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Effective use of brackish water for improving soil properties and chickpea (*Cicer arietinum*) growth through organic amendments

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Abstract

Due to water scarcity, the use of underground brackish water in an efficient way is a dire need to improve soil conditions as well as crop growth. To obtain this objective, a field study was conducted to evaluate the efficacy of organic amendments (compost, farm yard manure and poultry manure) alone and in combination to mitigate the negative impact of poor quality water on chickpea (Cicer arietinum) growth and soil properties. Soil samples were collected before organic amendments application and also after crop harvesting. At flowering, plants were uprooted from each plot for collecting nodulation data whereas data regarding growth and yield components of chickpea was recorded at maturity. The results showed that application of organic fertilizers not only caused significant effect on growth and yield components of chickpea but also improved physico-chemical properties of soil by mitigating the negative impact of brackish water. Soil electrical conductivity, sodium adsorption ratio was significantly low and nitrogen, phosphorus and organic matter contents were higher in organic amendments treated soil. Organic manures also differed significantly regarding their effect and better results were obtained where farmyard manure was applied alone or in combination with poultry manure and compost. The results indicate that application of organic manure could be a better strategy to alleviate the negative impact of brackish water on crop and soil.

Keywords: Brackish water, soil properties, organic amendment, growth, chickpea

Introduction

Agriculture in arid and semiarid region is threatened with acute shortage of irrigation water. In such regions, groundwater is the common source of irrigation; however, this water is poor quality due to low rainfall and high evaporation rate (Jalali and Merrikhpour, 2008). Long term use of such water can lead to deterioration of physico-chemical properties of soil and also cause negative impact on plant growth (Farooq *et al*., 2008).

Leguminous crops play important role in maintaining soil fertility by converting and fixing atmospheric nitrogen in available form through symbiosis with rhizobial strains. Chickpea (*Cicer arietinum* L.) is an important legume crop that is not only a good source of protein and vitamins (Ali *et al.*, 2010) but is also considered a suitable crop for improving soil nutrient status particularly in water deficit areas (Sabaghpour *et al*., 2006; Mohammadi *et al*., 2010). However, legumes are generally salt sensitive and a significant reduction in biomass is observed under saline conditions (Katerji *et al*., 2000; Bruning and Rozema, 2013). This reduction might be due to saline soil or application of salty water. As observed in case of chickpea where a significant reduction in growth and yield has been observed by the application of brackish water (Sexena, 1987; Turner *et al*., 2013; Kaur *et al.*, 2014).

Application of brackish water caused significant negative impact on plant growth and development. A long term field study conducted by Choudhry *et al*. (2006) showed that sodic water application on normal soil significantly reduced the yield of sunflower. Similar findings were also reported by Hussain *et al*. (2011) who observed that brackish water significantly affected the growth parameters of jojoba (*Simmondsia Chinensis*). They observed that the negative impact of the brackish water increased as the salinity concentration increased. This negative impact of poor quality water is not only on plant growth but on soil properties as well (Vance *et al*., 2008). Cucci *et al.* (2013) studied the impact of saline-sodic water on physical and chemical properties of soil. They observed that application of saline-sodic water increased the EC_e, SAR, exchangeable Na and decreased the exchangeable K, Ca and Mg. Other researchers also reported the negative impact of poor quality water on plant and soil (Emdad *et al*., 2006; Abro *et al*., 2007; Admau, 2013).

Brackish water can be used effectively for crop production purpose if proper management practices are followed (Qadir *et al*., 2001; Kahlon *et al*., 2012). The application of organic amendments like pressmud, poultry manure and farmyard manure can reduce the risk of soil deterioration and yield reduction (Ashraf *et al*., 2005;

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Munir *et al.*, 2012). The organic amendments could be useful for reducing the accumulation of salts and enhancing the water holding capacity, aggregate stability and microbial activities of the soil (Qadir *et al*., 2001; Walker and Bernal, 2008; Tahboub *et al*., 2008; Mahmoodabadi and Ronaghi, 2014). It has been observed that application of organic matter improved the physical, chemical and biological properties of soil that ultimately enhanced plant growth and development (Choudhary *et al*., 2004; Wong *et al*., 2009; Sharif *et al*., 2014).

