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Response of barley grown under saline condition to some fertilization treatments

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Abstract Two field experiments were conducted at 2010–2011 and 2011–2012 winter seasons under the saline conditions of El-Tena plain (17,000 ppm), North Sinai, to investigate the effect of different organic fertilization sources (30 m^3 fed.$^{-1}$ of animal dung, 6 tones fed.$^{-1}$ of each of rice straw with Olive Mill Wastewater compost (OMW compost) and the regular rice straw compost (RS-compost) besides 20 m^3 fed.$^{-1}$ as the conventional dose of animal dung as the control treatment in addition to foliar application with different concentrations of zinc sulphate (0, 10, 20 and 30 ppm) on the growth, productivity, free proline content and total chlorophyll content of Giza 123 Cultivar of barley (*Hordeum vulgare* L.).

Results obtained indicated that both RS-compost and OMW-compost had positive effects on soil properties where barley growth and productivity were more than the conventional organic fertilization under saline conditions; yet, applying OMW-compost under the saline conditions should be under precautions to prevent increasing the EC of the soil.

Applying $ZnSO_4$ as a foliar application into barley plants increased the plant productivity as a result of enhancing the plant metabolism and growth. The highest results were obtained from applying 30 ppm. Free proline concentration was found to be directly proportional to higher salinity level.

For the interaction between OMW-compost and $ZnSO_4$ foliar application, the highest results except for the free proline were obtained from RS-OMW compost × 30 ppm $ZnSO_4$.

Introduction

Barley is considered as one of the most important cereal crops in Egypt. Since early history it occupied a very important position in the Egyptian cropping system for its moderate salt tolerance, and capability for growing in a wide range of environmental stresses including arid, poor or saline soils (Abd El-Hady, 2007). It also can tolerate high densities of chemical pollutants and gain an economical yield under adverse conditions (Ayman, 2015).

The olive oil production of Mediterranean countries represents ca. 98% of the entire worldwide production (Food and Agriculture Organization, 2013). Olive mill wastewater

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(OMW) is the main waste product produced by the three-phase extraction of olive oil. The disposal and treatment of this liquid waste are the main problems of the olive oil industry because of its high organic load and content of phytotoxic and antibacterial phenolic substances, which resist biological degradation (Aktas et al., 2001). OMW has also a high potassium concentration and notable levels of nitrogen, phosphorus, calcium, magnesium, and iron (Paredes et al., 1999), which are important factors in soil fertility. However, many authors have observed negative effects on plants and soil properties when OMW is used directly as an organic fertilizer (Sierra et al., 2001; Casa et al., 2003; Cereti et al., 2004). Hence, a conditioning treatment of this waste is necessary to produce a stable and easily manageable end-product. Different methods have been proposed for OMW treatment based on evaporation ponds, thermal concentration, and different physicochemical and biological treatments (Martıinez Nieto and Garrido Hoyos, 1994). However, generally, most methods are very expensive and unable to solve the problem completely because of the need to dispose the sludge or other by-products deriving from the process.

Composting is a widely used treatment for organic wastes particularly for rice straw which induces a serious environmental problem that is known in Egypt as black clouds; thus, the composting of rice straw and OMW to obtain organic fertilizers could be an economically and ecologically acceptable way to dispose it. During the process of OMW composting, the organic matter is biodegraded mainly through exothermic aerobic reactions, producing carbon dioxide, water, mineral salts, and a stable and humified organic material. Composting experiments with OMW have been performed by different research groups (Tomati et al., 1995; Paredes et al., 1996, 2000; Vlyssides et al., 1996) who observed that OMW needed lignin–cellulosic wastes as bulking agents and other materials as a nitrogen source for its suitable composting, so that the phytotoxicity could be eliminated and a final product with stabilized and humified organic matter obtained. However, not enough data are currently available on composting process of OMW and to evaluate its effects during the composting process. The effect of OMW compost on crop production and soil properties has been studied only scarcely. Cabrera et al. (1990) observed a higher ryegrass yield with inorganic fertilizer than with OMW compost, at doses of 20 and 50 tones compost ha^{-1}, and the nutritional status of the plants, in general, was very similar in all treatments. Also, Galli et al. (1994) found that lettuce yield increased with increasing OMW compost dose, but crop production comparable to mineral fertilization was obtained only with high compost application rates (above 80 tones ha^{-1}). The biomass yields of maize fertilized with OMW compost at 60 and 90 tones ha^{-1} were, respectively, similar to and higher than those receiving inorganic fertilizer (Tomati et al., 1996). Cabrera et al. (1990) observed that OMW compost application in the soil caused positive effects on physical, chemical, and biological properties of the soil.

