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Effect of soil amendments on wheat (*Triticum aestivum* L.) yield and nutritional status in sandy calcareous saline soil

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Abstract: Two field trials were carried out in sandy calcareous saline soil (EC 6.3 dS m^{-1} and Ca CO_3 5.6 -19 %) during two successive winter seasons on a private farm at Belbais, Sharkia Governorate. The experiments aimed to investigate the effect of compost application at 0 and 24 m^3 ha^{-1} when combined with N at (0, 108, 144 and 180 kg N ha^{-1}) and K at (0, 57.6, 115.2 and 172.8 kg K_2O ha^{-1}) on wheat yield and nutrient content of leaves and grains. The results showed significant main effects due to compost application at 24 m^3 ha^{-1} on wheat yield and yield components. Grain and straw yields were significantly increased as a result to compost application. Meanwhile, grain yield was significantly increased with the inorganic N fertilizer up to 180 kg N ha^{-1}. Potassium applications significantly increased grain yields, and the increase due to K application was approximately 20% greater than control treatment. On contrast, no significance were detected for interactions between compost and K, suggesting that the effects of these mineral fertilizers on grain yield were additive. The chemical analysis of the vegetative plants revealed that there were some immediate benefits from addition of compost, where significant increases in N and Fe concentrations were detected. In addition, Mn and Cu concentrations were significantly increased due to the interaction between compost and N at 180 kg N ha^{-1}. The chemical composition of wheat grains revealed some evidence of beneficial increases in N, K and the microelements (Fe, Mn, Zn and Cu) due to compost application, although only the increase in Mn was significant. In general, the data showed that following two applications of compost, wheat grain composition was comparable to the normal farm practice with inorganic fertilizer. It could be concluded from this study that application of compost at 24 m^3 ha^{-1} combined with 144 kg N ha^{-1} increased wheat yield. Meanwhile, K should be included to maximize wheat grain yield under such conditions. In general, application of compost may increase wheat yields and improve the nutritional status of the plants on such sandy calcareous saline soils.
Key words: wheat, compost, Nitrogen, Potassium, nutrient, yield.

Introduction

Considerable attention has been devoted to increase wheat production in Egypt. Therefore, great efforts are being continued to increase the area cultivated with wheat, especially in the new reclaimed soils[1]. Recently the government aims at expanding in 1.5 million feddan (ha = 2.4 feddan) to reduce wheat gap production. However, the newly reclaimed soils in Egypt are characterized by low fertility, high salt content and poor moisture retention[2]. The areas under reclamation are mostly calcareous, saline and sandy soils. Since animal manures are not readily available for soil application, alternative materials such as organic wastes from the food industry and composts should be tested and used to meet the organic matter requirement of these soils[3].

Application of organic materials: farmyard and chicken manures are traditionally used by many investigators as soil conditioners and fertilizers for increasing growth and yield of many field crops and vegetables[4-6]. Compost, far from being merely include a group of wastes, should be regarded as a natural resource to be conserved and used rather than discarded. Its use in agriculture is widely regarded as the best practical environmental option, and the most sustainable of waste management options. In view of both environmental protection and economic development, composting is the best method to manage and utilize wastes. The application of compost to the soil improve the chemical, physical, and biological characteristics of soils. It improves water retention and soil structure by increasing the stability of soil aggregates[7]. Moreover, effects of the organic matter applied to the soil in compost are seen in increased efficiency of mineral fertilizer utilization by crops and improved performance[8,9]. In addition organic manures plays an important role in improving the physical properties of soils, especially the sandy and calcareous ones, they are valuable resources rich in P, N and micronutrients essential for plant growth, that are slowly released after degradation by microorganisms. IN this concern, Mostafa (2004)[10] reported that application of chicken manure or farmyard manure, at a rate equivalent to 100 kg N fed^{-1} significantly improved dry weight of wheat plants grown on soils of different textures, but response of plants to the organic manure treatments was more pronounced in sandy and calcareous soils than in the clayey ones. Recently, El Sheikha (2016)[9] concluded that the integrated use of organic manure and recommended dose of chemical fertilizers resulted in significant improvement in crop yields and quality.