Different kinds of organic amendments are used to improve physico-chemical properties as well as fertility status of soils. For example, application of livestock and poultry wastes proved useful for increasing the nutrient status of soil by supplying major nutrients like nitrogen phosphorus, potassium, calcium and magnesium required for proper plant growth and development (Dobermann *et al*., 2003; Abdelhamid *et al*., 2004; Adeleye and Ayeni, 2010; Muhammad *et al.*, 2013). The application of such amendments is also useful for reducing soil bulk density, increasing organic matter and moisture contents (Abdelhamid *et al*., 2004). Similarly, compost that is a rich source of nutrients and organic matter contents also proved useful for improving soil properties and increasing crop yield (Hussain *et al*., 2001; Mrabet *et al*., 2012).

The above discussion shows that the application of poor quality water negatively affects plant growth and soil properties. It is also observed that the use of organic material could be useful for maintaining soil health and improving plant growth. However, variable results have been obtained with respect to water quality and type of organic amendments. Therefore further research is needed to find out the better option for sustainable use of poor quality water in the presence of organic material. The soil of research area is poorly structured and having low fertility status and currently available water source for irrigation is only underground water that is brackish in nature. Therefore, present study was undertaken with the objectives to make the effective use of poor quality underground water by the application of organic amendments and also to monitor the changes in physico-chemical properties and fertility status of soil by the use of organic materials in the presence of brackish water.

Materials and Methods

The experiment was conducted at research area of The Ghazi University, Dera Ghazi Khan, Pakistan. Six treatments (T_1= Control, T_2= Farm Yard Manure (FYM), T_3= Compost, T_4= Poultry Manure (PM), T_5= FYM + PM + Compost, T_6= inorganic fertilizer) in three replicates were applied according to randomized complete block design (RCBD). Chickpea was sown and brackish water was applied to fulfill the irrigation requirements of the crop.

Collection of soil samples and treatments application

Soil samples were collected at random from each plot with the help of soil augor before application of treatments. The collected samples were dried, sieved and composite soil sample was prepared after through mixing of individual samples. The composite sample was analyzed for soil properties including pH, electrical conductivity (ECe), sodium adsorption ratio (SAR), cation exchange capacity (CEC) and bulk density according to standard procedures described in US salinity Lab Staff Manual (1954). Soil nitrogen, phosphorus, potassium and organic matter contents were determined according to the methods described by Ryan *et al*. (2001).

Farmyard manure, poultry manure and compost were analyzed (Table 1) and applied alone and in combination in each respective plot and mixed thoroughly. Farmyard manure, poultry manure, compost was applied at 12 t ha^{-1} about thirty (30) days before crop sowing. After mixing the organic fertilizers, plots were kept as such so that decomposition may start. Inorganic fertilizer was applied at the time of sowing.

Table 1: Composition of organic fertilizers used in the experiment

Characteristic	FYM	PM	Compost
pH	7.84	7.62	7.21
EC	0.57	0.24	0.16
N (%)	1.84	2.14	1.22
P (%)	0.91	1.24	1.74
K (%)	0.74	1.01	1.24
Organic carbon (%)	24.2	16.2	12.5
C/N	13.3	7.57	10.2

FYM: Farmyard manure; PM: Poultry manure

Chickpea sowing and data collection

Seeds of chickpea were obtained from Ayub Agriculture Research Institute, Faisalabad. Seeds were sown in each untreated (T1= Control) and treated (T_2= Farmyard Manure (FYM), T_3= Poultry Manure (PM), T_4= Compost, T_5= FYM + PM + Compost, T_6= inorganic fertilizer) plots according to RCBD. Combine application of FYM, PM and compost was applied in the ratio of 1:1:1. The plot size was 390 x 570 cm and seeds were sown at row to row distance (R X R) 30 cm. Nitrogen, phosphorus and potassium was applied at 100, 50 and 50 kg ha^{-1} in the form of urea, diammonium phosphate (DAP) and sulphate of potash (SOP). Half dose of nitrogen and full dose of phosphorus and potassium was applied to the T_6 i.e. NPK.

