to show to what extent organic carbon can alleviate salinity stress on BNF process.

Nitrogen is the largest element needed by plant for growth, yield and to complete its life cycle. Nitrogen content of the most soils is not sufficient to meet plant need [18]. Therefore, plant need for N must be secured through addition of mineral nitrogen fertilizer and/or biofertilizer. Biological Nitrogen Fixation (BNF) by Rhizobium bacteria is the main BioSource of N, although some of free-living microorganisms have the ability to fix Nitrogen in soils. Therefore, it is of considerable importance in arid regions to increase the efficiency of BNF process [19].

Effect of level of soil salinity and organic matter on the level of total nitrogen in soils after harvesting is shown in Table 3. Total nitrogen in soils without the addition of organic matter after harvesting was the least at the highest salinity level as in J3 soil and the highest was in the soil of the least salinity level J1 soil. The reduction in total nitrogen in soils with the increase of soil salinity was also reported by numerous investigators [20]. These results also showed that remained total nitrogen in one soil was the highest at the highest organic matter addition. However, at high salinity level (i.e. 12. dSm-1) organic matter added showed no effect on N remined in soils after harvesting. N remain in soil as affected by organic matter addition was found to be best fitted to a linear increase model as in the following:

$$Y=0.1131 + 0.0004X \quad R2=0.9604 \text{ ----------}1$$

Y:% of N remained in soils after harvesting
X: Percentage of added OM

The high regression coefficient clearly indicate that effect of OM addition on%N remained in soil best described and quantified by a linear model as it was shown in equation 1 above. Numerous reports were found in literature which confirm the increase in BNF with the increase of organic matter supplements [21] [6]. However, the rate of increase in%N remains after harvest was markedly low (0.004%N/ mg OM kg-1 Soil) which may be attributed to the fact that appreciable percentage of N remains may either lost as N gas by denitrification, or absorbed by existing crops or leached down the soil profile.

Table 3 Effect of level of soil salinity and organic matter on the level of total nitrogen in soils after harvesting

level of organic matter	N%		
	S1	S2	S3
M0	0.08333	0.1110	0.08667
M1	0.19667	0.16667	0.08333
M2	0.2300	0.17333	0.08333
M3	0.28667	0.26333	0.08333

LSD $p \leq 0.05$ = 0.176

The result (Table 3) also showed that N remined in J2 soil of 8.2 dSm-1 after harvesting markedly increased with the increase of the amount of OM added. Which again confirm the role of OM added in alleviating salt stress on BNF process. However, at higher soil salinity stress J3 soil of 12.4 dSm-1 organic matter added showed no effect on BNF process. These results are in agreement with those of [22] who found that organic material reduce the effect of salt stress on BNF just to certain level of soil salinity. They reported that the salinity critical level after which organic matter showed no effect on BNF process is 3.0 dsm-1.

Effect of soil salinity on BNF in soils was best fitted to decreasing linear equation of the following type as indicated by high and significant value of the regression coefficient.

$$Y=a - bX$$

Y=40.5 – 306.8X R2: 0.992 ……. 2

Where:

Y=%N remained after harvesting

a: is the Y intercept which is%N at no salinity

b: is the slope which represent the decrease in%N per each unit of increase in salinity

This finding is in agreement with those of The Effects of Salinity and Sodicity upon Nodulation and Nitrogen Fixation in Chickpea (Cicer arietinum) [22] [23].

These results indicate large decrease in%N remains with the unit increase in salinity (i.e. -360 per unit increase in salinity as indicated in the equation above. The large decrease in%N remain may be attributed to the factors mentioned under OM addition in addition to high sensitivity of N fixing bacteria to drought and salinity stress.

Effect of level of organic matter added to the three soils of different salinity level on total N in cowpea plant is shown in table 4.

Table 4 Effect of organic matter added to soils on total Nitrogen content in cowpea plant

Levels of Organic Matter	N%		
	S1	S2	S3
M0	2.1267	2.0367	1.2900
M1	2.8200	2.1900	1.5867
M2	3.0100	2.4367	2.0467
M3	4.123	3.1867	2.0333

LSD $p \leq 0.05$ = 0.2096

Total N in Cowpea plant grown in J1 soil and J2 soil linearly increase with the increase of level of organic matter addition. However, rate of Increase in total N in plant varied depending on salinity level, being the highest at the lowest salinity level soil J1 and being the least at the highest soil salinity level J3. The results also showed that at any level of organic matter addition total N in plant linearly decreased with the increase of salinity level in soil. This clearly indicated that OM added to soil reduced the effect of salinity stress which is in agreement with the findings of [22]. These results may also suggest the importance of the adequate level of OM in soils of arid regions for reducing the hazardous effect of salinity stress to BNF process.