Zn is one of the micronutrients that play a very important role in plant metabolism particularly under stress environments including saline conditions; it had a positive effect on growth parameters, yield and yield components under water stress conditions as reported by Abd El-Hady (2007). He also suggested that Zn has a control mechanism and/or a regulatory function on the Na and Cl uptake and translocation rate. The role of Zn in this mechanism is not explained clearly; hence, Zn might possibly be involved in the integrity and function of the bio-membranes of plants as reported by Yilmaz et al. (1997).

The aim of the present work was to evaluate the effect of OMW on the composting of organic wastes including rice straw as biological tool or bioremediation of OMW and as new method for disposal of rice straw. The effect of both compost and foliar application of $ZnSO_4$ and their interactions on barley growth and productivity was also studied.

Material and methods

Two field experiments were conducted at 2010–2011 and 2011–2012 winter seasons under the saline conditions (17,000 ppm) of El-Tena plain, North Sinai, to investigate the effect of different organic fertilization sources (30 m^3 $fed.^{-1}$ of animal dung, 6 tones $fed.^{-1}$ of each of rice straw with Olive Mill Wastewater (OMW) compost and the regular rice straw compost and 20 m^3 $fed.^{-1}$ as the conventional dose of animal dung as the control treatment) in addition to foliar application with different concentrations of zinc sulphate (0, 10, 20 and 30 ppm) on the growth, productivity, free proline content and total chlorophyll content of barley.

Barley (*Hordeum vulgare* L.) Cultivar Giza 123 grains were kindly obtained from Field Crops Res. Inst., Agricultural Research Center, Giza, Egypt. Following the common agricultural practices of the region, the experimental plot area was 11.2 m^2 with eight rows of 4 m in length and 35 cm in width. Barley grains were sown on the upper third of rows, on 20 November in both seasons with seeding rate 50 kg $fed.^{-1}$.

Compost raw materials were obtained from different locations i.e., Olive Mill Wastewater (OMW) was obtained from different olive mills in El-Arish city-North Sinai Governorate, rice straw (RS) was obtained from Sharkia Governorate, and animal dung (AD) was obtained from the location. The analyses of the starting materials are shown in Table 1.

Two piles were prepared by mixing AD with RS then OMW was added to one of the piles (pile 1), and RS had similar contents of hemicellulose and lignin (approximately 33% of each) and high cellulose content (46.5%) according to European Commission (2001). The mixtures were prepared in the following proportions, on a fresh weight basis (dry weight basis in brackets):

Pile 1: 33% AD + 67% RS + 0.9 l OMW kg^{-1} (9:88:3).
Pile 2: 39% AD + 61% RS (12:88).

The mixtures (about 2000 kg each) were composted in a pilot plant in trapezoidal piles (1.5 m height with a 2 × 3 m base). The Rutgers static pile composting system was used (Finstein et al., 1985), both piles were covered with polyethylene sheet and were mixed once every 40 days for homogenizing the pile contents, the piles were matured after 120 days of incubation.

In the raw materials and the composting samples (Table 1), electrical conductivity (EC), pH, cation exchange capacity (CEC), germination index (GI), dry matter, organic matter (OM), total nitrogen (NT), C_{org}, water-soluble organic carbon (CW), 0.1 M NaOH-extractable organic carbon (CEX), fulvic acid-like carbon (CFA), humic acid-like carbon (CHA),

Table 1 Analysis of the starting materials: olive mill wastewater (OMW), animal dungs (AD), and rice straw (RS); (dry weight basis).

Parameters	OMW[a]	AD	RS
Dry matter (%)	1.9	18.9	91.8
pH	5.5	6.8	7.0
EC ($S\ m^{-1}$)	0.53	0.42	0.43
OM (%)	1.3	67.3	84.3
C_{org} ($g\ kg^{-1}$)	9.2	360.0	450.6
N_T ($g\ kg^{-1}$)	0.2	65.9	24.0
C/N	46.0	5.4	20.3
NH_4^+-N ($mg\ kg^{-1}$)	n.d.	6891	530
P ($g\ kg^{-1}$)	0.1	36.9	1.8
K ($g\ kg^{-1}$)	1.2	9.6	16.9
Fe ($mg\ kg^{-1}$)	41	2450	1680
Cu ($mg\ kg^{-1}$)	1	118	12
Mn ($mg\ kg^{-1}$)	1	82	109
Zn ($mg\ kg^{-1}$)	4	793	39
Ni ($mg\ kg^{-1}$)	12	41	68
Cr ($mg\ kg^{-1}$)	9	83	70
Cd ($mg\ kg^{-1}$)	8	5	2
Pb ($mg\ kg^{-1}$)	1	152	1

EC: electrical conductivity; OM: organic matter; C_{org}: total organic C; N_T: total N; n.d.: not determined.
[a] Data of OMW on fresh weight basis, w/v ($g\ l^{-1}$).