Remaining half nitrogen was applied at the time of first irrigation. In $T_{1,}$ no fertilizer was applied and was kept unfertilized for comparison. Irrigation requirement of crop was fulfilled by applying underground brackish water.

At flowering, five plants from each plot were uprooted at random and data regarding number of nodules per plant, nodules fresh weight and dry weight were collected. At maturity, data regarding growth and yield components of chickpea was collected. Soil samples were also collected after harvesting of crop and analyzed for physico-chemical characteristics as described above. Data were analyzed statistically according to Steel *et al.* (1997) using SPSS software version 19.

Results

The results of water analysis shows that the underground water quality is not good for crop production (Table 2). The water has high electrical conductivity value i.e. 5.62 dS m^{-1} however, SAR value is low that is due to the presence of more calcium and magnesium compared to the sodium.

Table 2: Analysis of water used for irrigation

Characteristic	Unit	Value
pH_s	-	8.10
EC	dS m^{-1}	5.62
CO_3	m mol L^{-1}	1.67
HCO_3	m mol L^{-1}	6.03
Cl	m mol_c L^{-1}	22.8
SO_4	m mol_c L^{-1}	25.7
Na^+	m mol_c L^{-1}	24.7
Ca + Mg	m mol_c L^{-1}	31.5
SAR	$(m\ mol\ L^{-1})^{1/2}$	6.22
RSC	m mol_c L^{-1}	Nil

The results showed that application of brackish water caused significant negative impact on chickpea growth. However, the application of organic amendments mitigated the negative impact of salty water. The data presented in Table 3 showed that brackish water caused significant decrease in number of nodule, nodule fresh and dry weight. The maximum number of nodules were counted in T_2 i.e. FYM that was statistically similar with T_3, T_4 and T_5. The application of FYM caused 81% increase in nodule number compared to control. The application of NPK also caused significant increase in number of nodules compared to control, however, it was statistically less effective compared to organic amendments. Similarly organic amendments also caused significant improvement in nodule fresh and dry weight. The maximum nodule fresh and dry weight was observed in case of FYM (T_2) treated plot (59% and 1.11 fold more than control, respectively) while minimum in case of control. The application of PM and NPK showed statistically similar results regarding nodule fresh weight while T_3 (compost), T_4 (PM), T_5 (FYM + PM + C) in case of nodule dry weight.

The data regarding root length (Table 3) showed that maximum root length was noted in case of FYM treated plot that was 57% more than control, however, it was statistically similar with all other treatments. Similarly in case of root dry weight, the maximum weight was observed in case of T_2 (FYM) followed by T_5, T_3 and T_4. Up to 66% increase in root dry weight was observed due to the application of organic amendments. The application of NPK and untreated control plot showed statistically similar results regarding root dry weight.

The application of organic and inorganic fertilizers caused significant increase in plant height and plant biomass compared to control (Table 4) however, non significant difference was observed among organic and inorganic treatments regarding plant height and plant biomass. Up to 24 and 48% increase was observed in case of pant height and plant biomass, respectively, compared to control. The data regarding number of pods per plant mentioned in Table 5 showed that maximum number of pods were observed in case of T_2 (FYM) that was statistically similar with T_4 (PM), and T5 (FYM + PM + C). Up to 57% increase in number of pods was observed due to the application of FYM compared to control which was treated with brackish water.

