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**Original Article**

# Effect of different amendments on soil chemical characteristics, grain yield and elemental content of wheat plants grown on salt-affected soil irrigated with low quality water

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**Abstract** A field trial experiment was carried out during the winter season of 2010/2011 to investigate the effect of different amendments i.e. gypsum, citric acid, farmyard manure, compost and the combination among them on heavy clay salt-affected soil irrigated with wastewater and also, their effects on wheat production. The experiment was conducted in north El-Hosinia plain, Sharkia Governorate that is irrigated with Bahr El-Baqar drain water. Obtained results showed that the chemical characteristics of the studied soil i.e. pH, $EC_e$, soluble ions, SAR and ESP were improved by application of the amendments under irrigation with Bahr El-Baqar drain water. The better effect was shown by using 50%gypsum + 50%FYM. Regarding to DTPA-extractable heavy metals i.e. Fe, Mn, Zn, Cu, Ni and Cd in soil, the applied amendments increased the downward movement of heavy metals as indicated by increasing their concentrations with increasing soil depth which means reducing such heavy metals concentration in plant root zone. Gypsum amendment was superior in reducing the chemically available heavy metals in the studied soil.

The grain yield, weight of 1000 grains and NPK concentration of wheat plants were significantly increased due to the application of these amendments compared to the control, especially for 50%gypsum + 50%FYM treatment. In addition, heavy metals concentrations under investigation in root parts of wheat plants were higher than shoot parts. It is worthy to mention that the heavy metals concentrations in grains were the lowest ones and within the normal range except for

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Cu and Ni. Regarding to whole plant parts the heavy metals concentrations were reduced by application of gypsum to the used soil.



## Introduction

Salt affected soils occupy wide regions scattered all over the world [about 954 millions of hectares, Szaboles (1989)]. In meantime, salt stress is one of the most serious limiting factors for crop growth and production in arid and semi-arid regions. In Egypt, the north regions, particularly of northeastern Delta, are mainly saline or saline-sodic soils with heavy texture. El-Hosinia plain is one of the new reclaimed saline-sodic soils after drying a large area from El-Manzala Lake. This area is not only heavy texture with inherited high saline-sodic characteristics, but also the farmers are using low quality irrigation water from Bahr El-Baqar drain; which is a mixture of industrial, sewage and agricultural wastewaters. Thus, high amounts of potential toxic substances including heavy metals could be transported. Galavi et al. (2010) studied the effects of treated municipal wastewater on soil chemical properties. The results indicated that irrigation with wastewater lead to a significant increase in N, P, K, Ca, Na, Mg, SAR, EC and OC%. Mojiri et al. (2011) studied the effects of urban wastewater treatments on chemical properties of saline and alkaline soils which caused an increase in EC, OM, total N, CEC, Na, Mn and Ni but soil pH was decreased. However, extractable Cd and Cr concentrations were not affected.

Meanwhile, the addition of organic matter in conjunction with gypsum has been found to reduce the adverse soil properties associated with sodic soils (Wong et al. 2009). Abou El-Defan et al. (2005) studied the effect of farmyard manure, gypsum and mix of them on some soil characteristics irrigated with drainage water. They found that both EC and ESP values significantly decreased with different treatments, especially with application of farmyard manure mixed with gypsum. Jones and Kochian (1996) reported that citrate increased the dissolution rates of two fold in comparison to experiments performed without citrate. Also, they found that citrate not only complexed Al in solution but also complexed Al directly from the mineral phase.

In meantime, wheat is the first major and staple food crop in Egypt. Over 30% of the caloric intake comes from wheat flour products. However, the total production of wheat is still so far from the country requirements by about 40–50%, which covered through importation. El-Banna et al. (2004) found that treating the soil with gypsum + FYM as well as the potassium fertilization; insure a better environmental condition for wheat plants to grow healthy. Such treatment makes it easier to use saline water or drainage water for irrigating plants and solving the problem of shortage in fresh water resources. In addition, Cu uptake in nutrient solution culture by lettuce and Cu toxicity in mungbean was reduced as Ca increased in the solution (Barker and Pilbeam, 2007). Najeeb et al. (2009) studied the effect of citric acid on Mn phytoextraction and Juncus effusus plant growth. They stated that citric acid caused a significant increase in Mn accumulation which was obvious from the microscopic visualization of mesophyll cells.

Thus, the aim of this study is to investigate the effect of certain amendments on some chemical characteristics of salt-affected soil of El-Hosinia plain irrigated with wastewater of Bahr El-Baqar drain and also, their effects on wheat production.