NH_4^+–N, NO_3^-–N, organic-N, P and K contents were analysed according to the methods described by Paredes et al. (2000). After $HNO_3/HClO_4$ digestion, Na was determined by flame photometry and Ca, Mg and heavy metals by atomic absorption spectrometry. Concentrations of lignin and cellulose were determined according to the American National Standards Institute and American Society for Testing and Materials (1977a,b), and holocellulose according to the Browning (1967) method. Hemicellulose content was calculated as the difference between the holocellulose and cellulose concentrations. In soil samples, EC and pH were measured in water suspensions (1:5 and 1:2 w/v, respectively). $NO3^-$–N, Cl^-, and SO_4^{-2} were determined by ion chromatography in a 1:20 (w/v) water extract. For the analysis of NH_4^+–N, C_{org}, N_T, N_{org}, and CEC, the methods were the same as for the organic wastes. The 0.5 M $NaHCO_3$-extractable phosphorus (P_{AV}) was determined according to the Watanabe and Olsen method and the Na_W and 1 M NH4OAc-extractable potassium (K_{AV}) by flame photometry. Equivalent $CaCO_3$ was measured in an acid medium using a Bernard calcimeter, particle size by the pipet method, and texture was determined from the particle size analysis using the texture diagram of the United States Salinity Laboratory Staff (Kalra and Maynard, 1991).

Different organic fertilization treatments were added to soil during soil preparation as 30 m^3 $fed.^{-1}$ for animal dung, rice straw with OMW compost, the conventional rice straw compost referring to Abdelbasset et al. (2009), and 20 m^3 of the animal dung as the control treatment.

Foliar application treatments of zinc sulphate with different concentration i.e., 0, 10, 20 and 30 ppm were applied into barley plants at the late tillering stage (45 days after sowing date) in both seasons referring to Abd El-Hady (2007).

The experimental design used in this experiment was split plot design in three replicates, where the organic fertilization treatments occupied the main plots, and zinc sulphate treatments were arranged in the sub-main plots.

The physical and chemical properties of the experimental soil are shown in Tables 2 and 3, while the chemical analysis of the irrigation water is shown in Table 4 according to Abd El-Hady (2007).

Ten guarded barley plants were taken as sample at heading stage (110 days after sowing date) to determine growth characters i.e., plant height (cm), plant fresh weight (g), plant dry weight (g), number of tillers per plant in addition to total chlorophyll using Minolta SPDA-502 leaf chlorophyll meter then converted into total chlorophyll (a + b) as $\mu mol\ m^{-2}$ referring to John et al. (1988) and free proline (μmol proline/g fresh weight) as indicted by Bates (1975). At harvested, (150 days from sowing date) one square metre plants were harvested, then converted into kg per feddan to determine yield and its attributes i.e., spike length (cm), weight of 1000 grains (g), biological yield (kg/fed.), grain yield (kg/fed.), straw yield (kg/fed.) and harvest index (%).

Pooled data were subjected to analyses by M-STAT C, (Russell, 1991), while Duncan's multiple range test was used to verify the significant differences between treatments means as described by Duncan, 1955.

Table 2 The physical and chemical properties of the experimental soil at El-Tena plain – North Sinai.

Soil depth	Sand	Silt	Clay	Text	pH	EC_e	O.M.	Pb (g/cm^3)	$CaCo_3$
0–15	55.0	36.6	8.3	SL	8.32	15.45	0.58	1.77	10.9
15–30	61.6	29.9	8.5	SL	8.4	17.65	0.51	1.81	8.5
30–60	46.7	43.3	10	L	8.68	20.6	0.51	1.78	9.5

Table 3 Continuation of the chemical properties of the experimental soil at El-Tena plain – North Sinai.

Soil depth	($mg\ kg^{-1}$)										
	Na	K	Ca	Mg	Cl	SO_4	Fe	Mn	Zn	HCO_3	CO_3
0–15	83.9	4.1	38.6	15.4	128	51.2	7.7	3.26	1.56	1.4	0
15–30	125	7.6	29.2	70.4	150	80.6	6.1	3.46	0.4	1.32	0
30–60	106	5.4	30.8	54.4	182	13.2	6.58	4.9	0.7	1.1	0

Table 4 The chemical properties of the irrigation water at El-Tina plain – North Sinai.