The data regarding grain yield of chickpea (Table 4) showed that application of brackish water caused significant decrease in grain yield however, the application of organic amendments caused significant improvement in grain yield. The maximum grain yield was obtained from FYM treated plot (T_2) that was 1.07 fold higher than control. It was statistically similar with T_5 (FYM + PM + Compost). Application of compost (T_3) and FYM + PM + Compost (T_5) showed statistically similar results and caused up to 92% increase in yield compared to control. The application of NPK also caused significant increase in grain yield that was 61% more than untreated control where only brackish water was applied. Similarly, data regarding 100 grain weight showed that maximum 100 grain weight was observed in case of T_5 followed by T_2, T_3 and T_4. Although the application of organic and inorganic amendments caused significant increase in 100 grain weight however, the organic amendments were statistically similar regarding 100 grain weight. Results showed that maximum harvest index value was obtained in case of FYM treatment that was statistically similar with combine application of FYM, compost and PM (Figure 1). In control, the value of harvest index was low followed by NPK. Poultry manure (T_4) and NPK (T_6) showed statically similar results.

The application of brackish water caused significant impact on soil physico-chemical properties (Table 5). The pH of soil before initiation of experiment was 8.46 that increased to 8.85 due to application of brackish water. However, significant decrease in soil pH was observed due to application of FYM (T_2), compost (T_3) and T_4 (FYM + PM + C). The brackish water caused increase in soil EC both in treated and untreated plots however, the increase in EC was more significant in control where only brackish water was applied. The maximum soil EC was observed in control plot that was 2.39 fold more than original soil EC i.e. 2.01 dS m^{-1}. The minimum EC was observed in plot treated with FYM (T_2) followed by T_3 and T_6. Although the soil EC of the treated plot was also high than the original EC, however, it was 54% lower than the untreated control plot. No significant increase in soil SAR was observed if compared with original SAR. However, the application of treatments caused significant decrease in SAR compared to control. High SAR was observed in control plot while low SAR value was noted in case of plot treated with FYM and mixture of organic amendments. Similar results were also obtained in case of bulk density and 53% decrease in bulk density was observed by the application of FYM, PM and compost in combination followed by T_2 (FYM). The application of organic and inorganic amendments caused significant increase in cation exchange capacity of soil. Although in all plots, the CEC values are more than the original soil however, maximum increase was noted in case of T_5 that was 16% more than untreated control. The application of NPK showed statistically similar results regarding CEC when compared with control.

The data regarding fertility status of soil has been presented in Table 6. A significant increase in major nutrients (N, P and K) and soil organic matter contents was observed due to application of organic and inorganic fertilizers. The maximum nitrogen contents were observed

Table 3: Effect of organic and inorganic fertilizers on number of nodule, nodule fresh weight, nodule dry weight, root length and root dry weight

Treatment	No. of nodules per plant	Nodule fresh weight	Nodule dry weight	Root Length	Root Dry weight (g plant^{-1})
T_1= Control,	32 c	2.66 e	0.17 c	15.3 b	1.2 b
T_2= FYM	58 a	4.23 a	0.36 a	24.0 a	2.0 a
T_3= Compost	52 ab	3.70 ab	0.33 ab	20.0 ab	1.7 ab
T_4= PM	50 ab	3.43 cd	0.27 b	18.6 ab	1.7 ab
T_5= FYM + PM + C	56 a	3.96 ab	0.33 ab	22.6 ab	1.9 a
T_6= NPK	42 b	3.16 d	0.27 b	20.3 ab	1.4 b

Table 4: Effect of organic and inorganic fertilizers on plant height, plant biomass, no. of pods per plant, grain yield and 100 grain weight