In Egypt, various studies have assessed the benefits of organic manures including compost on the physical characteristics of Egyptian soils and in increasing crop yields (Zaki *et al*., 2012)[1] Moreover, several investigators reported increments in grain and straw yields of wheat in newly reclaimed desert soils or in arid regions[11].

Therefore, the aim of the work is to investigate the effect of compost combined with some macronutrients on the yield and chemical composition of wheat grown in reclaimed sandy calcareous saline soils.

Materials and Methods

Two field trials were carried out in the winter of 2013/14 and 2014/15 seasons on a private farm in the Belbais District, 8 km east of Bilbeis, south of Ismailia canal, Sharkia Govemorate, Egypt, in a newly reclaimed sandy calcareous soil. The objective of the trials was to investigate the effect of compost application in combination with N and K on wheat yields in saline soil (EC 6.3 ds m^{-1}, Ca CO_3 5.6 -19 %). Another objective of this work was to monitor the nutritional status in wheat leaves and grains. The area of each trial was 0.69 hectares, physical and chemical analyses of the soil are listed in Table (1). Each experiment included 32 treatments which were the combinations of two levels of compost (0 and 24 m^3 ha^{-1}), four levels of nitrogen fertilizer (0, 108, 144 and 180 kg N ha^{-1}) and four levels of potash fertilizer (0, 57.6, 115.2 and 172.8 kg K_2O ha^{-1}). The experimental design in the trials was split-split plot with four replicates in which the compost levels occupied the main plots, N levels in the sub-plots, and K levels were allocated to the sub-sub-plots. The chemical analysis of the compost applied was (58-73%) dry solids, N (0.9 -2.1%), P (0.36-1.36), Iron (1.27-1.85%), Mn (275-319 mg kg^{-1}) and Zn (141-112 mg kg^{-1}) compost density was 0.65-0.70 (ton m^{-3}). The experimental soil was ploughed twice and divided to experimental units each of 54 m^3 area. Thereafter, the compost was calibrated on a volumetric basis and applied to the assigned main plots. Compost application was carried out manually according to common farmyard manure application in this district. In order to ensure homogenous incorporation with the soil surface layer, a rotary cultivator was used. Wheat (*Triticum aestivum* L.) c.v. Gemiza-9 was sown on 29 November 2013 and 25 November 2014, respectively. Sowing was carried out by mechanical seed drill at 15 cm distance between rows. Surface irrigation was applied at two weeks intervals.

Table 1. Physico-chemical properties of soil samples from profile inspection pits at the field trial site.

Depth (cm)	Gravels (% >2mm)	$CaCO_3$ (%)	Gypsum (%)	pH	EC (dS m^{-1})	Cation concentration (me l^{-1})				Anion concentration (me l^{-1})		
						Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}
0-20	25.6	5.6	0.23	8.81	6.3	30.2	11.1	25.1	1.2	2.4	29.3	35.9
20-80	28.8	18.0	0.09	8.66	7.1	35.6	12.1	30.4	1.7	3.6	28.1	48.1
80-150	19.2	19.2	0.14	8.83	7.5	40.1	9.3	33.6	1.3	3.8	35.1	45.4

following the normal farmer practice. During seed-bed preparation, the phosphatic fertilizer treatments were applied as calcium superphosphate (15.5% P_2O_5). Nitrogen was applied as ammonium nitrate (33.5% N) in two equal doses before the first and the second irrigations, while the potassium treatments were applied as potassium sulphate (48-52% K_2O) before the third irrigation. Harvesting of wheat was carried out on 20 April 2014 and 5 May 2015 for the first and second seasons, respectively. Grain and straw yields were determined using a quadrat (3 x 3.5 m). The plants were threshed to obtain yield per plot and yield (t ha^{-1}). Straw yield (t ha^{-1}) and 1000-grains weight were determined.

Chemical analysis:

During the growing seasons, vegetative samples (5 plants per plot) were taken at 80 days from sowing and analysed for nutrient content. Grain samples taken at harvest were analysed for their contents of nutrients. Chemical analysis was carried out on dried and ground samples. Nitrogen was determined by micro-Kjeldahl according to the[12]. After wet digestion of the samples, according to[13], P was determined by spectrophotometry, K by flame photometer (Jackson, 1967)[14] and Fe, Mn, Cu and Zn were determined by atomic absorption spectrophotometry. Other analyses were according to the methods described by[14].

