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Composting: a useful tool to improve the agronomic aptitude of sewage sludge in saline soil for growing durum wheat

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ABSTRACT

A field-scale experiment established the agronomic performance of air-dried sewage sludge and composted sludge for winter wheat. The objective of the study was to initial measure the response of nutrient uptake once applying air-dried sewage sludge, composted sewage sludge and a commercial fertiliser to soil in grain and straw of winter wheat (Triticum turgidum L. cv. Vitron), to research the variations within the main soil characteristics in relevancy the initial soil once applying fertilizer treatments, and to determine the variations among treatments once harvest. Composted sewage sludge kept constant the organic matter level in soil after harvest and promoted higher Zn, Cu and Mn contents and yields than air-dried sewage sludge or the commercial fertiliser. No significant differences occurred among treatments for the studied parameters, except for nitrogen, organic matter and Zn in soil. Fe and Cu content in straw were higher when air-dried sewage sludge was used. No significant differences in grain nutrients content were observed.

Variations in soil composition were similar among treatments. Since no nutritional imbalances were observed in the grain or straw of durum wheat, sewage sludge from the Alcázar de San Juan WWTP (especially composted) is recommended as an alternative to standard commercial fertilisation.

Key words: *Sewage sludge, Agronomy*

Introduction

Sewage sludge is an unavoidable by-product in wastewater treatment processing which isn't mentioned as a source of recyclable nutrients within the European Commission's draft revision of the Fertiliser Regulation. Including it might provide a crucial source of nutrients and contribute to Circular Economy, while reducing costs and needs on imports.

Improper management of this waste would cause secondary pollution by, for instance, pathogens or heavy metals [1]. In any case, the agronomical aptitude of using sewage sludge in different crops has been repeatedly studied and tested in scientific studies for years [2-9].

Although it is not a replacement issue, it seems to be essential an accurate classification of individual wastewater sludges so on manage decisions about their specific use [10]. The agronomic use of sewage sludge within the EU is regulated by Directive 86/278/EEC. The alternatives for the disposal of sludge are agricultural use, composting, incineration, and landfill [11,12]. The Spanish legislation (Royal Decree 1310/90) is in accordance with the aforementioned European Directive, consistent with both laws the permissible levels of heavy metal concentrations in sludge and soil to which sludge is to be applied, and thus the utmost annual quantities of heavy metals which can be introduced into agricultural soils, are provided in Tables 1 and 2 Anyhow, the characteristics of sludge depend upon the degree of pollution, the character of the pollutants within the wastewater subjected to treatment and therefore the methods of treating the sludge [13].

Table 1: Characteristics of the original soil. Results were interpreted according to Yañez (1989)[21].

Parameter	Units	Value	Interpretation	
Sand	%	58		
Silt	%	39	Sandy loam texture (USDA)	
Clay	%	4		
pH		9.15	Very basic	
E.C.	mmhos cm^{-1}	13.65	Very saline	
Chloride	mg kg^{-1}	153	High	
Sulphate	mg gypsum 100^{-1} g soil	2102		
Organic matter	%	2.22	Medium	
Total N	%	0.1	Low	
C:N Ratio		13	Low nitrogen release	
Nitric N	mg kg^{-1}	19		
Assimilable P	mg kg^{-1}	9	Low	
Total Carbonates	%	15.6	Medium	
Active limestone	%	7.2	Medium	
Assimilable K	meq 100 g^{-1}	0.77	High	
Assimilable Na	meq 100 g^{-1}	3.8	Very high	
Assimilable Ca	meq 100 g^{-1}	87.14	Very high	
Assimilable Mg	meq 100 g^{-1}	17.74	Very high	
K:Mg Ratio		0.04	Possibly Mg deficiencies	
Ca:Mg Ratio		4.9	Possibly Mg deficiencies	
Cation Exchange Capacity (CEC)	meq 100 g^{-1}	10	Correct	
Assimilable Fe	mg kg^{-1}	0.35	Low	
Assimilable Zn	mg kg^{-1}	0.38	Medium	
Assimilable Cu	mg kg^{-1}	0.35	Medium	
Assimilable Mn	mg kg^{-1}	2.15	Medium	
Assimilable B	mg kg^{-1}	2.45	Without deficiencies	
			R.D. 1310/90 values limit	
			Soil with pH<7	Soil with pH>7
Total Cd	mg kg^{-1}	<0.10	1	3
Total Cu	mg kg^{-1}	<1.00	50	210
Total Cr	mg kg^{-1}	2.21	100	150
Total Hg	mg kg^{-1}	<0.10	1	1.5
Total Ni	mg kg^{-1}	1.5	30	112
Total Pb	mg kg^{-1}	4	50	300
Total Zn	mg kg^{-1}	<20.0	150	450