	Plant height (cm)	Plant biomass (t ha^{-1})	No. of pods per plant	Grain yield (t ha^{-1})	100 grain weight (g)
T_1= Control,	34.0 b	6.3 b	39.6 c	1.3 e	29.6 c
T_2= FYM	42.3 a	9.3 a	62.0 a	2.7 a	35.3 ab
T_3= Compost	40.3 a	8.4 a	54.0 b	2.4 bc	34.3 ab
T_4= PM	39.6 a	8.4 a	55.3 ab	2.2 cd	34.3 ab
T_5= FYM + PM + C	43.3 a	8.9 a	60.3 ab	2.5 ab	37.0 a
T_6= NPK	40.0 a	8.8 a	57.0 ab	2.1 d	32.0 b

Table 5: Physico-chemical characteristics of soil before and after the experiment

Characteristic	Unit	Before sowing	After chickpea harvesting					
			T_1	T_2	T_3	T_4	T_5	T_6
pH_s	--	8.46	8.85 a	8.10 b	8.19 b	8.50 a	8.55 a	7.95 bc
EC_e	dS m^{-1}	2.01	6.82 a	3.11 e	3.85 cd	4.01 c	4.82 b	3.94 d
SAR	--	7.52	7.54 a	6.91 c	6.85 d	7.12 b	7.20 ab	6.94 c
Bulk density	Mg m^{-3}	1.57	1.87 a	1.39 d	1.50 c	1.49 c	1.32 d	1.69 b
CEC	C mol_c kg^{-1}	8.14	8.17 c	9.22 a	9.00 ab	8.87 b	9.45 a	8.20 c

in case of PM treated plots followed by T_6, T_2 and T_5. Up to 3.5 fold increase in nitrogen content was observed in case of T_4 compared to control. A significant increase in phosphorus content was observed in T_2 that was statistically similar with T_6. The maximum potassium concentration was observed in plot treated with NPK (T_6) that was statistically similar with T_5 (FYM + PM + C).

Table 6: Soil fertility status before and after experiment

Characteristic	Unit	Before sowing	After chickpea harvesting					
			T_1	T_2	T_3	T_4	T_5	T_6
Total nitrogen	mg kg^{-1}	140	90 c	540 b	420 bc	840 a	520 b	640 b
Available P	mg kg^{-1}	3.84	2.45 d	4.12 a	4.01 ab	3.74 c	3.97 b	4.25 a
Extractable K	mg kg^{-1}	114	109 c	119 ab	117 b	108 c	126 a	121 a
Organic matter	%	0.27	0.19 d	0.54 ab	0.48 bc	0.46 bc	0.61 a	0.24 d

Table 7: Correlation analysis of chickpea growth and yield parameters

Parameter	No. of pods	No. of nodules	Root length	Nodule weight	Plant height
Grain yield	0.95^{**}	0.97^{**}	0.93^{*}	0.91^{*}	0.96^{**}
No. of pods		0.88^{*}	0.93^{*}		0.97^{**}
No. of nodules	0.88^{*}		0.88^{*}		0.93^{*}
Plant height	0.97^{**}	0.93^{*}			

* = Significant; ** = Highly Significant

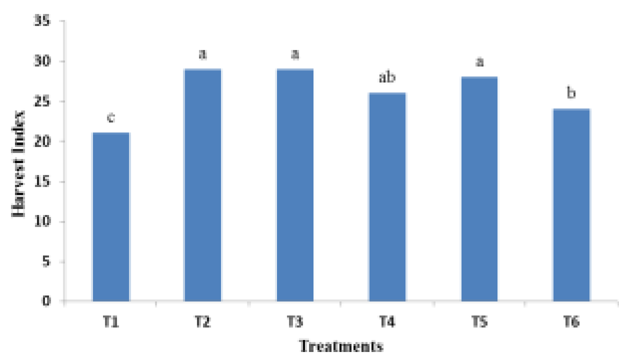

Figure 1: Effect of organic amendments and inorganic fertilizer on harvest index of chickpea

The application of organic material caused significant increase in organic matter content of the soil (Table 6). Maximum organic matter was observed in plot treated with a combination of FYM, PM and compost that was statistically similar with T_2 (FYM). Upto 1.25 fold increase in organic matter content compared to control of was noted due to combined application of organic amendments. Although the application of NPK also caused an increase in organic matter however, it was statistically similar with untreated control.