Statistical analysis:

The data were subjected to the proper statistical analysis using COHORT 6 package. Since the data in both seasons took similar trends‘ Bartlett's test was applied and the combined analysis of the data was done. For means comparison Least Significant Difference (LSD) at 5% level was applied.

Results and Discussion

As expected, the soils originating from reclaimed desert land contain a large proportion of gravels and the soils are alkaline with high pH values where the pH of soil sample taken from 0 – 20 cm depth was as high as pH 8.8. The soil is also saline and this is reflected in the larger concentrations of cations and anions present such as sodium, chloride and sulphate. Concentrations of total and DTPA-extractable trace elements in the soil samples were measured. However, manganese and iron were barely detectable by DTPA extraction whereas low to moderate concentrations of the elements were extractable with DTPA in soil samples. It is worthy to note that soil profile inspection revealed that both EC and $CaCO_3$ (%) criteria markedly increased in the sub soil profiles (20-80) and (80-150). Therefore, hard ploughing in such soil may cause rapid salinization and calcifying the top soil through bringing the sub-soil layers to the surface layer and it is better to maintain the chemical structure to protect the surface layer.

Effect of compost, N and K application on yield and yield components of wheat.

Data presented in Tables (2-4) show significant effects due to addition of compost on plant height, spike length and weight. Nitrogen application treatments significantly affected these characters as well as 1000-grain weight, while K application significantly affected only spike length. The data of the second order interactions (Table, 7) did not reveal significant effects on these characters except (Nitrogen X Compost) which affected spike weight.

Grain and straw yields.

Data presented in Tables (2-4) show significant main effects of compost, N and K fertilizer treatments on grain yield. There were significant main effects of compost and N application on straw yield. The main effect means show that grain and straw yields were significantly increased by compost. Grain yield increased significantly with the rate of inorganic N up to 144 kg N ha^{-1}. The yield obtained at 188 kg N ha^{-1} was not statistically significant than 144 kg N ha^{-1} treatment, indicating that grain production had attained the maximum potential yield in response to N supply at 144 kg N ha^{-1}.

Table 2. Effect of compost application on wheat yield and yield components characters.

Compost application (m^3 ha^{-1})	Plant height (cm)	Spike length (cm)	Spike weight (g m^{-2})	1000 grain weight (g)	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})
0 (C0)	90.59	8.99	373.4	50.98	2.19	5.53
24 (C1)	97.00	9.76	545.9	51.10	2.77	6.11
LSD at 0.05	3.2	0.15	57.7	ns	0.12	0.23

Table 3. Effect of nitrogen levels on wheat yield and yield components characters.

Nitrogen (kg N ha^{-1})	Plant height (cm)	Spike length (cm)	Spike weight (g m^{-2})	1000 grain weight (g)	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})
0 (N0)	88.1	8.67	390.9	48.86	1.691	5.348
108 (N1)	96.1	9.33	472.8	51.22	2.424	5.803
144 (N2)	96.7	9.95	504.7	52.08	2.829	5.890
180 (N3)	96.7	9.54	470.3	52.00	2.956	6.227
LSD at 0.05	4.8	0.63	81.6	1.42	0.174	ns

Table 4. Effect of potassium levels on wheat yield and yield components characters.

potassium rate (K_2O ha^{-1})	Plant height (cm)	Spike length (cm)	Spike weight (g m^{-2})	1000 grain weight (g)	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})
0 (k0)	92.7	9.5	436.9	50.2	2.173	5.619
57.6 (K1)	93.9	9.4	498.8	51.2	2.522	5.575
115.2 (K2)	95.4	9.2	453.1	51.2	2.552	5.683
172.8 (K3)	93.2	9.5	450.0	51.5	2.655	6.391
LSD at 0.05	ns	0.63	ns	ns	0.17	ns

Significant interactions effects were apparent between compost and N fertilizer according to ANOVA for both grain and straw yields, Table (5). There was no effect of N fertilizer addition on straw yield when compost was applied, indicating that the maximum straw yield potential was realized from the addition of compost alone without mineral N. By contrast, grain yield generally increased when compost and N fertilizer were supplied together, except for the 144 kg N ha^{-1} treatment, when equivalent yields were obtained irrespective of compost application. However, a further increase in grain yield with compost was apparent at the highest rate of inorganic N fertilizer, suggesting that factors other than N supply were limiting grain production.