Table 2: Characteristics of the three substrates (Alcázar de San Juan WWTP sewage sludge, composted sewage sludge and commercial fertiliser) used in the study (d.m.: dry matter; T.U.: toxicity units; c.f.u.: colony-forming units).

Parameters	Units	Air-dried sewage sludge	Composted sewage sludge	Commercial fertiliser		
pH		6.99	6.44			
Moisture	%	84.66	9.33			
Electrical conductivity	µS cm^{-1}	3096	5830			
Total organic matter	% d.m.	68.5	52	22		
Total N	% d.m.	6.15	4.17	8		
P2O5	% d.m.	5.82	5.33	11.5		
K2O	% d.m.	0.28	0.46	8		
CaO	% d.m.	6.54	11.61			
MgO	% d.m.	0.9	1.28			
Fe	mg kg^{-1} d.m.	50688	10218			
C:N Ratio		6.32	6.77			
Salmonella spp	Salmonella/25 g	Absence	Absence			
E. coli	c.f.u.	1.2 105	<10			
Compost Maturity Index			6			
Toxicity	T.U.		<2			

					R.D. 1310/90 Values limit for sewage sludge	
					Soil with pH<7	Soil with pH>7
Cd	$mg\ kg^{-1}$ d.m.	0.35	2.4		20	40
Cu	$mg\ kg^{-1}$ d.m.	191	118	208	1,000	1,750
Ni	$mg\ kg^{-1}$ d.m.	24.8	26.5		300	400
Pb	$mg\ kg^{-1}$ d.m.	29.8	30.1		750	1,200
Zn	$mg\ kg^{-1}$ d.m.	510	433	559	2,500	4,000
Hg	$mg\ kg^{-1}$ d.m.	0.46	<0.2		16	25
Cr	$mg\ kg^{-1}$ d.m.	31.2	35.4		1,000	1,500

Composting is an applicative technique for converting sewage sludge into safe and stable compost reused in agricultural application. Besides, composting organic waste has long since been considered an attractive sludge management option to effectively reduce its volume, and it facilitates its management [14].

Then again, soil degradation and salinisation are two of the utmost threats to affect agricultural areas and derive from the increasing use of poor quality water and inappropriate cultural practices [15,16]. In saline soil, Na^+ constitutes a highly dispersive agent that leads on to the breakup of aggregates. it's a well-known incontrovertible fact that salt concentration in soil, especially NaCl, is one among the factors that would negatively affect germination and crop development. The beneficial use of sewage sludge for not only conventional agricultural applications, but also to remedy seriously degraded soils, has been studied [17]. In this sense, sewage sludge composted uses do not completely solve the underlying explanation for the salinity problem, but improve soil physico-chemical properties, microbial biomass and plant growth in saline soils. It offers a short-term reprieve for farming on soils with medium to high salinity or in soils with temporary high salinity[15]. The role of compost in salt-affected soils is significant because the organic source is that the ultimate opportunity to enhance the physical properties of those soils1 [16].

Wheat (*Triricum aestivum L.*) is that the most generally cultivated crop within the world because of its wide adaptation to local environments and good processing properties [18]. It provides up to 50% of the entire calorie intake in several areas like the Mediterranean Basin and other regions with an identical climate. According Forte (2018) [19], in Spain the production of durum wheat, although much less than *Triticum aestivum*, experienced a rise throughout the amount into account, and reached over 1 million metric tons in 2017. Wheat is grown mainly without irrigation so yields answer wide rainfall variability (240-700 mm). Winter wheat is sown in October–December and spring wheat in February–March. Wheat is harvested between late June and mid-August.