The data regarding NPK uptake by the chickpea plant showed that maximum nitrogen uptake was recorded in case of combine application of organic amendments (Figure 2). The plant treated with NPK and poultry manure showed statistically similar results regarding nitrogen uptake. Minimum nitrogen uptake was recorded in control. Maximum phosphorus content was recorded in compost treated plants that was statistically similar with T5 (FYM + PM + Compost). Minimum uptake was recorded in control followed by FYM and NPK treated plants. Like nitrogen maximum potassium uptake was recorded in T5 followed by T3 and T4 and minimum with control.

A correlation analysis was also done to determine the correlation between grain yield and number of pods, number of nodules, nodule weight and root length (Table 7). The number of pods were positively correlated with number of nodules and root length. The results showed that all parameters were positively correlated with grain yield. Plant height was also positively correlated with number of pods and number of nodules.

Discussion

The present study was undertaken to evaluate the effectiveness of organic fertilizers for improving the chickpea growth and soil properties in the presence of poor quality underground water. The experiment area is facing water shortage due to non availability of good quality canal water. It is also evident from Table 8, that no rain was received during the experimental period. According to whole year metrological data of the experimental area (data not mentioned) only 31 mm annual rainfall was received during the whole year while an increase in temperature up to 49 ^{o}C in summer was noted. At present, the only available source for irrigation is poor quality underground water that is not fit for crop production. Similar situation is also present in other areas of the country. Therefore, there was a dire need to utilize the available resources in a better

Table 8: Meteorological data of the area during the experiment period

Month	Temperature			Rain (mm)	Humidity (%)
	Maximum (^oC)	Minimum (^oC)	Mean (^oC)		
November	30.2	13.9	22.0	-	47.4
December	21.8	6.0	13.9	-	39.1
January	19.4	4.9	12.1	-	66.1
February	20.9	5.22	13.0	-	72.5
March	27.0	11.6	19.3	-	58.5

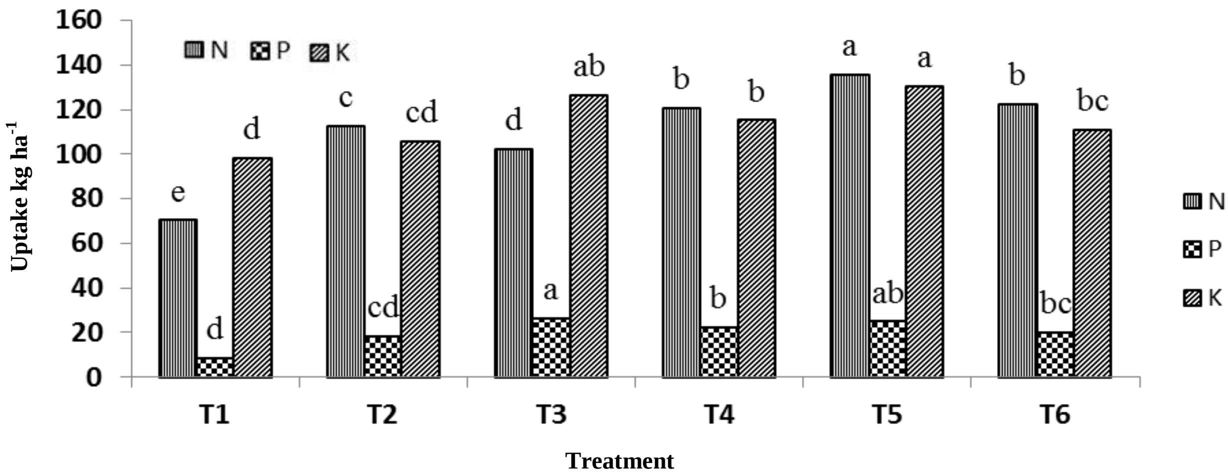

Figure 2: Effect of treatments on nitrogen, phosphorus and potassium uptake of chickpea plant
$\mathbf{T_1}$ = Control, $\mathbf{T_2}$ = FYM, $\mathbf{T_3}$ = Compost, $\mathbf{T_4}$ = PM, $\mathbf{T_5}$ = FYM + Compost + PM, $\mathbf{T_6}$ = NPK