## Materials and methods

A field trial experiment was carried out in north El-Hosinia plain, Sharkia Governorate, clay soil (Vertic Torrifluvents). Some physical and chemical characteristics of the studied soil are given in Table 1. Such soil was irrigated for many years with water of Bahr El-Baqar drain; some chemical characteristics of the used water for irrigation are shown in Table 1. Nine treatments were applied as follows:

1. Control (without any amendments).
2. Gypsum (G), at a rate of 3.48 g $kg^{-1}$ soil (equal to 4.64 ton/fed./20 cm). The amounts of gypsum were added to reduce the SAR of soil to 8 or ESP to 10% as an acceptable level according to Richards (1954).
3. Citric acid (Ci), at a rate of 0.98 g $kg^{-1}$ soil (equal to 1.31 ton/fed./20 cm), according to Ahmed Shaimaa (2008).
4. Farmyard manure (FYM), at a rate of 1% OM (equal to 51.3 ton/fed./20 cm), according to Paulose et al. (2007).
5. Compost (Com), at a rate of 1% OM (equal to 71.7 ton/fed./20 cm), according to Clemente et al. (2006).
6. A mixture of 50%G + 50%FYM.
7. A mixture of 50%G + 50%Com.
8. A mixture of 50%Ci + 50%FYM.
9. A mixture of 50%Ci + 50%Com.

The amendments were applied to soil and mixed thoroughly with the upper 20 cm layer. The used amendments were subjected to some chemical analyses as shown in Table 2. Bahr El-Baqar drain water was used for irrigation to bring the soil to field capacity and the soil was left in the air temperature (23.4 ± 2.5 °C) for 15 days before cultivation of plant for equilibrium. Each treatment was replicated three times in a completely randomized design.

Wheat grains (Triticum aestivum, c.v Sakha 93) were cultivated (in 15 November 2010), while, the recommended dose of single superphosphate was added at a rate of 15 kg $P_2O_5$/fed., before plant cultivation. Also, nitrogen fertilizer was added in the form of urea at a rate of 75 kg N/fed., in three batches after plant cultivation. At the end of harvest, 155 days from sowing, the plant samples were collected, prepared and kept for NPK and heavy metals determination.

Soil samples were collected after plant harvest at depth of 0–15, 15–30 and 30–60 cm. The collected samples were air dried, crushed, sieved through a 2 mm sieve and stored for chemical characteristics determination.

Routine analysis of the tested soil was determined according to the standard methods published by Richards (1954)

**Table 1** Some characteristics of the studied soil (0–20 cm depth), and water used for irrigation.

| Character | Soil | Water | Character | Soil | Water |
|---|---|---|---|---|---|
| Particle size distribution, % | | | SAR | 14.9 | |
| Sand | 40.0 | | ESP, % | 17.2 | |
| Silt | 16.0 | | | | |
| Clay | 44.0 | | | | |
| Texture class | Clay | | Total content of heavy metals, mg $kg^{-1}$ | | Heavy metals content, mg $L^{-1}$ |
| Field capacity, % | 51.5 | | Fe | 44000 | 1.69 |
| $CaCO_3$, % | 6.50 | | Mn | 1010 | 1.10 |
| OC, % | 1.02 | | Zn | 191 | 0.88 |
| OM, % | 1.76 | | Cu | 185 | 0.65 |
| CEC, cmol $kg^{-1}$ | 45.0 | | Ni | 60.2 | 0.31 |
| pH (soil paste) | 7.60 | $pH_w$, 7.20 | Cd | 3.65 | 0.10 |
| $EC_e$, dS $m^{-1}$ | 6.13 | $EC_w$, 3.28 | Chemically available heavy metals, mg $kg^{-1}$ | | |
| Soluble ions, meq $L^{-1}$ | | | Fe | 14.7 | |
| $Ca^{2+}$ | 7.75 | 3.11 | Mn | 41.6 | |
| $Mg^{2+}$ | 9.05 | 6.16 | Zn | 18.8 | |
| $Na^{+}$ | 43.1 | 20.3 | Cu | 7.04 | |
| $K^{+}$ | 1.21 | 0.40 | Ni | 4.96 | |
| $HCO3^{-}$ | 6.60 | 3.20 | Cd | 0.51 | |
| $Cl^{-}$ | 46.6 | 22.5 | | | |
| $SO_4^{2-}$ | 7.91 | 4.27 | | | |

Carbonate ions were not detected.