The starting hypothesis of this work is that composting the sludge from the Alcázar de San Juan WWTP can improve its aptitude for agricultural use in saline soil and does not produce nutritional imbalances in wheat crops. To verify this, the main goal of this field trial was to assess the response of nutrient uptake after applying three different fertiliser treatments (air-dried sewage sludge commercial fertiliser, or composted sewage sludge) to winter wheat (*Triticum turgidum* L. cv. Vitron). The objectives of this study were to investigate: (i) variations in the main soil characteristics in relation to the original soil after applying sewage sludge, compost and a commercial fertiliser and comparing among treatments after harvest; (ii) the nutrient content (macro- and micronutrients) in the grain and straw of durum wheat after applying the above fertiliser treatments; (iii) yield differences among the fertiliser treatments applied to soil.

Results

As Table 1 shows, the original test soil plot texture was sandy loam [20] (sand: 58%; silt: 39%; clay: 4%), very basic pH [21] (9.15), which was very saline according to electrical conductivity (13.65 mmhos cm^{-1}) and cation exchange capacity (10 meq 100 g^{-1}) was correct. The C:N ratio (13) indicated low nitrogen release. Organic matter (2.22%), total carbonates (15.60%), active limestone (7.20%), assimilable Zn (0.38 mg kg^{-1}), assimilable Cu (0.35 mg kg^{-1}) and assimilable Mn (2.15 mg kg^{-1}) contents (Table 2) were medium; total nitrogen (0.10%), assimilable P (9 mg kg^{-1}) and assimilable Fe (0.35 mg kg^{-1}) levels were low. Both ratios Ca:Mg (4.9) and K:Mg (0.04) suggested possible Mg deficiencies, with no deficiencies regarding assimilable B content (2.45 mg kg^{-1}). Chloride (153 mg kg^{-1}) and assimilable K (0.77 mg kg^{-1}) levels were high, while assimilable Na (3.80 meq 100 g^{-1}), assimilable Ca (87.14 meq 100 g^{-1}) and assimilable Mg (17.74 meq 100 g^{-1}) contents were very high.

Table 3 shows the soil composition after applying studied treatments F, S and C.

Table 3: Soil composition after applying the studied treatments (F, S and C). P-value when comparing treatments: Different letters mean groups with significant differences at P<0.05 among treatments according to the LSD test. (*) denotes significant differences. (**) N-soil was calculated according to the equation N-soil = (N-nitric x 50)/(10xdensity), where N-nitric is expressed as mg kg^{-1} and density is 1.

	pH	Electrical Conductivity mmhos cm^{-1}	Chloride mg kg^{-1}	Sulphate mg 100^{-1} g	Total organic matter (e%)	Total -N %	C:N	Nitric-N mg kg-1	Soil-N kg ha^{-1} (**)	Assimilable P mg kg^{-1}	Total Carbonates %
F	9.14 a	19.86 a	286.3 a	857 a	1.6 a	0.15 a	6.36 a	25.0 a	94 a	< l.d.	14.19 a
S	9.01 a	18.56 a	362.6 a	860 a	1.8 a	0.16 a	6.7 a	38.0 b	143 b	< l.d.	15.18 a
C	9.01 a	18.38 a	327.3 a	860 a	2.25 b	0.20 b	6.46 a	40.7 b	153 b	< l.d.	13.34 a
P-valor	0.546	0.9607	0.65	0.9965	0.0077*	0.0406*	0.9763	0.0094*	0.0101*	--	0.7015
	K:Mg	**Ca:Mg**	**Assimilable Fe mg kg^{-1}**	**Assimilable Zn mg kg^{-1}**	**Assimilable Cu mg kg^{-1}**	**Assimilable Mn mg kg^{-1}**	**Assimilable B mg kg^{-1}**	**CEC meq 100^{-1} g**	**Assimilable K meq 100^{-1} g**	**Assimilable Na meq 100^{-1} g**	**Assimilable Ca meq 100^{-1} g**
F	0.05 a	3.03 a	0.30 a	0.34 a	0.38 a	3.54 a	3.59 a	12.27 a	1.89 a	6.80 a	100.1 a
S	0.09 a	3.86 a	0.50 a	0.92 b	0.46 a	3.88 a	5.83 a	15.26 a	2.16 a	5.88 a	93.28 a
C	0.06 a	2.80 a	0.40 a	0.94 b	0.49 a	3.92 a	4.43 a	15.10 a	2.06 a	7.16 a	100.05 a
P-valor	0.5112	0.5975	0.438	0.0257*	0.4301	0.9349	0.4923	0.1648	0.6826	0.7266	0.3756

