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FARM MANURE IMPROVED SOIL FERTILITY IN MUNGBEAN-WHEAT CROPPING SYSTEM AND RECTIFIED THE DELETERIOUS EFFECTS OF BRACKISH WATER

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A series of field experiments were conducted at Research Farm, College of Agriculture, Dera Ghazi khan (30.03˚ N and 70.38˚ E) sub campus of University of Agriculture, Faisalabad to study the effect of farm manure (FM) on soil pH, $EC_{1:5}$, SAR, NPK and organic carbon under Mungbean-wheat cropping system using brackish water for irrigation during 2009-2011. Farm manure was incorporated into soil at the dose of 0, 10, 20 and 30 Mg ha^{-1}. Results indicated that soil $EC_{1:5}$ SAR and pH values were reduced with the application of farm manure under brackish water application. While organic Carbon, Nitrogen, available Phosphorus and Potassium was improved by manure application. Although farm manure application increased the concentration of NPK but their concentration decreased as depth of soil increased. It can be concluded that farm manure application reduced the deleterious effects of brackish water as indicated in EC and pH, and enhanced the fertility level of the soil.
Keywords: Farm manure, soil fertility, brackish water, Mungbean, wheat

INTRODUCTION

Pakistan falls in the arid to semi-arid climatic region of the world. Due to arid climate and high temperature, extremely low levels of soil organic carbon (SOC) contents have been found in most soils, ranging from 8 to 10 g kg^{-1} or 0.52 to 1.38% (Azam *et al*., 2001). College of Agriculture Dera Ghazi Khan is located in the area which is among the dry areas of Pakistan. It suffer from problems such as high temperature, less rainfall, high evapotranspiration rate, brackish water and wind storm which has lead to high risk of desertification and exacerbated by the effect of land use changes. The whole area is left abandoned due to poor quality of soil and water. A major point of concern is the impoverishment of soil quality and increase of soil erosion and water loss due to degrading top soil. Potential evapotranspiration is considerably higher as compared to rainfall received. High temperature promotes capillary movement of salts upwards causing deposition of salts on the soil surface.

Agriculture in arid and semiarid region is in danger with sharp shortage of irrigation water. According to Ansari (1995) in Pakistan canal net work could supply only one cusec of water for 350 acres compared to 70 acres in U.S.A. To make up the gap canal water resources can be supplemented by ground water but unfortunately 70-75% of total water being pumped out in the country is of brackish nature (Azhar *et al*., 2003) and intuitive use of this water is deteriorating the soil health and crop yields (Khan *et al.*, 1991; Hussian *et al.*, 1991). Soil properties undergo severe changes when soil is irrigated with brackish water. The soluble salts present in the rhizosphere as a result of brackish water affect the crop growth by reducing ability of plant roots to absorb water due to osmotic pressure effect (Maas and Nieman, 1978). However, brackish water can efficiently be used for irrigation if proper management practices are followed (Ghafoor *et al.*, 2001; Qadir *et al.*, 2001). Composting is beneficial (Farhad *et al*. 2011) and addition of organic materials such as farm manure is of extreme importance in improving the soil properties (Hou, 2012), which are otherwise failing when brackish water is being used. Brackish water can be used for irrigation with proper management practices without substantial loss to soil health and crop productivity (Murtaza *et al.,* 2002). For testing the use of brackish water with farm manure, no work has been done at field level under such conditions on long term basis. For that reason, it is suitable for making productive use of soils, involving the use of brackish water; manuring should be experienced. Keeping in view the possibility of using brackish water, present study was planned to evaluate the effectiveness of organic amendment (Farm manure) in rectifying the deleterious effects of brackish water.

MATERIALS AND METHODS

Field experiments were conducted for two years at Research Farm, College of Agriculture, Dera Ghazi Khan sub campus of University of Agriculture, Faisalabad to study the effect of farm manure (FM) on soil pH, $EC_{1:5}$, SAR, NPK and organic carbon under Mungbean-wheat cropping system using brackish water for irrigation during 2009-2011. In the area where this experiment was conducted, most of the soil is coarse textured which is brought under cultivation for the first time having poor fertility status. The underground water is brackish. This experiment was conducted with the aim to use marginal quality water (brackish water) and barren land (sandy soil) by utilizing easily and less costly available resources (farm manure). The results of this study will provide useful information to the poor farmers so that they can get maximum output with minimum inputs.