EC (dSm^{-1})	pH	Cations ($mg\ L^{-1}$)				Anions ($mg\ L^{-1}$)			
		Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Cl^{-}	SO_4^{-2}	HCO_3^{-}	CO_3^{-2}
1.56	7.95	2.40	3.5	0.3	11.8	8.6	6.1	3.6	0.0

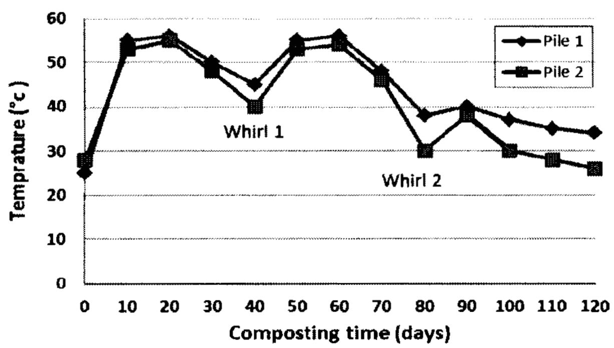

Fig. 1 Temperature development during composting of pile 1 [animal dung (AD) + rice straw (RS) + olive mill wastewater (OMW)] and pile 2 (AD + RS).

Results and discussion

Composting process

The temperature increased quickly at the beginning of the process to thermophilic values, reaching the ceiling level (Fig. 1).

In both piles the temperature was equal or above 55 °C for about 15 days, which contributed to the hygienization and sanitization of the end-product due to pathogen, weed and seed reduction. When the temperature started to decrease, the piles were turned (whirl) twice once every 40 days in order to improve both the homogeneity of the material and the fermentation process. The thermophilic phase lasted at least 40 days after both whirls.

The biooxidative phase of composting was considered finished when the temperature of the piles was stable and close to that of the atmosphere. This occurred after 120 days for both piles.

The chemical properties, total plant nutrient and heavy metal concentrations in mature composts (dry weight basis) are shown in Table 5.

As presented in Table 5, the higher EC in the pile containing OMW was clear from the beginning of the process and was probably due to the soluble salts provided from OMW. In addition to the reduction of the C_{org} concentration in both piles, another consequence of the organic matter degradation was that the C/N ratio reached values below 12, which suggested that both composts had an acceptable degree of maturation (Bernal et al., 1998).

Table 5 Chemical properties of the produced compost Pile 1: AD + RS + OMW and Pile 2: AD + RS, as dry weight basis.

Parameter	Pile 1	Pile 2	Parameter	Pile 1	Pile 2
OM (%)	56.3 a	64.8 a	N_T ($g\ kg^{-1}$)	31.1 a	36.5 a
pH	7.58 a	8.01 a	P ($g\ kg^{-1}$)	8.7 a	7.1 b
EC_e ($ds\ m^{-1}$)	0.73 a	0.67 b	K ($g\ kg^{-1}$)	38.4 a	47.3 a
C_{org} ($g\ kg^{-1}$)	293.6 b	355.5 a	Ca ($g\ kg^{-1}$)	72.9 a	64.8 b
C_w (%)	0.89 a	1.12 a	Mg ($g\ kg^{-1}$)	10.5 a	10.6 a
N_T ($g\ kg^{-1}$)	31.1 b	36.3 a	Fe ($mg\ kg^{-1}$)	5000 a	3800 b
NH_4^+–N ($mg\ kg^{-1}$)	315 b	400 a	Cu ($mg\ kg^{-1}$)	52 a	38 b
No_3^-–N ($mg\ kg^{-1}$)	2739 b	5200 a	Mn ($mg\ kg^{-1}$)	241 a	220 b
C/N	9.4 a	9.8 a	Zn ($mg\ kg^{-1}$)	245 a	213 b
C_{HA}/C_{FA}	0.74 b	3.35 a	Ni ($mg\ kg^{-1}$)	63 a	22 b
CEC[a] ($meq\ 100\ g^{-1}$)	233.2 b	285.3 a	Cr ($mg\ kg^{-1}$)	70 a	34 b
GI (%)	94.4 a	70.3 b	Cd ($mg\ kg^{-1}$)	5 a	4 a
C_W/N_{org}	0.32 a	0.37 a	Pb ($mg\ kg^{-1}$)	68 a	55 b

N_{org}: Organic N, C_{HA}/C_{FA}: Ratio of humic acid lick C/fulvic acid lick C, CEC[a]: cation exchange capacity, GI: germination index, C_w: water soluble organic carbon.
Means having similar letters in the same column are not statistically differed at $P \geqslant 0.05$.

Table 6 Effect of organic fertilization treatments on barley growth characters, yield and its attributes.