**Table 2** Some characteristics of the used amendments.

| Characteristics | Gypsum | Citric acid | FYM | Compost |
|---|---|---|---|---|
| pH (1:2.5)[a] | 4.22 | 1.60 | 6.95 | 7.42 |
| EC, dS.$m^{-1}$ (1:2.5)[a] | 2.62 | 8.87 | 10.2 | 13.8 |
| Organic carbon,% | n.d. | 37.7 | 15.1 | 10.8 |
| Organic matter,% | n.d. | 100 | 26.0 | 18.6 |
| C/N ratio | n.d. | n.d. | 11.5 | 11.9 |
| *Total content of macronutrients, %* | | | | |
| Ca | 20.7 | 0.15 | 4.00 | 3.56 |
| Mg | 3.75 | 0.05 | 0.24 | 0.36 |
| N | 0.05 | n.d. | 1.31 | 0.91 |
| P | 0.02 | n.d. | 13.5 | 15.2 |
| K | 0.15 | 0.20 | 1.78 | 1.20 |
| *Total content of heavy metals, mg $kg^{-1}$* | | | | |
| Fe | 81.0 | 3.95 | 960 | 905 |
| Mn | 19.0 | 2.00 | 432 | 297 |
| Zn | 5.30 | 1.30 | 98.3 | 90.0 |
| Cu | 2.80 | 0.70 | 56.2 | 43.1 |
| Ni | 1.10 | 0.10 | 13.1 | 10.7 |
| Cd | 0.49 | 0.05 | 1.63 | 1.06 |
| *Chemically available heavy metals, mg $kg^{-1}$* | | | | |
| Fe | 2.50 | 1.41 | 27.0 | 21.5 |
| Mn | 1.70 | 0.95 | 9.31 | 8.75 |
| Zn | 1.30 | 0.40 | 12.0 | 7.90 |
| Cu | 1.27 | 0.53 | 5.90 | 4.86 |
| Ni | 0.57 | 0.02 | 2.94 | 1.26 |
| Cd | 0.12 | 0.01 | 0.37 | 0.23 |

n.d. = Not detected.
[a] (1:2.5) = Amendment:water ratio.

and Jackson (1958). Chemically available heavy metals were extracted with DTPA solution from soils according to Lindsay and Norvell (1978). Thereafter, heavy metals in the extracts were determined using atomic absorption spectrophotometer (analytik jena, AS 51S).

Total nitrogen in plant was determined by Kjeldahl method (Chapman and Pratt, 1961). Total phosphorus in plant was determined colorimetrically using ascorbic acid method described by Watanabe and Olsen (1965). Total potassium in plant was determined by Flame photometer (Jackson, 1958). Total heavy metals in plant were determined by atomic absorption spectrophotometer (Jackson, 1958).

Data were statistically analyzed using the analysis of variance adopting a SAS software package (SAS Institute, 1996).

## Results and discussion

### *Soil chemical characteristics*

The effects of applied amendments on some chemical characteristics of soil irrigated with Bahr El-Baqar drain water are shown in Table 3. It is clear that application of such amendments decreased soil pH values when compared to the control. The treatment of 50%citric acid + 50%FYM has the highest effect in lowering pH values followed by 50%citric acid + 50%compost. Also, 50%gypsum + 50%FYM and 50%gypsum + 50%compost have moderately values. While, citric acid, FYM, compost and gypsum have the lowest values. In general, subsurface layers (15–60 cm) showed higher values of soil pH compared with the surface one (0–15 cm). Moustafa (2005) found that application of farmyard manure and gypsum reduced pH values in the alkali soil with maximum decrease in the upper layer (0–20 cm). These results could be attributed to the reduced amounts of soluble and exchangeable sodium and increased forms of both soluble and exchangeable calcium due to amendments' applications. Also, the positive effect of organic substances on improving soil chemical properties could be due to release of $CO_2$ during the degradation process

**Table 3** Effect of different amendments on some chemical characteristics of El-Hosinia plain soil irrigated with Bahr El-Baqar drain water after harvesting wheat plants.