and efficient way to protect the soil and also get maximum benefits in the form of crop yield. As it is evident from results, that the application of this water not only caused negative impact on chickpea growth but also deteriorated the soil properties. However, the application of organic amendments mitigated the negative impact of this poor quality underground water by enhancing plant growth and improving soil quality parameters.

Certain factors and conditions restricted the use of poor quality water in agriculture sector. Some of the major factors include plant sensitivity, nutritional imbalance, specific ion toxicity and deterioration of soil quality (Ghafoor *et al*., 2004; Lauchli and Grattan, 2007; Jouyban *et al*., 2012). A number of studies showed that application of such water caused negative impact on plant growth as well as soil properties (Ghafoor *et al*., 2004; Izhar-ul-Haq *et al*., 2007; Ismail, 2013). However, this water can be used effectively if proper management practices are adopted. For example, the application of certain amendments such as farmyard manure, poultry manure, pressmud as well as chemical amendment could be useful for the safe use of this water. It is also evident from our study that the application of brackish water having high proportion of soluble salts caused negative impact on chickpea growth and development, however, the presence of organic amendments alleviated this negative impact. The application of brackish water alone decreased chickpea nodulation. This low nodulation might be due to the inhibitory effect of salts present in this water. It was also observed from the work of other researchers that salinity caused negative impact on nodulation of soybean, pea and faba beans (Singleton and Bohlool, 1984; Siddiqui *et al*., 1985; Yousaf and Sprent, 1986). In general, the grain legumes are salt sensitive (Katerji *et al*., 2000) and high salt concentration affects the rhizobium efficiency to fix nitrogen by causing negative impact on its growth (Alexander, 1984; Katerji *et al*., 2001). On the other hand, the application of organic materials improved nodulation even in the presence of brackish water (Figure 3). This enhanced nodulation might be due to increase in exchangeable calcium (Ca). It has been observed that Ca content affects the attachment of rhizobia to roots (Smit *et al*., 1991) and therefore enhances nodulation (Lawson *et al*., 1995). The application of organic material in soil increased the organic matter content of the experiment soil that was very low before experiment initiation. The high organic matter contents are very favorable for enhancing microbial activity in the soil (Rangaraj *et al*., 2007). This higher microbial activity, due to the release of CO_2 enhances the solubility of Ca (Krauskopf, 1967; Abbas and Fares, 2009) that ultimately improved rhizobium ability to fix nitrogen. This improvement in rhizobium-legume interaction is also reflected in this study that showed more number of nodules in case of organic fertilizer amended plots compared to inorganic and control treatments. The favorable soil environments enable the bacteria to reside in unfavorable conditions and perform its function in a better way. The improvement in growth, nodulation and yield of mungbean in the presence of stress tolerance bacteria under salt affected conditions was also observed by Ahmad *et al*. (2013).