Organic fertilization treatments	Plant height (cm)	Plant fresh weight (g)	Plant dry weight (g)	No. tillers/plant	Spike length (cm)	No. grains/ spike	Wight 1000 grains (g)	Biological yield (kg/ fed.)	Grain yield (kg/fed.)	Straw yield (kg/fed.)	Harvest index (%)
Conventional[b]	53.7 c	3.15 c	1.064 c	2.3 b	5.8 c	25.7 c	0.644 c	1969 c	588 c	1381 c	29.9 b
Animal dung 30 m^3	55.5 b	3.90 b	1.160 b	2.4 b	6.5 b	27.7 b	0.764 b	2119.3 b	667.9 b	1451.4 b	31.5 b
Rice straw & OMW[a] compost	57.3 a	4.05 a	1.374 a	2.6 ab	7.1 a	29.1 a	0.835 a	2237.5 a	731.3 a	1506.2 a	32.7 ab
Rice straw compost	59.2 a	4.20 a	1.261 a	3.0 a	7.3 a	30.3 a	0.907 a	2303.8 a	764.1 a	1539.7 a	33.2 a

Means having similar letters in the same column are not statistically differed at $P \geqslant 0.05$.
[a] OMW is Olive Mill Wastewater.
[b] Conventional: 20 m^3 $fed.^{-1}$ animal dung.

The C_W fraction includes the easily degradable organic compounds and is the most microbiologically active phase. Therefore, the C_W concentration mainly decreased during the bio-oxidative phase, although C_W continued to be mineralized during the maturation period. The C_W level of the mature composts was below 1.7%, so that both composts could be considered as sufficiently mature (Bernal et al., 1998). The C_W/N_{org} ratio also fell during the composting process to reach, in both composts, values below 0.55 that was declared by Bernal et al. (1998).

The N_T and NH_4^+–N concentration expressed high values in both piles as indicated by Paredes et al. (2002) which happened probably as a consequence of a concentration effect caused by the reduction in pile weight, which induced an

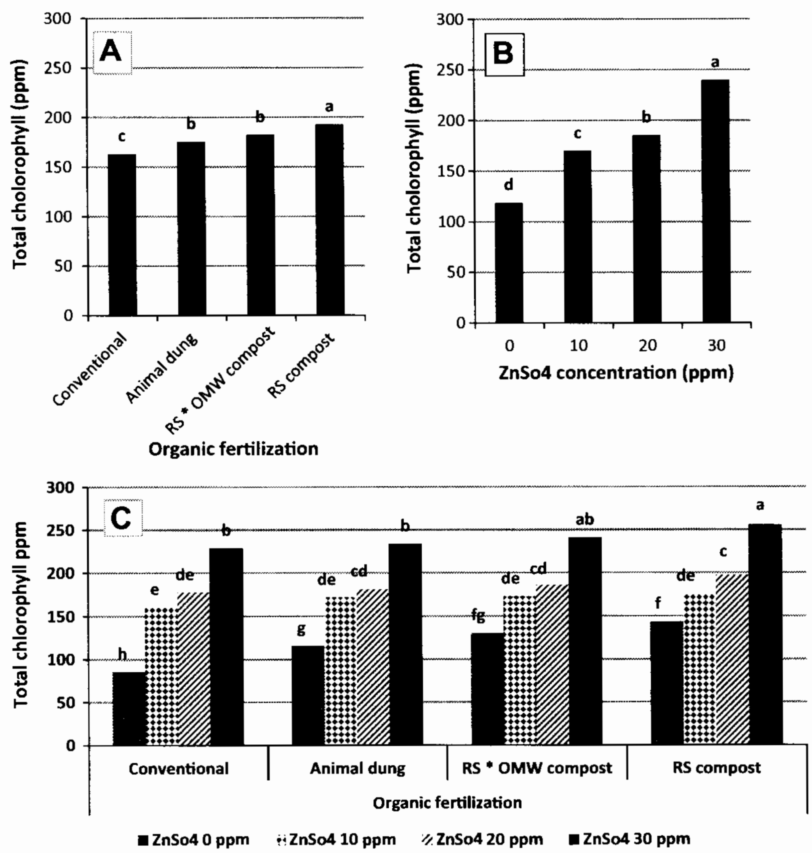

Fig. 2 Total chlorophyll as affected by: (A) different organic fertilization treatments; (B) foliar application with different concentration of $ZnSO_4$ (p.p.m); and (C) the interaction between different organic fertilization treatments and the $ZnSO_4$ foliar application with different concentrations.