| Treatment | Depth | pH | $EC_e$ | Soluble ions, meq $L^{-1}$ | | | | | | | SAR | ESP % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm | (soil paste) | dS $m^{-1}$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | | |
| Control | 0–15 | 7.88 | 6.30 | 7.50 | 9.13 | 45.0 | 1.07 | 7.00 | 47.5 | 8.20 | 15.6 | 17.9 |
| | 15–30 | 7.90 | 6.16 | 6.95 | 8.80 | 42.5 | 1.02 | 6.50 | 45.1 | 7.67 | 15.1 | 17.4 |
| | 30–60 | 7.94 | 5.96 | 6.80 | 8.58 | 41.0 | 0.96 | 6.15 | 43.8 | 7.39 | 14.8 | 17.0 |
| Mean | | 7.91 | 6.14 | 7.08 | 8.84 | 42.8 | 1.02 | 6.55 | 45.5 | 7.75 | 15.2 | 17.4 |
| Gypsum | 0–15 | 7.85 | 4.78 | 14.8 | 13.0 | 18.4 | 1.09 | 9.90 | 21.4 | 16.0 | 4.94 | 5.68 |
| (G) | 15–30 | 7.86 | 4.94 | 15.3 | 13.5 | 19.3 | 1.11 | 10.5 | 22.5 | 16.2 | 5.08 | 5.87 |
| | 30–60 | 7.90 | 5.03 | 15.1 | 13.4 | 20.2 | 1.16 | 10.3 | 23.0 | 16.6 | 5.36 | 6.23 |
| Mean | | 7.87 | 4.92 | 15.1 | 13.3 | 19.3 | 1.12 | 10.2 | 22.3 | 16.3 | 5.13 | 5.93 |
| Citric acid | 0–15 | 7.66 | 5.08 | 9.30 | 10.8 | 28.5 | 1.11 | 11.2 | 30.2 | 8.31 | 8.99 | 10.7 |
| (Ci) | 15–30 | 7.75 | 5.15 | 9.50 | 11.0 | 29.4 | 1.19 | 12.0 | 30.7 | 8.40 | 9.18 | 10.9 |
| | 30–60 | 7.80 | 5.27 | 9.90 | 11.4 | 30.1 | 1.21 | 12.3 | 31.4 | 8.90 | 9.22 | 11.0 |
| Mean | | 7.74 | 5.17 | 9.57 | 11.1 | 29.3 | 1.17 | 11.8 | 30.8 | 8.54 | 9.13 | 10.9 |
| Farmyard manure (FYM) | 0–15 | 7.72 | 4.88 | 11.4 | 11.0 | 24.9 | 1.33 | 13.1 | 25.7 | 9.85 | 7.44 | 8.85 |
| | 15–30 | 7.76 | 5.10 | 10.8 | 11.4 | 27.4 | 1.39 | 12.6 | 28.9 | 9.42 | 8.24 | 9.82 |
| | 30–60 | 7.82 | 5.27 | 11.4 | 12.0 | 27.8 | 1.43 | 14.1 | 29.0 | 9.53 | 8.13 | 9.69 |
| Mean | | 7.77 | 5.08 | 11.2 | 11.5 | 26.7 | 1.38 | 13.3 | 27.9 | 9.60 | 7.93 | 9.45 |
| Compost | 0–15 | 7.75 | 5.02 | 10.2 | 11.3 | 26.4 | 1.29 | 11.2 | 28.4 | 9.60 | 8.06 | 9.61 |
| (Com) | 15–30 | 7.77 | 5.11 | 11.3 | 11.5 | 26.9 | 1.31 | 11.8 | 28.7 | 10.5 | 7.98 | 9.51 |
| | 30–60 | 7.85 | 5.25 | 11.0 | 11.3 | 28.5 | 1.34 | 11.3 | 31.7 | 9.20 | 8.53 | 10.2 |
| Mean | | 7.79 | 5.13 | 10.8 | 11.4 | 27.3 | 1.31 | 11.4 | 29.6 | 9.77 | 8.19 | 9.76 |
| 50%G + 50%FYM | 0–15 | 7.62 | 4.55 | 16.0 | 13.0 | 14.9 | 1.41 | 13.1 | 15.5 | 16.7 | 3.91 | 4.32 |
| | 15–30 | 7.69 | 4.66 | 15.9 | 13.3 | 15.7 | 1.48 | 14.5 | 15.9 | 16.0 | 4.11 | 4.59 |
| | 30–60 | 7.77 | 4.84 | 16.5 | 14.1 | 16.3 | 1.53 | 16.0 | 16.1 | 16.3 | 4.16 | 4.65 |
| Mean | | 7.69 | 4.68 | 16.1 | 13.5 | 15.6 | 1.47 | 14.5 | 15.8 | 16.3 | 4.06 | 4.52 |
| 50%G + 50%Com | 0–15 | 7.64 | 4.63 | 15.5 | 13.0 | 15.1 | 1.35 | 11.7 | 17.1 | 16.2 | 4.00 | 4.43 |
| | 15–30 | 7.73 | 4.87 | 15.8 | 13.5 | 16.5 | 1.42 | 13.8 | 17.1 | 16.3 | 4.31 | 4.85 |
| | 30–60 | 7.79 | 5.14 | 16.2 | 14.5 | 18.0 | 1.43 | 14.9 | 18.4 | 16.8 | 4.59 | 5.23 |
| Mean | | 7.72 | 4.88 | 15.8 | 13.7 | 16.5 | 1.40 | 13.5 | 17.5 | 16.4 | 4.30 | 4.84 |
| 50%Ci + 50%FYM | 0–15 | 7.60 | 4.83 | 13.8 | 12.1 | 20.7 | 1.57 | 14.9 | 22.2 | 11.1 | 5.75 | 6.74 |
| | 15–30 | 7.61 | 4.96 | 14.1 | 12.4 | 21.4 | 1.61 | 15.1 | 22.9 | 11.5 | 5.88 | 6.90 |
| | 30–60 | 7.65 | 5.10 | 14.7 | 13.0 | 21.6 | 1.68 | 15.9 | 23.5 | 11.6 | 5.80 | 6.80 |
| Mean | | 7.62 | 4.96 | 14.2 | 12.5 | 21.2 | 1.62 | 15.3 | 22.9 | 11.4 | 5.81 | 6.81 |
| 50%Ci + 50%Com | 0–15 | 7.60 | 4.95 | 13.3 | 11.6 | 22.3 | 1.55 | 14.0 | 23.3 | 11.5 | 6.32 | 7.46 |
| | 15–30 | 7.68 | 5.06 | 13.9 | 12.1 | 23.0 | 1.59 | 14.6 | 24.8 | 11.2 | 6.38 | 7.54 |
| | 30–60 | 7.72 | 5.16 | 14.4 | 12.5 | 22.8 | 1.70 | 15.1 | 24.4 | 11.9 | 6.22 | 7.33 |
| Mean | | 7.67 | 5.06 | 13.9 | 12.1 | 22.7 | 1.61 | 14.6 | 24.2 | 11.5 | 6.31 | 7.44 |
| $L.S.D_{0.05}$ | | 0.06 | 0.04 | 0.12 | 0.12 | 0.54 | 0.01 | 0.14 | 0.57 | 0.17 | 0.21 | 0.23 |

and thus decreased the precipitation of $Ca^{2+}$ and $CO3^{2-}$ ions in the $CaCO_3$ form (Sekhon and Bejawa, 1993).