Potassium application significantly increased grain yield by approximately 20% compared to the control treatment (Table, 4) although no significant difference was detected between the different rates of K addition. K and N fertilizer application had no effect, or only a marginal influence, upon straw production compared to the control treatment. The comparison of means in the same tables show that the differences in straw yield were not significant when comparing the four mean values. Significant interactions effects for grain and yields were apparent between compost and K fertilizer levels according to ANOVA, (Table, 6). The greatest grain yield was attained with compost application and fertilizing wheat with 57.2 kg K_2O ha^{-1}. On contrast, the interaction between Nitrogen and Potassium as well as the third order interaction (Compost x Nitrogen x Potassium), (Table, 8) were insignificant on grain and straw yields per hectare.

Table 5. Effect of the second order interaction (Compost x N levels) on wheat yield and yield components characters.

Treatment	Plant height (cm)	Spike length (cm)	Spike weight (g m^{-2})	1000 grain weight (g)	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})
Comp. X N						
C0 x N0	81.8	7.9	257.5	49.3	1.298	4.880
C0 x N1	92.4	8.9	355.6	51.0	2.110	5.718
C0 x N2	96.4	9.6	462.5	51.8	2.780	5.723
C0 x N3	91.7	9.5	418.1	51.8	2.552	5.789
C1 x N0	94.3	9.4	524.4	48.4	2.085	5.815
C1 x N1	99.8	9.8	590.0	51.5	2.738	5.888
C1 x N2	97.0	10.3	546.9	52.3	2.878	6.057
C1 x N3	96.9	9.6	522.5	52.2	3.361	6.665
LSD at 0.05	ns	ns	ns	ns	0.17	0.955

Table 6. Effect of the second order interaction (Compost x K levels) on wheat yield and yield components characters.

Treatment	Plant height (cm)	Spike length (cm)	Spike weight (g m^{-2})	1000 grain weight (g)	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})
Comp. X K_2O						
C0 x k0	92.6	9.4	409.4	49.9	1.959	5.295
C0 x k1	90.7	8.9	350.6	51.1	2.214	5.274
C0 x k2	90.8	8.9	356.9	51.7	2.249	5.379
C0 x k3	88.3	8.8	376.9	51.3	2.319	6.162
C1 x k0	92.8	9.5	464.4	50.6	2.387	5.942
C1 x k1	97.1	9.9	646.9	51.4	2.829	5.876
C1 x k2	100.0	9.5	549.4	50.8	2.854	5.987
C1 x k3	98.1	10.1	523.1	51.7	2.991	6.621
LSD at 0.05	ns	ns	81.6	ns	0.455	ns

Table 7. Effect of the second order interaction (N levels x K levels) on wheat yield and yield components characters.

Treatment	Plant height (cm)	Spike length (cm)	Spike weight (g m^{-2})	1000 grain weight (g)	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})
N X K_2O						
N0 x k0	87.0	8.6	320.0	48.8	1.395	4.960
N0 x k1	88.5	8.6	448.8	49.2	1.624	5.062
N0 x k2	89.3	8.8	413.8	49.7	1.788	5.025
N0 x k3	87.5	8.7	381.3	47.8	1.959	6.344
N1 x k0	93.1	9.3	455.0	50.3	2.027	5.289
N1 x k1	100.6	9.2	547.5	51.3	2.617	5.361
N1 x k2	100.4	9.2	440.0	50.5	2.537	6.217
N1 x k3	90.4	9.6	448.8	52.8	2.515	6.346
N2 x k0	97.5	10.2	508.8	50.3	2.623	5.746
N2 x k1	93.6	10.4	535.0	53.5	2.976	5.900
N2 x k2	96.4	9.9	505.0	51.9	2.918	5.537
N2 x k3	99.4	9.4	470.0	52.7	2.800	6.378
N3 x k0	93.1	9.7	463.8	51.5	2.646	6.480
N3 x k1	92.8	9.4	463.8	50.9	2.870	5.978
N3 x k2	95.6	9.0	453.8	52.9	2.963	5.954
N3 x k3	95.6	10.1	500.0	52.7	3.347	6.498
LSD at 0.05	ns	ns	ns	ns	0.19	0.956