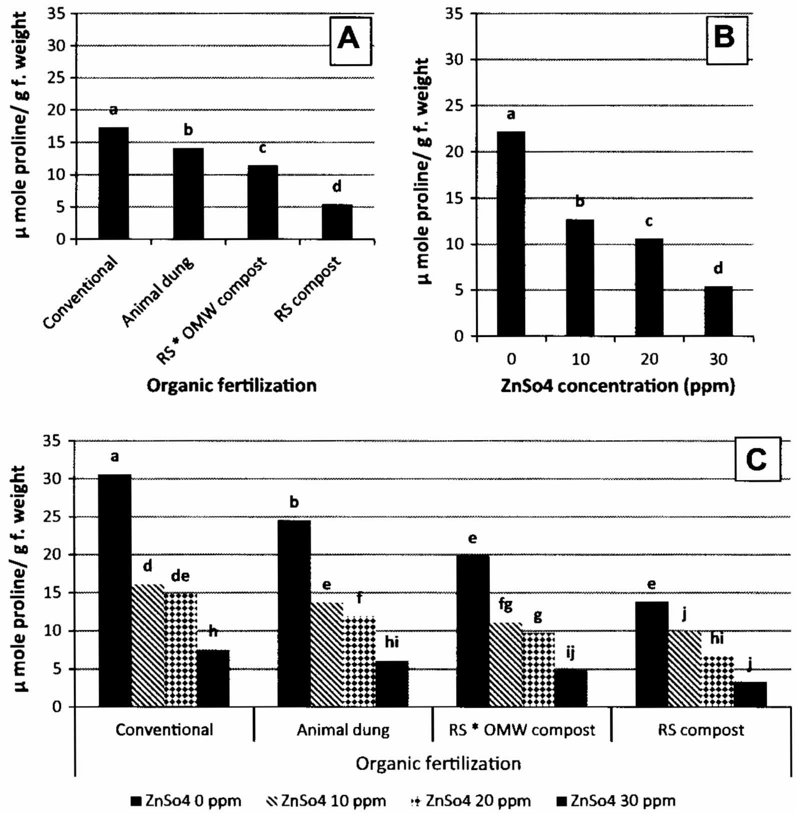

Fig. 3 Free proline (µ mole/g fresh weight) as affected by: (A) different organic fertilization treatments; (B) foliar application with different concentration of $ZnSO_4$ (p.p.m); and (C) the interaction between different organic fertilization treatments and the $ZnSO_4$ foliar application with different concentrations.

increase at the beginning of the process through organic N mineralization, but then diminished, due to either volatilization losses or nitrate formation.

Both piles reached an NH_4^+–N level below or close to 400 mg kg^{-1} after the maturation period, which is the maximum recommended value for a mature compost (Zucconi and De Bertoldi, 1987). Although substantial quantities of nitrate were found in both piles, nitrification was clearly lower in the pile with OMW which may be related to the higher E_C values of this mixture. After the maturation period the NH_4^+/NO_3 values were 0.12 and 0.08 in piles 1 and 2, respectively so that both composts could be considered sufficiently mature according to the maximum level of 0.16 suggested by Bernal et al. (1998).

The ratio of (humic acid-like C/fulvic acid-like C) (C_{HA}/C_{FA}) did not show a clear tendency in pile 1; however, it rose in pile 2, indicating the humification of the OM. The OM humification process also led to an increased CEC during the bio-oxidative and maturation phases of both piles. It is interesting to point out that both composts reached GI values above 50%, indicating that the application to soil of the products obtained would not injure plants (Zucconi et al., 1981). The high phenol and organic acid contents of the OMW were probably responsible for the initial phytotoxicity of pile 1 with respect to pile 2.

Both composts had high levels of macronutrients, especially K, compared with those found by Cegarra et al. (1993) in composts, made from manures, which were used commonly as

Table 7 Effect of zinc sulphate fertilization foliar treatments on barley growth characters, yield and its attributes.

Foliar application with $ZnSO_4$	Plant height (cm)	Plant fresh weight (g)	Plant dry weight (g)	No. tillers/plant	Spike length (cm)	No. grains/ spike	Wight 1000 grains (g)	Biological yield (kg/ fed.)	Grain yield (kg/fed.)	Straw yield (kg/fed.)	Harvest index (%)
Control	52.0 d	3.16 d	1.055 d	1.8 d	6.1 d	24.1 d	0.604 d	2040.2 d	629.6 d	1410.7 d	30.9 d
10 ppm	56.6 c	3.69 c	1.266 c	2.5 c	6.4 c	26.9 c	0.733 c	2141.8 c	684.5 c	1457.4 c	32 c
20 ppm	57.9 b	4.10 b	1.261 bc	2.8 b	6.9 b	29.2 b	0.824 b	2185.6 b	703.7 b	1481.9 b	32.2 b
30 ppm	59.2 a	4.36 a	1.322 a	3.1 a	7.2 a	32.6 a	0.988 a	2262 a	733.7 a	1528.3 a	32.4 a

Means having similar letters in the same column are not statistically differed at $P \geqslant 0.05$.

Table 8 Effect of the interaction between organic fertilization and zinc sulphate foliar application treatments on barley growth characters, yield and its attributes.