In meantime, the obtained data showed that the application of different amendments, under irrigation with drainage water, caused pronounced reductions in the $EC_e$ values as compared to the control. The highest effect in decreasing EC values was obtained by the treatment of 50%gypsum + 50%FYM. Generally, surface layers had lower $EC_e$ values than the subsurface ones. This may be due to increasing leachability of soluble and exchangeable $Na^+$ throughout the soil profile. Beheiry et al. (2005) reported that addition of organic manures decreased soil salinity and they attributed that to improving physical properties of the soil which in turn facilitate the leaching of salts outside from the root zone.

Application of different amendments to the soil, under irrigation with Bahr El-Baqar drain water, caused different effects on soluble cations which could be arranged as follows: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$. The highest values of soluble $Ca^{2+}$ were found with application of the 50%gypsum + 50%FYM followed by 50%gypsum + 50%compost. On the other hand, soluble $Na^+$ significantly decreased but $Mg^{2+}$ increased due to amendments application. Soluble $K^+$ slightly increased as a result of amendments application. Values of soluble cations were lower in soil surface layers than the subsurface ones. This trend went hand by hand with that of $EC_e$ values. The benefit effect could be resulted from presence of excess $Ca^{2+}$ in both organic matter and gypsum amendments as well as citric acid.

As shown in Table 3, application of such amendments to the soil significantly decreased $Cl^-$ ions compared to the control. The treatment of 50%gypsum + 50%FYM caused the highest decreases in $Cl^-$ concentration. On the other hand, $SO_4^{2-}$ and $HCO_3^-$ in the soil paste extract were significantly increased with application of such amendments to the soil,

**Table 4** Effect of different amendments on DTPA-extractable heavy metals of El-Hosinia plain soil irrigated with Bahr El-Baqar drain water after harvesting wheat plants.

| Treatment | Depth (cm) | Fe (mg $kg^{-1}$) | Mn (mg $kg^{-1}$) | Zn (mg $kg^{-1}$) | Cu (mg $kg^{-1}$) | Ni (mg $kg^{-1}$) | Cd (mg $kg^{-1}$) |
|---|---|---|---|---|---|---|---|
| Control | 0–15 | 13.0 | 24.3 | 18.0 | 6.50 | 5.60 | 1.19 |
| | 15–30 | 10.8 | 46.3 | 13.3 | 6.09 | 5.15 | 0.99 |
| | 30–60 | 9.37 | 28.6 | 12.3 | 5.84 | 5.15 | 0.92 |
| Mean | | 11.0 | 33.1 | 14.5 | 6.14 | 5.30 | 1.03 |
| Gypsum | 0–15 | 9.03 | 11.4 | 13.0 | 5.78 | 5.04 | 0.41 |
| (G) | 15–30 | 8.77 | 26.5 | 10.8 | 5.68 | 5.12 | 0.43 |
| | 30–60 | 8.49 | 19.3 | 11.6 | 5.70 | 4.95 | 0.46 |
| Mean | | 8.76 | 19.1 | 11.8 | 5.72 | 5.04 | 0.43 |
| Citric acid | 0–15 | 8.61 | 19.8 | 15.5 | 5.90 | 5.06 | 0.47 |
| (Ci) | 15–30 | 8.82 | 41.7 | 12.2 | 5.99 | 5.14 | 0.48 |
| | 30–60 | 8.93 | 37.5 | 12.8 | 6.41 | 4.98 | 0.55 |
| Mean | | 8.79 | 33.0 | 13.5 | 6.10 | 5.06 | 0.50 |
| Farmyard manure | 0–15 | 8.78 | 19.8 | 15.7 | 6.09 | 5.27 | 0.45 |
| (FYM) | 15–30 | 13.1 | 33.9 | 14.8 | 6.04 | 5.18 | 0.49 |
| | 30–60 | 10.8 | 31.7 | 12.3 | 5.87 | 5.18 | 0.47 |
| Mean | | 10.9 | 28.5 | 14.3 | 6.00 | 5.21 | 0.47 |
| Compost | 0–15 | 10.0 | 18.7 | 15.3 | 6.62 | 5.31 | 0.41 |
| (Com) | 15–30 | 9.64 | 32.1 | 13.1 | 6.25 | 5.15 | 0.41 |
| | 30–60 | 9.96 | 32.2 | 14.0 | 4.67 | 5.17 | 0.49 |
| Mean | | 9.88 | 27.6 | 14.2 | 5.85 | 5.21 | 0.43 |
| 50%G + 50%FYM | 0–15 | 13.7 | 23.8 | 14.8 | 6.40 | 5.40 | 0.55 |
| | 15–30 | 18.6 | 43.4 | 17.0 | 6.89 | 5.54 | 0.66 |
| | 30–60 | 19.0 | 49.9 | 13.7 | 6.73 | 5.63 | 0.68 |
| Mean | | 17.1 | 39.0 | 15.2 | 6.67 | 5.53 | 0.63 |
| 50%G + 50%Com | 0–15 | 14.9 | 21.0 | 14.1 | 6.32 | 5.28 | 0.56 |
| | 15–30 | 17.7 | 42.0 | 17.4 | 6.54 | 5.50 | 0.58 |
| | 30–60 | 12.5 | 51.2 | 13.0 | 6.37 | 5.51 | 0.61 |
| Mean | | 15.1 | 38.1 | 14.8 | 6.41 | 5.43 | 0.58 |
| 50%Ci + 50%FYM | 0–15 | 17.0 | 30.2 | 15.7 | 6.88 | 5.46 | 0.73 |
| | 15–30 | 19.8 | 47.9 | 16.4 | 6.91 | 5.64 | 0.76 |
| | 30–60 | 17.2 | 55.0 | 18.1 | 6.95 | 5.68 | 0.96 |
| Mean | | 18.0 | 44.4 | 16.7 | 6.91 | 5.59 | 0.82 |
| 50%Ci + 50%Com | 0–15 | 15.8 | 25.6 | 13.7 | 6.68 | 5.47 | 0.66 |
| | 15–30 | 20.9 | 43.7 | 15.4 | 6.94 | 5.52 | 0.71 |
| | 30–60 | 16.2 | 58.4 | 17.8 | 6.99 | 5.64 | 0.81 |
| Mean | | 17.7 | 42.6 | 15.6 | 6.87 | 5.55 | 0.73 |
| $L.S.D_{0.05}$ | | 0.15 | 0.31 | 0.11 | 0.06 | 0.05 | 0.06 |