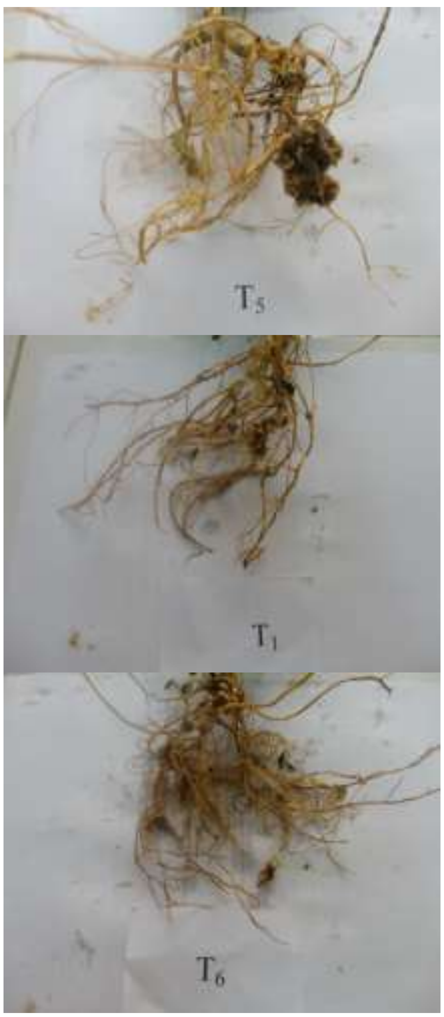

Figure 3: Effect of organic manure and inorganic fertilizer on nodulation of chickpea irrigated with brackish water

T_1=Control; T_5=Farm yard manure + Compost + Poultry manure; T_6 = NPK

A significant reduction in chickpea growth and yield parameters was observed by the application of brackish water. Saxena (1987) also observed upto 50% yield reduction of chickpea at an EC_e of 3 dS m^{-1}. The application of organic amendments mitigated this negative impact of poor quality water and caused significant increase in yield. This yield enhancement might be due to improvement in soil CEC and decrease in SAR, besides increased fertility status of soil. Soil organic matter encouraged granulation, increased CEC and therefore improved soil adsorbing power (Brady, 2005). Munir *et al*. (2012) also found the positive effect of FYM in mungbean-wheat cropping system in the presence of brackish water. They observed that FYM decreased the deleterious effect of brackish water and enhanced soil fertility. The increase in soil fertility status by the addition of these organic material showed that these material are rich in micro and macro nutrients. Earlier findings also showed that such organic materials increase organic matter, N, P, K, Ca, and Mg contents of the soil (Odedina *et al*., 2003; Ayeni, 2008). The better uptake of NPK by chickpea in organic fertilizer treated plots further indicated the improved nutrition of soil treated with these amendments. This improved nutrition enhanced the growth of chickpea that resulted in better yield. It is also evident from correlation analysis that showed a positive correlation between yield and plant height, number of pods, number of nodules and nodule weight.

Although, no significant decrease in soil pH was observed however, treatments receiving organic materials showed relatively low pH as compared to the control treatment where only brackish water was applied. Hussain *et al*. (2001) also found no significant effect of organic material on soil pH. However, other workers found a decrease in soil pH by the application of organic materials (Yaduvanshi, 2001; Smiciklas *et al*., 2002). Qamar *et al*. (2011) in a field experiment observed a decrease in pH_s and EC, SAR of soil and increase in grain yield of wheat with the application of FYM and gypsum alone and in combination in the presence of low quality underground water. Similarly, Zaka *et al*. (2003) also found a decrease in soil SAR with the use of FYM, rice straw and green manuring. The production of organic acids during decomposition of organic material would be the cause of this decrease in soil pH.

The organic amendments showed variable response regarding their effectiveness for enhancing chickpea growth and improving soil properties. The FYM and mixture of FYM, compost and poultry manure showed relatively better results compared to other treatments. The application of

NPK also enhanced chickpea growth however, its effect was not so significant particularly on soil properties when compared with organic amendments. It has also been observed in a previous study that application of FYM is more effective compared to gypsum (Yadav and Kumar, 1994).

The present study shows the effectiveness of organic materials for improving plant growth and soil properties. Keeping in view the scarcity of good quality water and population growth in the region, it has become vital to use the available soil and water resources in an efficient way. On the basis of results obtained from this study, it can be concluded that poor quality underground water can be used efficiently for sustainable agriculture production in this region. However, further field work is needed to evaluate the long lasting effect of such water on soil properties in the presence of organic materials so that a suitable strategy on sustained basis can be suggested for this region.

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