Experiments were laid out in Randomized Complete Block Design with four replications. Crops were grown up to maturity. Soil samples were collected from 0-15, 15-30, 30-45, 45-60, 60-90 and 90-120 cm soil depth before sowing (Table 1) and at each crop harvest and were analyzed for different soil parameters mentioned above. Mungbean cultivar AZRI-2006 was sown in the plots having net size of 3 m x 6 m with drill by maintaining row to row distance of 30 cm and plant to plant distance of 7 cm. Mungbean was sown during first week of July 2009 and last week of May 2010, respectively and harvested during September, 2009 and August, 2010 respectively. Farm manure was incorporated into soil at the time of sowing crop as per treatments (0, 10, 20 and 30 Mg ha^{-1}). Farm manure contained 1.32 % N (Kjeldhal method for N; Bremner and Mulvancy, 1982), 0.19 % P (Olsen method; Watanabe and Olsen, 1965) 1.46 % K (flame photometer; Method 11a, Salinity Lab. staff, 1954), 49 % organic matter (Moodie *et al.*, 1959) and 48 % moisture (Hesse, 1971). Recommended doses of fertilizers were used after taking into account the nutrients supplied by FM**.** Brackish water (EC 5.85 dSm^{-1}, pH 8.02, TSS 58.5 me L^{-1}, SAR 8.29 $mmol_c$ L^{-1}) was used as and when required during whole season of crop growth.

Wheat cultivar Fareed-2006 was sown by hand drill in plots having net size 3 m x 6 m (after Mungbean experiment) at row to row distance of 25 cm. Seed rate was used 135 kg ha^{-1}. Crop was sown on last week of November, 2009 and first week of December, 2010 respectively. After crop establishment thinning was done and plant to plant distance was kept 10 cm. Nitrogen, P_2O_5 and K_2O were applied @ 158: 114: 62 kg ha^{-1} by using their sources as Urea, Diamonium Phosphate (DAP) and Sulphate of Potash (SOP). Whole of the Phosphorus and Potassium and 1/3rd of Nitrogen were applied at sowing. Remaining Nitrogen was applied at first and 2nd irrigation respectively. Harvesting was done during last week of March 2010 and first week of April 2011. Manure was incorporated into soil at the time of sowing as per treatment (0, 10, 20 and 30 Mg ha^{-1}). Farm manure contained 1.23 % N, 0.37 % P, 1.14 % K, 34.49 % organic matter and 63 % moisture. Brackish water (EC 5.85 dSm^{-1}, pH 8.02, TSS 58.5 me L^{-1}, SAR 8.29 $mmol_c$ L^{-1}) was used as and when required during whole season of crop growth.

Soil analysis:

***Electrical conductivity of soil suspension*:** For determining $EC_{1:5}$, suspension of 1:5 was made by taking 20 g soil with distilled water to make its volume 100 ml. Electrical conductivity was noted with digital Jenway conductivity meter (Method 3a and 4b, U.S. Salinity Lab. Staff, 1954).

***Sodium adsorption ratio ($mmol_c$ $L^{-1})^{1/2}$*:** Sodium adsorption ratio (SAR) was calculated by following equation using concentrations of the Na^+, Ca^{2+} and Mg^{2+} in $mmol_c$ L^{-1}.

$$SAR = \frac{Na^+}{[Ca^{2+} + Mg^{2+}/2]^{1/2}}$$

***pH of soil suspension*:** The pH of soil was determined by making soil suspension of 1:5. For this, about 10 g soil was saturated with distilled water to make its volume 50 mL. The suspension was allowed to stand for one hour and pH was recorded (Method 21a, U.S. Salinity Lab. Staff, 1954) by using pH meter.

Table 1. Physical and chemical properties of experimental soil before experimentation

Characteristics	**Unit**	**Soil depth (cm)**					
Physical Analysis		**0-15**	**15-30**	**30-45**	**45-60**	**60-90**	**90-120**
Sand	%	78.98	74.35	68.54	65.38	64.92	63.54
Clay	%	11.65	13.67	17.72	18.17	16.14	15.82
Silt	%	9.35	11.44	14.47	17.08	18.89	19.16
Texture class		Loamy sand	Loamy sand	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Chemical Analysis							
pH	-	8.53	8.61	8.68	8.72	8.78	8.81
EC	dSm^{-1}	2.83	2.15	2.35	2.32	1.89	1.35
Organic carbon	g kg^{-1}	0.96	0.78	0.36	0.24	0.00	0.00
Total Nitrogen(N)	g kg^{-1}	0.145	0.135	0.116	0.105	0.00	0.00
Available Phosphorous(P)	mg kg^{-1}	5.09	4.13	3.59	3.32	2.86	2.49
Extractable Potassium(K)	mg kg^{-1}	119	101	91.0	74.4	58.2	49.5