as have been similarly reported by Ahmed Shaimaa (2008). Soluble anions concentration showed similar trend to $EC_e$ values as they increased with increasing soil depth.

The relatively higher mobility and leachability of $Na^+$ from soil as compared with $Ca^{2+}$ and $Mg^{2+}$ leads to lower values of SAR, with the highest effect by 50%gypsum + 50%FYM. This could be due to its high content of Ca, compared to gypsum or FYM alone. Obviously, SAR values increased with increasing soil depth. Raza et al. (2001) found that the gypsum application by broadcasting reduced the SAR of soil by 59% at 0–30 cm depth and 8% at 30–60 cm depth.

Values of ESP were markedly decreased with using such amendments, especially 50%gypsum + 50%FYM. The benefit effect of 50%gypsum + 50%FYM treatment could be attributed to presence of relatively high amounts of $Ca^{2+}$ ion as previously mentioned. In general, ESP values increased with increasing soil depth with similar trend to $EC_e$ and SAR. The present findings agree with that obtained by Moustafa (2005) who found that the application of gypsum, farmyard manure and gypsum + farmyard manure significantly decreased the exchangeable sodium with the maximum value for gypsum + farmyard manure treatment.

### *DTPA-extractable heavy metals in soil*

The effect of different amendments on the availability of heavy metals in the soil is presented in Table 4. Data show a positive effect on the amount of chemically available Fe, Mn, Zn, Cu, Ni and Cd due to application of 50%citric acid + 50%FYM followed by 50%citric acid + 50%compost, 50%gypsum + 50%FYM and 50%gypsum + 50%compost amendments to the soil. This may be due to the beneficial role of organic substances on physico-chemical properties of soil such as inducing chelating agents during organic substances

**Table 5** Grain yield, weight of 1000 grains, NPK and heavy metals concentrations of wheat plants cultivated in El-Hosinia plain soil as affected by different amendments under irrigation with Bahr El-Baqar drain water.