Treatments		Plant height (cm)	Plant fresh weight (g)	Plant dry weight (g)	No. tillers/plant	Spike length (cm)	No. grains/ spike	Wight 1000 grains (g)	Biological yield (kg/ fed.)	Grain yield (kg/ fed.)	Straw yield (kg/fed.)	Harvest index (%)
Organic fertilization	$ZnSO_4$ (p.p. m.)											
Conventional[b]	0	50.3 n	2.13 j	0.990 i	1.5 k	5.7 k	22.0 l	0.490 l	1896.2 n	552.1 m	1344.2 l	29.1 o
	10	51.1 m	3.31 i	1.040 h	1.6 k	5.7 k	23.9 k	0.576 k	2019.9 k	624.0 j	1395.9 j	30.9 k
	20	52.4 l	3.53 h	1.065 gh	1.8 j	6.4 h	24.9 j	0.650 i	2073.4 i	647.6 i	1425.8 i	31.2 j
	30	54.3 j	3.65 g	1.123 f	2.4 g	6.5 g	25.5 j	0.701 h	2171.3 f	694.6 f	1476.7 f	32.0 f
Animal dung 30 m³	0	53.6 k	3.25 i	1.040 h	2.0 i	5.7 k	24.9 j	0.623 j	1953.8 m	578.8 l	1375.1 k	29.6 n
	10	55.8 h	3.60 gh	1.072 g	2.2 h	5.9 j	26.2 i	0.705 h	2103.6 h	663.5 h	1440.2 h	31.5 i
	20	57.6 f	3.85 f	1.401 b	2.5 fg	6.8 f	27.7 h	0.765 g	2210.3 e	728.4 d	1481.9 f	33.0 e
	30	59.4 d	4.04 e	1.151 ef	3.1 cd	7.2 d	28.9 f	0.840 e	2299.5 d	767.2 c	1532.3 d	33.4 b
Rice straw & OMW[a] compost	0	55.1 i	3.54 h	1.062 gh	2.2 h	5.9 j	26.2 i	0.665 i	1981.4 l	593.9 k	1387.5 j	30.0 m
	10	56.7 g	4.17 d	1.176 e	3.1 cd	7.0 e	28.3 g	0.792 f	2130.7 g	676.4 g	1454.3 g	31.7 h
	20	59.0 d	4.26 d	1.257 d	2.8 e	7.4 c	30.2 d	0.877 d	2293.9 d	759.8 c	1534.1 d	33.1 d
	30	61.0 b	4.41 c	1.369 c	3.2 c	7.6 b	32.0 c	0.962 c	2336.2 c	784.5 b	1551.7 c	33.6 a
Rice straw compost	0	56.0 h	3.68 g	1.165 e	3.3 b	6.0 i	29.6 e	0.797 f	2044.6 j	627.5 J	1417.1 i	30.7 l
	10	58.3 e	4.49 c	1.351 c	2.6 f	7.3 cd	32.5 c	0.983 c	2223.0 e	707.8 e	1515.3 e	31.8 g
	20	60.3 c	4.58 b	1.372 c	3.1 d	7.6 b	33.4 b	1.047 b	2372.3 b	789.4 b	1582.9 b	33.3 c
	30	62.2 a	4.69 a	1.802 a	3.5 a	7.8 a	34.9 a	1.124 a	2408.0 a	810.0 a	1598.0 a	33.6 a

Means having similar letters in the same column are not statistically differed at $P \geqslant 0.05$.
[a] OMW is Olive Mill Wastewater.
[b] Conventional: 20 m^3 $fed.^{-1}$ animal dung.

organic fertilizers. Also, these composts showed potentially toxic heavy metal contents lower than the limits established by the second draft on Biological Treatment of Bio-waste of the European Commission (2001) for compost and stabilized bio-waste.

Effect of organic fertilization treatments on barley growth characters, yield and its attributes and chlorophyll & free proline contents

Results that illustrated in Table 6 indicate that applying the organic fertilization led to increase barley plant height (cm), plant fresh weight (g), plant dry weight (g), spike length (cm), weight of 1000 grains (g), biological yield (kg/fed.), grain yield (kg/fed.) and straw yield (kg/fed.). The highest observations were obtained from RS-compost and OMW-RS compost with no significant differences in between, followed by significant differences between 30 m^3 $fed.^{-1}$ of animal dung and its conventional dose respectively. In regard to the number of tillers per plant and harvest index, results indicated that there were no highly significant differences between the treatments.

In regard to the total chlorophyll (μmol m^{-2}) results shown in Fig. 2(A) indicated that highest significant observations were obtained from applying the RS-compost followed by RS-OMW compost and 30 m^3 $fed.^{-1}$ of animal dung with no significant differences in between and the animal dung conventional dose respectively. Concerning free proline (μmol proline/g fresh weight) as presented in Fig. 3(A), higher significant observations were obtained from applying the animal dung conventional dose then the 30 m^3 $fed.^{-1}$ of animal dung followed by RS-OMW compost then RS compost respectively.