Table 2. Meteorological data of the experimental site

Month	Rainfall (mm)	Relative Humidity (%)	Dew point	Temperature (°C)		
				Max	Min	Average
Year 2009						
June	None	41.5	17.0	45.0	25.3	35.0
July	28.5	45.6	19.0	41.0	28.0	34.5
August	54.6	72.4	28.0	38.1	30.1	34.1
September	14.8	60.6	23.0	34.2	23.1	28.5
October	None	51.3	17.0	31.0	21.2	26.1
November	3.8	39.6	12.0	25.1	17.1	21.2
December	5.9	54.8	7.0	20.2	8.0	14.2
Year 2010						
January	2.8	65.4	2.8	16.2	5.0	10.5
February	1.1	72.1	7.9	20.1	11.1	15.5
March	85.4	51.3	16.0	26.1	19.2	22.5
April	2.2	22.9	9.6	40.0	24.2	32.0
May	None	21.1	8.2	45.1	27.1	36.0
June	-	39.5	19.0	43.0	28.0	35.5
July	25.0	56.3	21.0	42.1	29.0	35.5
August	249.4	75.1	27.0	37.1	29.1	33.0
September		58.1	21.0	35.0	22.2	28.5
October	None	50.2	19.1	32.0	20.1	26.1
November	-	38.7	11.4	29.0	14.2	16.5
December	6.4	52.2	5.2	22.0	5.0	13.5
Year 2011						
January	2.8	68.2	3.6	18.0	4.5	11.5
February	11.4	70.2	8.5	22.0	9.0	15.5
March	6.4	66.4	11.1	23.5	11.5	17.5
April	None	23.8	8.80	38.0	22.0	30.0

***Total Nitrogen (g kg^{-1})*:** Kjeldhal method was used for digestion of samples, for that 1 g of soil was added in 15 mL of concentrated H_2SO_4 and 5 g of digestion mixture that contain (K_2SO_4: $CuSO_4$: Se, 100: 10: 1). From this digested material, 10 mL of the aliquot was taken and distillation was carried out with help of micro Kjeldhal's apparatus. The ammonia gas evolved was absorbed in a receiver containing 4 % boric acid solution and mixed indicator (Bromocresol green and methyl red). After distillation process the contents of receiver were titrated against 0.01 N H_2SO_4 (Bremner and Mulvancy, 1982) and N was calculated by following formula:

$$\%N = \frac{(V - B) \times N \times R \times 14.01}{Wt. \times 1000} \times 100$$

Where as

V = Volume of 0.01 N H_2SO_4 titrated for the sample (mL)

B = Digested blank titration volume (mL)

N = Normality of H_2SO_4 solution

14.01 = Atomic weight of nitrogen

R = Ratio between total volume of the digest and digest Volume used for distillation

Wt = Weight of air-dry soil (g)

***Available phosphorus (mg kg^{-1})*:** Olsen method was used to determine available phosphorus in which 5 g soil was extracted with 0.5 M $NaHCO_3$ solution and then its pH was adjusted to pH 8.5. Then five mL of clear filtrate was taken in 100 mL volumetric flask in which 5 mL color developing reagent (ascorbic acid) was also added. Volume was made up to the mark. Reading was noted on spectrophotometer using 560 nm wavelengths with the help of standard curve after calibrating with standard of P (Watanabe and Olsen, 1965).

***Extractable potassium (g kg^{-1})*:** Extraction was done with help of ammonium acetate (1 N of pH 7.0) solution and potassium was determined by using Jenway PFP-7 Flame photometer (Method 1la, Salinity lab. staff, 1954).

***Organic carbon (g kg^{-1})*:** Organic carbon was determined by the procedure devised by Moodie *et al.* (1959) in which one gram of soil sample was mixed with 10 mL 1N Potassium dichromate solution and 20 mL concentrated H_2SO_4 (commercial). Then 150mL of distilled water and 25 mL of 0.5N $FeSO_4$ solution were added and the excess was titrated with 0.1N Potassium permanganate solution to pink end point. A blank was also run similarly. Organic Carbon was calculated by following formula.

$$\%Oxidizable\ organic\ carbon = \frac{(Vblank - Vsample) \times 0.3 \times M}{Wt.of\ soil\ (g)} \times 100$$

$$\%Total\ organic\ carbon\left(\frac{w}{w}\right) = 1.33 \times \%Oxidizable\ organic\ carbon$$

Where as

M = Molarity of ferrous sulfate solution; V_{blank} = Volume of ferrous ammonium sulfate solution used for blank