| Treatment | Grain yield ($g/m^2$) | Weight of 1000 grains (g) | Part of plant | N (%) | P (%) | K (%) | Fe ($mg\ kg^{-1}$) | Mn ($mg\ kg^{-1}$) | Zn ($mg\ kg^{-1}$) | Cu ($mg\ kg^{-1}$) | Ni ($mg\ kg^{-1}$) | Cd ($mg\ kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | | | | 0.14 | 0.14 | 0.54 | 1865 | 118 | 98.8 | 71.7 | 38.6 | 10.7 |
| Control | | | | 0.14 | 0.14 | 0.54 | 1865 | 118 | 98.8 | 71.7 | 38.6 | 10.7 |
| | | | Shoot | 0.63 | 0.10 | 1.04 | 1204 | 107 | 92.0 | 63.7 | 31.8 | 4.25 |
| | 401 | 31.9 | Grains | 2.45 | 0.15 | 0.45 | 833 | 92.1 | 79.5 | 56.6 | 13.1 | 1.41 |
| Gypsum (G) | | | Root | 0.11 | 0.20 | 0.60 | 1739 | 106 | 75.6 | 61.8 | 31.2 | 5.40 |
| | | | Shoot | 1.55 | 0.11 | 1.52 | 999 | 91.6 | 68.6 | 33.2 | 19.5 | 2.68 |
| | 563 | 41.7 | Grains | 1.99 | 0.21 | 0.48 | 548 | 81.6 | 51.1 | 25.3 | 10.7 | 0.59 |
| Citric acid (Ci) | | | Root | 0.63 | 0.16 | 0.84 | 2050 | 161 | 125 | 66.0 | 35.9 | 6.31 |
| | | | Shoot | 1.33 | 0.10 | 3.46 | 1037 | 85.0 | 75.0 | 42.4 | 19.0 | 2.43 |
| | 427 | 33.1 | Grains | 1.36 | 0.26 | 0.58 | 600 | 68.3 | 58.0 | 25.9 | 11.3 | 1.02 |
| Farmyard manure (FYM) | | | Root | 1.26 | 0.20 | 1.25 | 1920 | 131 | 107 | 66.6 | 41.8 | 8.63 |
| | | | Shoot | 1.82 | 0.35 | 3.76 | 1063 | 98.0 | 74.4 | 57.3 | 20.2 | 3.58 |
| | 489 | 35.8 | Grains | 2.80 | 0.15 | 0.48 | 655 | 80.0 | 61.2 | 46.7 | 13.1 | 0.95 |
| Compost (Com) | | | Root | 1.26 | 0.22 | 0.80 | 1834 | 115 | 93.5 | 67.6 | 34.6 | 7.89 |
| | | | Shoot | 1.78 | 0.38 | 4.01 | 1038 | 96.4 | 75.4 | 47.4 | 20.6 | 2.12 |
| | 473 | 34.7 | Grains | 2.70 | 0.14 | 0.56 | 643 | 79.4 | 59.2 | 31.0 | 14.5 | 0.42 |
| 50%G + 50%FYM | | | Root | 1.46 | 0.44 | 0.98 | 1971 | 144 | 102 | 80.3 | 40.0 | 9.50 |
| | | | Shoot | 2.28 | 0.15 | 6.08 | 1156 | 109 | 94.2 | 73.8 | 29.1 | 3.76 |
| | 623 | 48.9 | Grains | 4.37 | 0.28 | 0.76 | 977 | 92.0 | 86.1 | 66.8 | 14.3 | 2.46 |
| 50%G + 50%Com | | | Root | 1.40 | 0.25 | 1.19 | 1960 | 128 | 94.3 | 76.3 | 39.2 | 8.48 |
| | | | Shoot | 1.68 | 0.24 | 5.54 | 1140 | 105 | 90.9 | 71.0 | 28.9 | 3.64 |
| | 595 | 47.1 | Grains | 3.30 | 0.27 | 0.59 | 970 | 95.8 | 86.2 | 63.4 | 13.9 | 2.65 |
| 50%Ci + 50%FYM | | | Root | 1.54 | 0.33 | 1.26 | 2001 | 152 | 121 | 87.7 | 44.0 | 11.3 |
| | | | Shoot | 1.71 | 0.14 | 5.40 | 1222 | 117 | 95.0 | 82.3 | 36.7 | 4.62 |
| | 531 | 38.5 | Grains | 2.91 | 0.25 | 0.53 | 980 | 107 | 80.6 | 77.2 | 16.0 | 2.62 |
| 50%Ci + 50%Com | | | Root | 1.58 | 0.16 | 0.89 | 1989 | 146 | 108 | 85.5 | 44.8 | 11.1 |
| | | | Shoot | 1.69 | 0.28 | 5.48 | 1220 | 112 | 100 | 79.6 | 29.2 | 4.17 |
| | 504 | 38.0 | Grains | 2.80 | 0.17 | 0.71 | 975 | 104 | 78.4 | 71.9 | 15.6 | 1.97 |
| $L.S.D_{0.05}$ | 4.86 | 0.34 | Root | 0.02 | 0.003 | 0.01 | 15.5 | 1.29 | 0.57 | 0.59 | 0.31 | 0.09 |
| | | | Shoot | 0.02 | 0.004 | 0.03 | 8.47 | 1.15 | 0.75 | 0.69 | 0.29 | 0.04 |
| | | | Grains | 0.03 | 0.003 | 0.003 | 7.59 | 1.05 | 0.72 | 0.74 | 0.22 | 0.03 |

decomposition. Negm et al. (2003) found that application of compost in combination with sulfur or phosphorus improved physical and chemical properties of soil, such as decreasing soil pH and increasing both macro and micronutrients availability in the soil.