It could be concluded from this trial that inorganic K fertilizer application provides a significant yield benefit for crop production grown in salt reclaimed desert soils. Meanwhile, the effect of K fertilizer on crop yield is additive and independent of the response to N fertilizer or compost application. This is because compost is not an agronomically significant source of K and does not influence directly crop K status. The optimum rate of K application, under the conditions of this trial, was 57.6 kg ha^{-1}, In contrast to K, crop yield response to compost and N fertilizer may be interactive because compost is an agronomically significant source of N for crop production. In addition to its significant N fertilizer replacement value, compost increases the potential maximum yield response achievable with inorganic N fertilizer application by the amelioration of soil conditions favorable for crop development. These beneficial effects are cleared through enhancing the chelating agent by active organic acids for micronutrients and their easily uptake by plants. Ali (2004)[15] and Mohammed (2004)[16] reported that, the conjunctive use of N fertilizers and local manure organic material in the newly cultivated desert soils had favorable higher influence on wheat productivity than the recommended dose of NPK fertilizers alone. This may be due to the role of these applied organic materials in augmented soil organic matter content, that increases available essential plant nutrients in the soil. Moreover, such organic manure encourages the biological uptake of the released nutrients by plant roots, their benefits extend to a long-term, and then positively reflected on grain yield and its content of nutrients.

Table 8. Effect of the third order interaction (Compost x Nitrogen x Potassium) on wheat yield and yield components characters.

Treatment			Plant height (cm)	Spike length (cm)	Spike weight (g m^{-2})	1000 grain weight (g)	Grain yield (ton ha^{-1})	straw yield (ton ha^{-1})
Compost	Nitrogen (kg N ha^{-1})	Potassium rate						
No compost	0	0	84.5	8.63	277.5	49.26	1.15	4.15
		57.6	82.3	7.88	247.5	50.31	1.22	4.34
		115.2	80.3	7.63	250.0	49.73	1.37	4.54
		172.8	80.3	7.63	255.0	47.91	1.44	6.48
	108	0	90.8	9.30	347.5	48.75	1.66	5.28
		57.6	96.8	8.38	395.0	52.18	2.45	5.38
		115.2	98.5	9.13	330.0	50.70	2.23	6.34
		172.8	83.8	8.75	350.0	52.31	2.11	5.90
	144	0	100.8	9.55	515.0	51.38	2.74	6.22
		57.6	92.0	9.95	432.5	52.21	2.76	5.74
		115.2	94.8	10.13	512.5	52.54	2.81	5.30
		172.8	98.3	8.88	390.0	51.27	2.83	5.64
	180	0	94.3	10.05	497.5	50.14	2.30	5.54
		57.6	91.8	9.33	327.5	49.51	2.42	5.64
		115.2	89.8	8.75	335.0	53.90	2.59	5.35
		172.8	91.0	9.88	512.5	53.59	2.90	6.62
24 m^3 ha^{-1}	0	0	89.5	8.63	362.5	48.40	1.66	5.78
		57.6	94.8	9.25	650.0	48.00	2.02	5.78
		115.2	98.3	10.05	577.5	49.65	2.21	5.52
		172.8	94.8	9.70	507.5	47.60	2.47	6.19
	108	0	95.5	9.38	562.5	51.93	2.38	5.30
		57.6	104.5	10.00	700.0	50.40	2.78	5.35
		115.2	102.3	9.25	550.0	50.29	2.86	6.12
		172.8	97.0	10.50	547.5	53.23	2.93	6.79
	144	0	94.3	10.75	502.5	49.18	2.52	5.28
		57.6	95.3	10.80	637.5	54.71	3.19	6.07
		115.2	98.0	9.63	497.5	51.29	3.05	5.76
		172.8	100.5	9.95	550.0	54.06	2.76	7.13
	180	0	92.0	9.38	430.0	52.95	3.00	7.42
		57.6	93.8	9.38	600.0	52.29	3.34	6.31
		115.2	101.5	9.25	572.5	51.85	3.34	6.55
		172.8	100.3	10.33	487.5	51.78	3.79	6.38
LSD at 5%			ns	ns	ns	ns	ns	ns