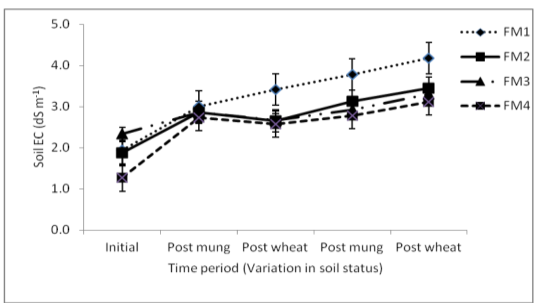
V_{sample} = Volume of sample

***Statistical analysis*:** Data were analyzed by using MSTATC a microcomputer statistical software package (Anonymous, 1986). Treatment means were compared at 5% probability level by using Least Significant Difference (LSD) test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

***Electrical conductivity*:** The electrical conductivity ($EC_{1:5}$) of soil is an indicative of salinity hazard of applied water. Farm manure has significant effect on soil $EC_{1:5}$ under Mungbean-wheat cropping system. Highest $EC_{1:5}$ (3.3 dS m^{-1}) was observed in control (FM_1) where only brackish water was applied and gradually lowered down by 2.8, 2.8 and 2.5 dS m^{-1} by increasing manure i.e. 10, 20 and 30 Mg ha^{-1} respectively (Fig. 1). Whereas highest increase in $EC_{1:5}$, i.e. 146.0, 115.0, 83.8 and 41.2 % was observed in FM_4 followed by FM_1, FM_2 and FM_3.

(a)



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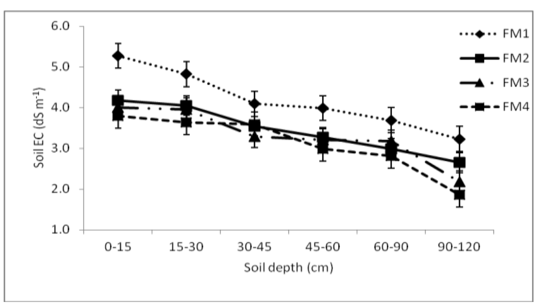


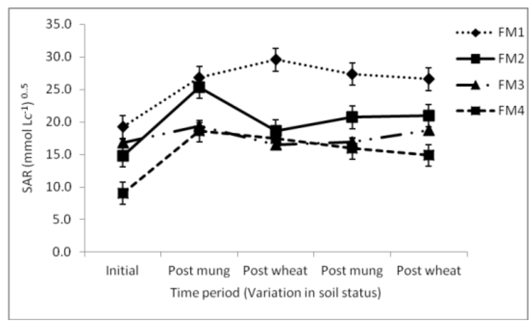
(FM_1- Control (no farm manure); FM_2-Farm manure @10 $Mgha^{-1}$; FM_3- Farm manure @20 $Mgha^{-1}$; FM_4- Farm manure @30 $Mgha^{-1}$)

Figure 1. Effect of farm manure on EC (dSm^{-1}) of soil while using brackish water for irrigation (Average of two years data); (a) crop wise position (b) soil depth wise position

Highest $EC_{1:5}$ were observed at upper soil depth 3.67 dS m^{-1} (0-15 cm) as compared to lower soil depth 90-120 cm (1.98 dS m^{-1}) in Mungbean-wheat cropping pattern. There was relatively less decrease in EC after wheat which appears mainly because of the time lapse between the last irrigation and time of soil sampling during the hot months of April and May every year. High evaporation during this period promotes salt accumulation in surface layers through capillary action (Armstrong *et al.*, 1996). Similar experiences have been reported by Mahmood *et al.* (2001) and Murtaza *et al.* (2006) and Ghafoor *et al.* (2008, 2012) in Pakistan and by Rao *et al.* (1994) in India. Where organic amendments like farm manure were applied $EC_{1:5}$ were increased but still below the critical limit. This was possibly due to the reason that organic amendments contained high concentration of ions like Ca^{2+}, K^+ which mitigate the ill effects of brackish water. Moreover these amendments helped to maintain the hydraulic conductivity, resulting in leaching of salts. The increase in ECe with the use of brackish irrigation water was also reported by Rhoades (1993) and Ghafoor *et al.* (1997).

***Sodium adsorption ratio (SAR) of soil (m mol_c L^{-1})$^{1/2}$*:** It was clearly observed from the data (Fig. 2) that farm manure has significant effect on SAR of soil. As farm manure level

(a)



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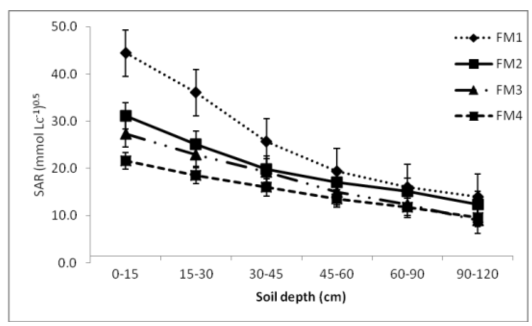