On the other hand, gypsum amendment was superior in reducing the chemically available heavy metals in the studied soil followed by compost, FYM and citric acid, respectively. Gypsum is sometimes recommended based on the ability of soluble Ca to counteract the effects of toxic levels of micronutrients and heavy metals in the soil. Barker and Pilbeam (2007) found that the Ca in high application rates of gypsum may have some beneficial effect on Cu contaminated soils. Application of organic matter in the metal-contaminated soil can efficiently reduce the concentration of Cd and Zn in the soil solution (Isabelle and Alian, 2001). Generally, DTPA-extractable heavy metals in all amendments were almost increased with increasing soil depth as compared to control, to show the downward movement by increasing solubility and leachability.

*Grain yield, grain quality, NPK and heavy metals concentration of wheat plants*

Data in Table 5 show the grain yield, weight of 1000 grains, N, P and K concentration of wheat plants cultivated in El-Hosinia plain soil as affected by different amendments, under irrigation with Bahr El-Baqar drain water. The addition of such amendments to the contaminated soil under investigation improved, relatively their chemical properties which in turn promote plants growth, improve general plant vigour and encourages their yields. The highest effect in increasing yield was obtained from the treatment of 50%gypsum + 50%FYM followed by 50%gypsum + 50%compost, 50%citric acid + 50%FYM and 50%citric acid + 50%compost. At the same time, gypsum, FYM and compost have moderately effect, while citric acid has the lowest one. Singh et al. (1989) reported that application of gypsum reduced pH and improved soil physical properties, which together were reflected on the yield and this effect was increased when gypsum combined with organic manure.

The obtained results indicate marked increases in macronutrients concentrations in whole wheat plant parts particularly N and K concentration due to treating soil with such amendments, especially 50%gypsum + 50%FYM (Table 5). This could be attributed to the effect of 50%gypsum + 50%FYM on improving physico-chemical characteristics of the soil and consequently improving plant growth conditions. Such improvements include one or more of the following reasons: (1) the improvement of soil physical properties which is reflected on both water and nutrients behaviour. (2) lowering $EC_e$ and SAR of the treated soil through 50%gypsum + 50%FYM addition and (3) improving soil chemical, biological and fertility properties. El-Banna et al. (2004) mentioned that gypsum amendment could be oxidized biologically in presence of organic matter in soil to produce $H_2SO_4$ which react with native $CaCO_3$ to form $CaSO_4$. Note worthy, the addition of acid form amendment lowers the soil pH, with well-known effects upon the availability of some nutrients in the soil, then increasing their uptake and concentrations in plants.

Heavy metals concentrations of wheat plants cultivated in the studied soil as affected by different amendments under irrigation with Bahr El-Baqar drain water are also shown in Table 5. Application of 50%citric acid + 50%FYM followed by 50%citric acid + 50%compost, 50%gypsum + 50%FYM and 50%gypsum + 50%compost amendments to the soil significantly increased the plant concentration of Fe, Mn, Zn, Cu, Ni and Cd compared to the control. This could be due to the role of organic acids such as citric acid in reducing soil pH and increasing solubility of such metals. Also, soluble organic complexes of certain heavy metals could play an important role in getting such metals more available to plant (Barness and Chen, 1991). On the other hand, gypsum amendment was superior in reducing the studied heavy metals in plant parts followed by compost, FYM and citric acid, respectively. The results show that heavy metals concentration in wheat plants were accumulated in roots > shoots > grains. Abou El-Naga et al. (1999) reported that trace elements tend to accumulate in roots of plants rather than shoots, flowers and grains.

In general, heavy metals concentrations in wheat plants reflect the amounts of the chemically available heavy metals present in the cultivated soil, which in turn is highly affected by both the source of contamination and kind of amendment applied to this soil. The obtained data was compared with the potentially toxic levels of trace elements in plants according to Jones (1967) and Kabata-Pendias and Pendias (1992). They found that 50–250, 30–300, 27–150, 5–30, 0.1–5 and 0.05–0.2 mg $kg^{-1}$ for Fe, Mn, Zn, Cu, Ni and Cd, respectively, were within the normal range. While, 400–1000, 100–400, 20–100, 10–100 and 5–30 mg $kg^{-1}$ for Mn, Zn, Cu, Ni and Cd, respectively, were considered contaminated. However, no limiting values were recommended for Fe. Therefore, heavy metals concentration in wheat plants at harvest period were within the sufficient range except for Cu, Ni and Cd particularly in plant roots, under irrigation with Bahr El-Baqar drain water.

From the abovementioned results, it can be concluded that application of different amendments especially 50%gypsum + 50%organic materials were improved the chemical properties of the soil under investigation, i.e. pH, $EC_e$, soluble ions, SAR and DTPA-extractable heavy metals; and led to improve the physical properties of soil. Also, these amendments raised the soluble Ca concentrations leading to enhance flocculation of soil colloids. Organic substances and gypsum provide both Ca and S for crop nutrition and has been used as a macronutrients source for growing plants. But continuous irrigation with drainage water of Bahr El-Baqar without any pretreatment could increase heavy metals concentration in the different parts of plants, especially for those cultivated in heavy clay soils. So, we recommend a secondary treatment for such quality of wastewater before its use in irrigation.

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