To evaluate the effect of the salinity stress on the bioactivity of rhizobium bacteria in the soils introduced to this study number of bacterial root nodules was calculated (Table 5).

Table 5 Number of root nodules on Cowpea roots as affected by salinity stress under different levels of Organic matter

Levels of Organic Matter	Number of bacterial root nodules		
	S1	S2	S3
M0	110.00	80.000	56.333
M1	103.667	98.333	60.333
M2	131.333	110.333	63.333
M3	139.333	119.333	70.000

LSD $p \leq 0.05$ =12.307

Number of root nodules reduced by 27.0% and 49.0% when soil salinity increased to 8.2 and 12.4 dSm-1, respectively, compared to that in soil of 3.5 dSm-1. However, number of root nodules in the three soils increased with the increase of organic matter addition and the least root nodules was observed on plant grown in soils of the highest salinity level. These results confirm the results obtained by Walker, 2008 and [12] who found that variants of salt treatment reduced plant growth and total nodule volume calculated per plant.

Weight of root nodules was also determined (Table 6). Which was comparable to the number of root nodules in the three soils and under different OM addition.

Table 6 Weight of root nodules on the roots of Cowpea grown under salinity stress and a range of organic matter addition

Levels of Organic Matter	Weight of root nodules		
	S1	S2	S3
M0	8.987	7.850	4.963
M1	7.757	7.200	6.353
M2	14.333	11.110	6.190
M3	17.120	12.100	7.767

LSD $p \leq 0.05$ = 2.8392

Weight of root nodules decreased by 45% when soil salinity increased by 42% which clearly indicate the effect of salinity stress on rhizobium growth and effectiveness. Results also showed that addition of OM at a rate of 250 mg OM Kg-1 soil to J1 soil (3.5 dSm-1) weight of root nodules increased by 47.0%. However, adding same rate of OM to J3 soil (12.4 dSm-1) weight of root nodules increased by 21.7% only. These results are in agreement with those of [24] and) [25] and confirm the importance of the addition of OM to the soils of arid regions.

Results (Table 7) also showed that dry weight of Cowpea plant grown in the three soils received different levels of OM decreased with the increase of soil salinity irrespective of level of OM addition which is in agreement of [26] who found that plant dry weight decrease under salinity stress in both medium and heavy textured soils.

Table 7 Effect of soil salinity and organic matter addition on Cowpea dry weight

Levels of Organic Matter	Cowpea dry weight		
	S1	**S2**	**S3**
M0	29.670	25.667	19.303
M1	30.263	26.900	21.277
M2	38.640	30.633	24.037
M3	49.080	40.947	24.657

LSD $p \leq 0.05$ = 2.6124

In one soil dry weight increased with the increase of level of OM addition. Addition of OM at a 5.0% rate of the weight of the three soils resulted in 65%, 60% and 28% increase in dry Cowpea dry weight in soil J1, J2 and J3, respectively. This may confirm the previous conclusion that effect of OM in enhancement of BNF markedly reduced by the increase of salinity stress in soil which is in agreement with [22] who had suggested that there must be a critical level of salinity stress. The increase in dry weight with the increase of OM addition may be attributed to the increase in N in the three soils and in the increase of root nodules as well. This is in agreement with previous findings which confirm the role of BNF in providing some of plant needs of N.

Seed yield of Cowpea grown under salinity stress as affected by OM is given in table 8.

Table 8 Seed Yields of Cowpea grown under salinity stress as affected by OM addition

Levels of Organic Matter	Seed yield		
	S1	**S2**	**S3**
M0	33.133	14.320	7.697
M1	53.717	9.753	9.623
M2	76.183	29.783	11.693
M3	78.153	49.377	23.030

LSD $p \leq 0.05$ = 18.342

Results showed that highest seed yield was obtained in soils J1 which is the least salts content. At zero level of OM addition seed yield at Soil J1 two times that in soil J2 and that in J2 was two times in J3 Soil, which clearly indicate hazardous effect of salinity stress on plant yield. Addition of OM at 150, 250, and 500 mg kg-1 J1 soil seed yield increased by 65%, 130, and 136% respectively. These results indicate that increasing of OM addition increased seed yield in comparable ration. Therefore, it is of considerable importance to determine the most effective addition ratio of OM which may be supported by report by [27] for salt affected soils.

In conclusion this study clearly indicates the hazardous effect of salinity stress on bioactivity of Rhizobia in soils and reducing the nitrogen input which in return reduce plant growth and yield. These results had confirmed the role of OM in alleviating hazardous effect of salinity stress on BNF process in soil.

4. Conclusion

In conclusion this study clearly indicates the hazardous effect of salinity stress on bioactivity of Rhizobia in soils and reducing the nitrogen input which in return reduce plant growth and yield. These results had confirmed the role of OM in alleviating hazardous effect of salinity stress on BNF process in soil.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interests to declare.

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