The positive response of wheat grain and straw yield to the applied K in this study could be due to its enhancement effect on compost decomposition and the subsequent release of plant nutrients. These results are in agreement with those stated by Hall (1985)[17], who pointed out that K content of all compost is low and not sufficient to make any significant difference to the recommended quantities of fertilizer K necessary for most cropping situations. In addition, the increase in grain and straw yields of wheat as a result to the interaction between N and compost was reported by[3]. In this respect it was found that, organic matter application in any form applied in sandy calcareous soil induced significant or highly significant increases in wheat growth and yield. Such increases are attributed to supplementation of nitrogen and other nutrients released from organic matter degradation, as well as to improvements of soil chemical, physical, nutritional and biological properties. Similar conclusions were reported by other investigators[18-20]. Many workers reported that application of organic manure can alleviate the adverse effects of soil salinity. In addition, adding organic manure as a soil amendment was more benefit for soil fertility status, because it attains more pronounced contents of macro- (N, P and K) and micronutrients (Fe, Mn, Zn and Cu), which consequently reflects on plant growth and yield[21-23] option not only for reducing the previous enormous consumption of chemical fertilizers, but also maintain soil fertility status and help to sustain crop productivity, as well as, to increase fertilizer use efficiency in the soil. The beneficial effects of organic materials on crop yield and its components suggested by many investigators such as Salib (2002)[24] who pointed out that the beneficial effect of soil treated with organic amendments was closely extended to the grown plants. In addition, crop yield and its components responded markedly to different organic amendments used either individually or mixed.

Mineral status of nutrients:

Effect of compost, N and K applications on nutrient concentrations in the vegetative plants.

The chemical analysis of young vegetative plants at 80 days age suggested that there was some immediate benefit from the application of compost since total concentrations of nitrogen and iron were generally increased by compost application (Tables 9 and 10). ANOVA also showed that significant interactions were also apparent for Mn and Cu in plant tissues which remained unchanged with compost at the different rates of nitrogen addition. One possible way to reduce the effect of salt stress is the application of compost[25]. The importance of compost is well known due to its multiple functions in soil. Compost can be beneficial not only to enhance organic matter, physical and chemical properties of soil, water holding capacity, and aeration in soil but also to provide plant nutrients[26].

Effect of Compost, N and K application on nutrient concentrations in wheat grains.

The mean values for the main effects of compost application and N and K fertilizer addition are presented in Table (11) and some general statistical properties of the data are shown in Table (12). This is a complex experimenta1 trial design and allows the interactive effects of compost and mineral fertilization on grain chemical composition to be quantified. Few significant main effects of the experimental treatments on wheat grain composition were detected by ANOVA, although a number of significant interactions were apparent (Table, 13). This suggested that only weak or marginal effects of the experimental treatments were apparent on the chemical content of wheat grain. In this respect El Naka *et al.* (2015)[27] indicated that it is important to incorporate biocompost with other amendments to increase the available N, P and K in sandy soil which was reflected on their content and uptake by wheat grains. In overall assessment, these data showed that, following two applications of compost, wheat grain composition was comparable to normal farm management practice with inorganic fertilizers.

Table 9. Mean nitrogen content of young winter wheat plants receiving 24 m^3 ha^{-1} of compost at Bilbeis field site compared with unamended control treatments.

Treatment	**Mean N content (%)**	**cv (%)**	**n**
Unamended control	0.55	25.3	36
Compost-amended	0.66	35.8	43
LSD at 5%	0.08		

Table 10. Probabilities of variance ratios (F) calculated by ANOVA for the effects of compost and N fertilizer applications on the concentrations of some nutrients in young winter wheat plants.