(FM_1- Control (no farm manure); FM_2-Farm manure @10 $Mgha^{-1}$; FM_3- Farm manure @20 $Mgha^{-1}$; FM_4- Farm manure @30 $Mgha^{-1}$)

Figure 2. Effect of farm manure on SAR ($mmol_c$ L^{-1})$^{0.5}$ of soil while using brackish water for irrigation (Average of two years data); (a) crop wise position (b) soil depth wise position

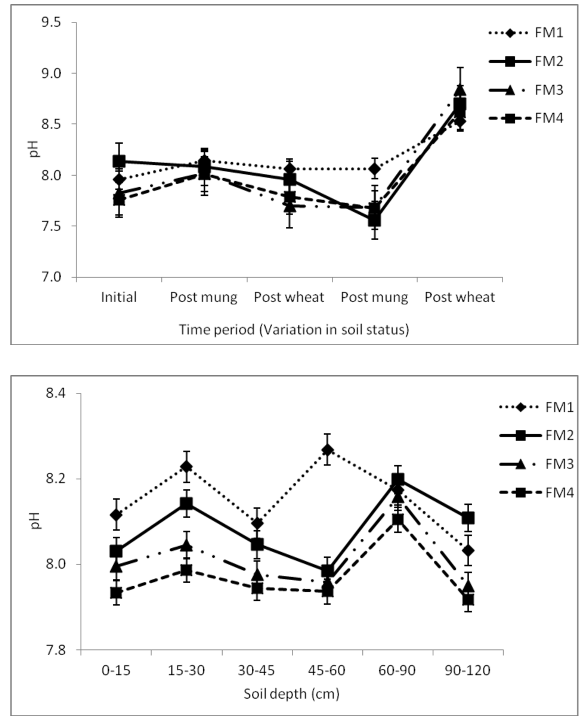
increased SAR goes on decreasing. Maximum value of SAR was observed in FM_1, i.e. 25.7 (m mol_c $L^{-1})^{1/2}$ where no farm manure was added only brackish water was applied. Whereas the minimum value, i.e. 13.9 (m mol_c $L^{-1})^{1/2}$ was observed in FM_4 in which maximum dose of farm manure was applied. SAR value in other levels of farm manure like FM_2 and FM_3 was 19.3 and 17.7 (m mol_c $L^{-1})^{1/2}$, respectively. Maximum increase, i.e. 56.8 % was observed in FM_4 followed by 44.2 % due to FM_1, 41.8 % was observed in FM_2 and 11.5 % due to FM_3 as compare to original soil in Mungbean-wheat rotation

As for as soil depth was concerned due to farm manure application (Fig. 2), maximum value of SAR, i.e. 29.4 (m mol_c $L^{-1})^{1/2}$ was observed at 0-15 cm soil depth followed by 25.8, 20.7, 18.0, 15.8 and 11.1 (m mol_c $L^{-1})^{1/2}$ at 15-30, 30-45, 45-60, 60-90 and 90-120 cm soil depth.

***pH of the soil*:** Farm manure application have non significant effect on soil pH (Fig. 3). Highest average value of pH (8.20) was observed in control and lowest (8.02) in 30 $Mgha^{-1}$. Maximum increase in pH was observed in case of FM_3 i.e, 10.3 % followed by 7.61, 7.59 and 4.68 % in FM_2, FM_4 and FM_1 respectively as compared to barren soil. Variable pH records were observed with soil depths. In case of various soil depths highest pH (8.16) was found at 60-90 followed by 15-30, 45-60, 0-15, 30-45 and 90-120 cm soil depth (8.10, 8.04, 8.02, 8.02 and 8.00) respectively. Our results coincide with the study of Murtaza *et al.* (2006). Previous studies suggest that as the salt concentration in soil solution increases Ca^{2+} precipitates as $CaCO_3$ and, to a lesser extent as $CaSO_4$, leaving preponderance of Na^+ in soil solution that subsequently induces Na^+ adsorption on the cation exchange sites (Suarez, 1981) and increases soil pH. This phenomenon was evident when changes in pH of different soil depths were evaluated as a consequence of accumulation of Na^+ through its movement from upper depths. The data on soil reaction indicated that there was no appreciable change in soil pH by the use of brackish water (Abro *et al.*, 2007). Application of organic matter lowered the soil pH from original values particularly in lower soil layers because organic amendments on their decomposition release CO_2 and organic acids which in turn decrease the soil pH (Hussain *et al.,* 1994). A slight increase has been observed in soil pH after the harvest of wheat while the same decline occurred after Mungbean. The possible reason for this increase was the high number of irrigations with brackish water given with little leaching taking place in wheat crop. However the pH somewhat reduced after the harvest of Mungbean crop. Singh *et al.* (2002) found that use of brackish water increased pH considerably even up to the 90 cm soil depth.