These results agreed with what observed by Bernal et al. (1993) and Paredes et al. (2006), and they suggested that applying the compost either RS or RS-OMW compost had positive impacts on saline soil properties and thus plant nutrition and therefore growth and productivity as proved by the total chlorophyll content in contrast with the free proline content and even more than the 30 m^3 $fed.^{-1}$ of animal dung then its conventional dose respectively because of the needed long period of animal dung decomposition in the soil. As RS-OMW compost had higher values of EC than RS compost, it may be a risk if we applied high doses of RS-OMW compost into saline soils, but it is much recommended to use it in saline soils that are not affected by secondary salinization.

Effect of zinc sulphate foliar fertilization treatments on barley growth characters, yield & its attributes and chlorophyll & free proline contents

Results that illustrated in Table 7 indicate that when the zinc sulphate was applied as foliar fertilization treatments on barley, it led to increase plant height (cm), plant fresh weight (g), plant dry weight (g), spike length (cm), weight of 1000 grains (g), biological yield (kg/fed.), grain yield (kg/fed.) and straw yield (kg/fed.). The highest observations were obtained from zinc sulphate foliar application with 30 ppm followed by 20 ppm then 10 ppm and then the control treatment respectively. The same trend was obtained in regard to the total chlorophyll (μmol m^{-2}); as shown in Fig. 2(A), while the opposite trend was obtained in regard to free proline (μmol proline/g fresh weight); where the highest significant results were obtained from 0 ppm, followed by 10, 20 then 30 ppm respectively as shown in Fig. 2(B). These agreed with the results observed by Abd El-Hady (2007), and he suggested that Zn has a control mechanism and/or a regulatory function regarding the Na and Cl uptake and translocation rate. As the role of Zn in this mechanism is not yet explained clearly, Zn might play an important role in the integrity and function of the biomembranes of plants. It seems that application of Zn-fertilizer has positive effects on curing the toxicity of Sodium and Cl that existed under saline conditions thus improved significantly plant growth and yield of barley plant under these stressful conditions.

Effect of the interaction between different organic fertilization treatments and different concentration of zinc sulphate foliar application on barley growth characters, yield & its attributes and chlorophyll & free proline contents

Results in Table 8 indicated that the interaction between different organic fertilization treatments and different concentration of zinc sulphate foliar application enhanced significantly plant height (cm), plant fresh weight (g), plant dry weight (g), spike length (cm), weight of 1000 grains (g), biological yield (kg/fed.), grain yield (kg/fed.) and straw yield (kg/fed.). The highest observations were obtained from the interaction between (RS-compost × 30 ppm $ZnSO_4$). In regard to the total chlorophyll (μmol m^{-2}) results shown in Fig. 2(C) indicated that highest significant observations were obtained from the interaction between (RS-compost × 30 ppm $ZnSO_4$) and (RS-OMW compost × 30 ppm $ZnSO_4$) respectively but with no significant differences in between. With respect to free proline (μmol proline/g fresh weight) as presented in Fig. 3(C), higher significant record was obtained from the interaction between (Conventional × 0 ppm $ZnSO_4$). This may illuminate that the integration between the mode of actions between the two studied factors i.e. organic fertilization treatments and $ZnSO_4$ application may improve the soil properties under saline conditions, while $ZnSO_4$ foliar application may possibly improve the plant metabolism and cure the toxicity of sodium and chlorine under these stressful conditions as reported by Paredes et al. (2006) and Abd El-Hady (2007) respectively.

Conclusion

Olive mill wastewater (OMW) is the main waste in olive oil extraction industry. Because of its high organic load and content of phytotoxic and antibacterial phenolic substances, it resists biological degradation. Composting of OMW to obtain organic fertilizers could be an economically and environmentally acceptable way to dispose it. Both the OMW and without OMD composts had higher OM and lower potentially toxic heavy metal contents than the limits established by the European legislation for compost and stabilized bio-waste. The OMW compost application to soil did not lead to phytotoxic effects on barley plants, producing plant yields similar to those of compost without OMW and more than the conventional organic fertilizer. The higher values of EC in OMW could be a major concern regarding the use of OMW compost at high rates in saline soil.

Zinc sulphate ($ZnSO_4$) foliar application had a control mechanism and/or a regulatory function regarding the Na and Cl uptake and translocation rate. It also might play an important role in the integrity and function of the biomembranes of plants. It has as well positive effects on curing the toxicity of Sodium and Cl that existed under saline conditions thus improved significantly plant growth and yield of barley plant under these stressful conditions.

The integration between OMW compost and ($ZnSO_4$) foliar application led to improve the soil properties, and may possibly improve the plant metabolism and cure the toxicity of sodium and chlorine under saline conditions.

The results of free proline content expressed how much the plant was exposed to the salt stress; i.e. the higher the free proline content of the environment the more stressful conditions the plant was living in.

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