Nutrients	N fertilizer	Compost	N x compost interaction
N	0.015 *	0.016 *	0.985 ns
P	0.290 ns	0.830 ns	0.983 ns
K	0.005 **	0.180 ns	0.966 ns
Mn	0.013 *	0.705 ns	0.029 *
Fe	0.005 **	<0.001 ***	<0.001 ***
Zn	<0.001 ***	0.129 ns	0.066 ns
Cu	0.540 ns	0.054 ns	0.035 *
Cr	0.004 **	0.005 **	0.120 ns
Co	0.525 ns	0.245 ns	0.137 ns

The elevation of N and some trace elements in young plants or grain of wheat may be due to the beneficial role of compost in maximizing the crop absorption efficiency[28]. Moreover, the high pH of such sandy calcareous soil reduces the potential uptake of trace elements by plants. In addition, adding organic manure as a soil amendment was more benefit for soil fertility status, because it attains more pronounced contents of macro- (N, P and K) and micronutrients (Fe, Mn, Zn and Cu), which was consequently reflects on plant growth and yield[21,22].

It could be concluded from this study that compost application to saline newly reclaimed soil is effective in improving crop productivity and the nutritional status of wheat in such problem soils. It is unlikely that a single factor in compost was responsible for this but is more likely to be due to the mixture of nutrients, micronutrients and organic matter that compost supplies.

Table 11. Mean values of the main effects of compost, and N and P fertilizer applications on wheat grain chemical composition (N, P and K as %; other elements as mg kg^{-1}).

Treatment	N	P	K	Fe	Mn	Zn	Cu	Co
Compost (m^3 ha^{-1})								
0 (C0)	1.63	0.47	0.37	50.1	23.6b	49.6	5.5	3.2b
24 (C1)	1.70	0.48	0.37	58.7	28.0a	51.5	5.0	4.3a
F probability	0.407	0.523	0.685	0.184	0.001	0.345	0.418	0.008
LSD at 5%	ns	ns	ns	ns	1.1	ns	ns	0.5
N fertilizer (kg N ha^{-1})								
0 (N0)	1.52b	0.47	0.37	57.5	23.9	49.2	4.9	3.9
108 (N1)	1.68ab	0.49	0.37	57.5	26.1	53.5	5.4	4.0
144 (N2)	1.65ab	0.45	0.36	48.9	26.9	50.5	5.2	3.4
180 (N3)	1.80a	0.48	0.37	52.9	26.3	49.2	5.3	3.9
F probability	0.017	0.312	0.784	0.253	0.069	0.105	0.428	0.215
LSD at 5%	0.22	ns	ns	ns	ns	ns	ns	ns
K fertilizer (kg K_2O ha^{-1})								
0 (k0)	1.66	0.46	0.37	49.0	24.3b	48.0	4.8	3.6
37.2 (k1)	1.72	0.49	0.37	54.9	25.5b	53.1	5.6	4.1
55.8 (k2)	1.60	0.46	0.36	57.5	28.0a	51.8	5.2	3.6
74.4 (k3)	1.66	0.48	0.37	57.5	25.5b	49.4	5.2	3.7
F probability	0.216	0.254	0.336	0.487	0.001	0.053	0.224	0.359
LSD at 5%	ns	ns	ns	ns	2.4	ns	ns	ns

Table 12. General statistical properties of wheat grain chemical composition (N, P and K as %; other elements as mg kg^{-1}).

Parameter	N	P	K	Fe	Mn	Zn	Cu
Minimum	0.7	0.3	0.3	14.0	17.0	22.0	0.4
Maximum	2.5	0.7	0.5	408.0	38.0	73.0	10.0
Mean	1.7	0.5	0.4	63.4	25.9	50.4	5.2
Sd	0.28	0.09	0.04	52.18	5.19	10.49	2.01
cv %	16.6	17.9	10.1	82.3	20.1	20.8	38.7

Table 13. Significance levels of the interactions between the effects of compost application and N and K fertilization on the chemical composition of wheat grain.

Interaction	N	P	K	Fe	Mn	Zn	Cu
Comp. x N	ns	ns	ns	**	ns	***	*
Comp. x K_2O	*	ns	ns	ns	*	**	**
Comp. x N x K_2O	ns	ns	ns	ns	**	**	***

Notation: ns, not significant (P > 0.05);*, P = 0.05; **, P = 0.01; ***, P = 0.001

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