(a)

(b)



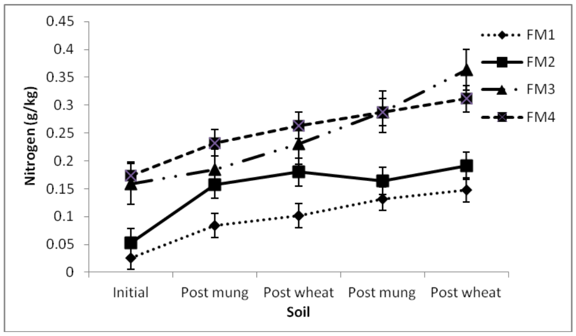
(FM_1- Control (no farm manure); FM_2-Farm manure @10 $Mgha^{-1}$; FM_3- Farm manure @20 $Mgha^{-1}$; FM_4- Farm manure @30 $Mgha^{-1}$)

Figure 3. Effect of farm manure on soil pH while using brackish water for irrigation (Average of two years data); (a) crop wise position (b) soil depth wise position

***Soil nitrogen contents*:** The effect of farm manure was significant during both years in Mungbean-wheat crop rotation. In Mungbean crop 2009 and 2010, maximum soil N was recorded in case of farm manure application @30 Mg ha^{-1} during both years (0.232 and 0.282 g kg^{-1}, respectively; Fig.4). Similar trend was found by Ibrahim (2009). During first year of Mungbean crop, farm manure of 30 Mg ha^{-1} recorded the highest (0.232 g kg^{-1}) and the lowest (0.084 g kg^{-1}) with no farm manure. The pattern was changed during the second year and the maximum soil N (0.288 g kg^{-1}) was recorded in both FM_3 and FM_4 and the lowest (0.132 g kg^{-1}) in FM_1. The greatest soil N concentrations (0.364 g kg^{-1}) were found in FM_3 (20 Mg ha^{-1}) in wheat 2010-11 crop and lowest (0.026 g kg^{-1}) in initial soil in FM_1 treatment. Similar trend was found in case of wheat crop, highest N (0.264 g kg^{-1}) was found in FM_4 and the lowest (0.102 g kg^{-1}) in FM_1. Our results coincide with the finding of Iqbal *et al.* (2005a & b). During second year, soil N was the maximum in FM_3 followed by FM_4, FM_2, and FM_1. Whereas maximum increase was observed in FM_3, i.e. 117 % followed by 100, 99 and 69 % in FM_2, FM_4 and FM_1 as compared to original soil. As for as depth of soil is concerned maximum value of

Soil N was observed at 0-15 cm (0.251 g kg^{-1}) and lowest (0.005 g kg^{-1}) at 90-120 cm soil depth during both of years. Seiter and Horwath (2004) stated that organic matter improves nutrient availability.

(a)



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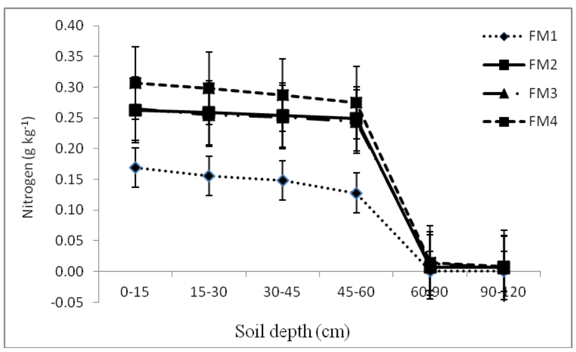
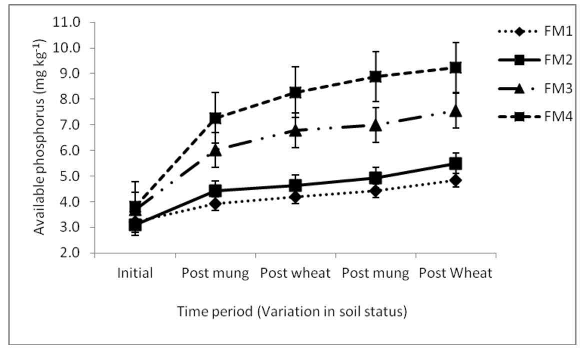


(FM_1- Control (no farm manure); FM_2-Farm manure @10 $Mgha^{-1}$; FM_3- Farm manure @20 $Mgha^{-1}$; FM_4- Farm manure @30 $Mgha^{-1}$)

Figure 4. Effect of farm manure on soil nitrogen (g kg^{-1}) while using brackish water for irrigation (Average of two years data); (a) crop wise position (b) soil depth wise position

***Soil available phosphorous (mg kg^{-1})*:** Available Phosphorus was significantly affected by application of farm manure. Highest value of available P was observed in FM_4 (8.4 mg kg^{-1}) and lowest in FM_1 (4.3 mg kg^{-1}; Fig. 5). Maximum increase, i.e. 27.1 % was observed in FM_4 followed by FM_3, FM_2 and FM_1, i.e. 25.7, 24.6 and 23.3 %, respectively. In case of soil depth in Mungbean-wheat rotation, highest mean value (9.1 mg kg^{-1}) was observed at 0-15 cm followed by 15-30, 30-45, 45-60, 60-90 and 90-120 cm soil depth (8.1,7.2, 6.5, 5.2 and 4.5 mg kg^{-1}). Selles *et al.* (1999) reported continuous increase in soil P concentration with continuous manure application and cropping with varying Olsen soil P from year to year. Stevenson (1986) concluded increased P concentration with addition of organic matter because the organic materials are the major sources of soil N and soil P.

(a)



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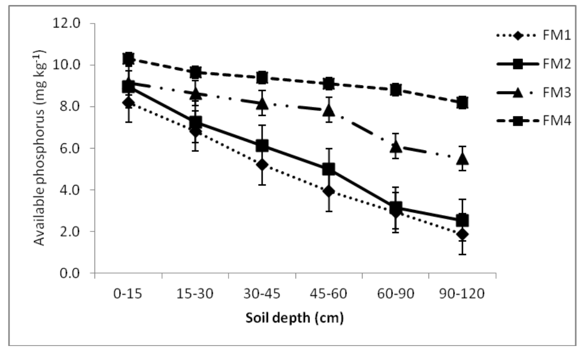


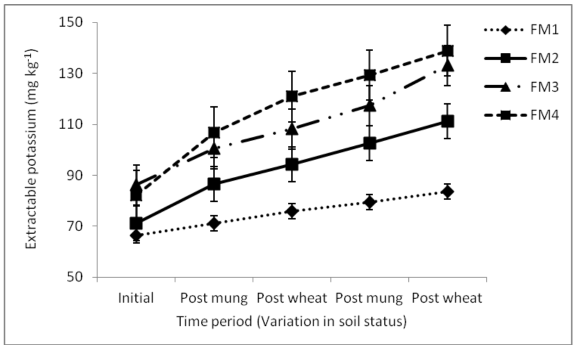
(FM_1- Control (no farm manure); FM_2-Farm manure @10 $Mgha^{-1}$; FM_3- Farm manure @20 $Mgha^{-1}$; FM_4- Farm manure @30 $Mgha^{-1}$)

Figure 5. Effect of farm manure on soil available phosphorous (mg kg^{-1}) while using brackish water for irrigation (Average of two years data); (a) crop wise position (b) soil depth wise position

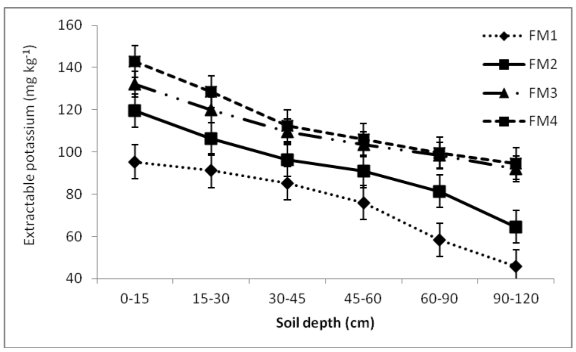
***Soil potassium (mg kg^{-1})*:** Farm manure significantly affected the extractable Potassium in the soil. Potassium contents were gradually increased with increase in farm manure application after two years Mungbean-wheat cropping system (Fig. 6). Highest Potassium contents were recorded with application of 30 $Mgha^{-1}$ followed by 20 $Mgha^{-1}$. However, minimum extractable Potassium was recorded with control (no farm manure application). Maximum increase, i.e. 66, 54, 56 % and minimum, i.e. 24 % was observed in FM_4, FM_3, FM_2 and FM_1, respectively.

Soil depth profile indicated that extractable Potassium gradually decreased with lower depth. The trend varied with the farm manure application rate as it enriched the soil profile with higher farm manure application. Addition of farm manure to the soil increases the availability of nutrients to plants (Sharif *et al.*, 1974). Increase in nutrient availability was due to CO_2 production (Swarup, 1992) which reduced the redox potential of soil and pHs. Increased accessibility of nutrients results in improvement of yield and mineral uptake of crops. Khan *et al.* (2010) reported that at harvest of crop, maximum Potassium contents in soil were recorded with FM (40 Mg ha^{-1}) followed by FM (20 Mg ha^{-1}) against the least value was observed in treatment where recommended K was applied.

(a)



(b)

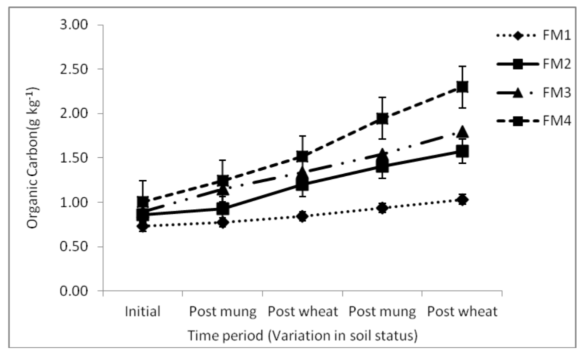


(FM_1- Control (no farm manure); FM_2-Farm manure @10 $Mgha^{-1}$; FM_3- Farm manure @20 $Mgha^{-1}$; FM_4- Farm manure @30 $Mgha^{-1}$)

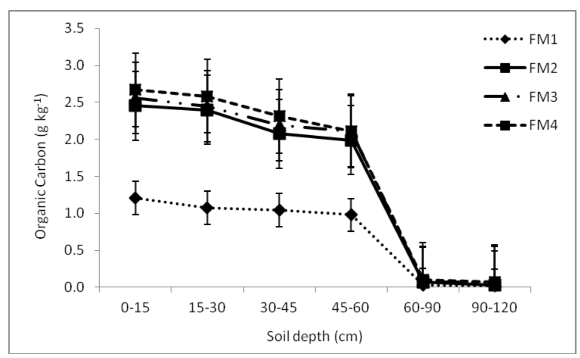
Figure 6. Effect of farm manure on soil extractable potassium (mg kg^{-1}) while using brackish water for irrigation (Average of two years data); (a) crop wise position (b) soil depth wise position

Soil organic carbon**:** Farm manure application also has significant effect on soil organic carbon (SOC; Fig. 7). Highest value of SOC obtained in FM_4, followed by FM_3, FM_2, and FM_1, i.e. 1.75, 1.46, 1.28 and 0.90 g kg^{-1}, respectively. The highest increase was found in FM_4, i.e. 128 % followed by FM_3, FM_2 and FM_1 about 101, 84.3 and 41.1 %, respectively. In case of Mungbean-wheat rotation highest values of SOC were obtained 2.02 g kg^{-1} at 0-15 cm followed by 1.92, 1.71, 1.61, 0.07 and 0.05 g kg^{-1} at 15-30, 30-45, 45-60, 60-90 and 90-120 cm soil depths respectively as compared to initial soil. Similarly, Ibrahim (2009) found that at 0-15 cm (depth), the SOC concentration was greater (0.113 Mg ha^{-1}) MT where FM was applied at 15 Mg ha^{-1}. Whereas at 15-30 cm soil depth, SOC contents was highest (0.127 Mg ha^{-1}) in case of CT with farm manure at 15 Mg ha^{-1} and the least was again recorded under DT at 15 Mg ha^{-1} farm manure. At lower soil depths (30-50 cm), the minimum tillage with FM at 15 Mg ha^{-1} was the highest. The depths (50-75 and 75-100 cm) recorded the highest SOC contents (0.112 and 0.117 Mg ha^{-1}) DT at farm manure of 15 Mg ha^{-1} From these results it was suggested that farm manure application increased the SOC concentration more at the upper soil surface as compared to lower soil layers. Maximum increase was observed at 45-60 cm soil depth about (431.5 %) followed by 418.1, 395.0, 357.1, 266.7 and 259.4 % at 45-60, 15-30, 30-45, 90-120, 60-90 and 0-15 cm respectively as compared to initial soil. Highest value of OC obtained in FM_4, followed by FM_3, FM_2, and FM_1 about 1.63, 1.55, 1.39 and 0.35 g kg^{-1} respectively. Highest increase was found in FM_1 57.8 % followed by FM_2, FM_3 and FM_4 about 42.2, 33.6 and 22.7 % respectively.

(a)



(b)



(FM_1- Control (no farm manure); FM_2-Farm manure @10 $Mgha^{-1}$; FM_3- Farm manure @20 $Mgha^{-1}$; FM_4- Farm manure @30 $Mgha^{-1}$)

Figure 7. Effect of farm manure on organic carbon content (g kg^{-1}) of soil while using brackish water for irrigation (Average of two years data); (a) crop wise position (b) soil depth wise position

Conclusions**:** Farm manure application rectified the deleterious effects of brackish water as it reduced EC, SAR and pH of the soil, while it improved the soil fertility status of the soil by enhancing nitrogen, available phosphorus and extractable potassium.

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