Table 4: Average contents of macronutrients (N, P, K, Mg, Ca and Na) and micronutrients (Fe, Mn, Cu, Zn and B) in wheat grain (A) and straw (B). F: Commercial fertiliser; S: Sewage sludge; C: Compost. Different letters mean groups with significant differences at P<0.05 among treatments according to the LSD test. (*) Denotes significant differences.

	Treatment	N%	P%	K%	Mg%	Ca%	Na%	Fe p.p.m.	Mn p.p.m.	Cu p.p.m.	Zn p.p.m.	B p.p.m.
(A)	F	2,45 a	0,25 a	0,53 a	0,13 a	1,03 a	0,57 a	73,33 a	22,67 a	3,33 a	35,11 a	0,20 a
	S	2,74 b	0,24 a	0,51 a	0,14 a	1,04 a	0,12 a	45,67 a	20,67 a	2,67 a	34,78 a	0,31 a
	C	2,53 ab	0,25 a	0,49 a	0,13 a	1,04 a	0,51 a	66,22 a	18,33 a	2,11 a	34,22 a	0,55 a
	P-value	0,0990	0,9722	0,5789	0,4921	0,9885	0,1642	0,2213	0,2041	0,3262	0,9862	0,3809
(B)	**Treatment**	**N%**	**P%**	**K%**	**Mg%**	**Ca%**	**Na%**	**Fe p.p.m.**	**Mn p.p.m.**	**Cu p.p.m.**	**Zn p.p.m.**	**B p.p.m.**
	F	0,57 a	0,06 a	1,96 a	0,32 a	1,18 a	1,2 a	42 ab	9,88 a	1,1 a	8,7 a	42,4 a
	S	0,75 a	0,07 a	1,77 a	0,44 a	1,16 a	1,4 a	57 b	8,33 a	5,0 b	10,2 a	34,7 a
	C	0,76 a	0,07 a	1,69 a	0,42 a	1,32 a	1,05 a	41 a	6,77 a	1,3 ab	7,6 a	33,1 a
	P-value	0,1517	0,4269	0,1612	0,1992	0,2772	0,2605	0,0072*	0,3559	0,0004*	0,0172*	0,8944

No significant differences were found between treatments in the post-harvest analysis, except for N (Total-N, Nitric-N and Soil-N), organic matter and Zn. The increase in Total-N in soil was promoted more with compost (0.20%), with significant differences than with sludge (0.16%) or the commercial fertiliser (0.15%). In contrast, no significant differences between S and C occurred with N-nitric (S: 38.0%; C: 40.7%) and Soil-N (S: 143 kg ha^{-1}; C: 153 kg ha^{-1}) compared to these same parameters with treatment F (94 kg ha^{-1}).

Comparing soil composition before (Table 2) and after treatments (Table 3), we can state that electrical conductivity, chloride, N, Mn, B, cation exchange capacity, K, Na and Ca values increased with all the treatments (F, S and C), and only sulphate and the assimilable phosphorus content were lower than the original soil by the end of the study.

The post-harvest Zn content in soil was significantly higher in S (0.92 mg kg^{-1}) and C (0.94 mg kg^{-1}) than in F (0.34 mg kg^{-1}).

Finally, total carbonates and pH had scarcely varied by the end of the experiment.

Regarding grain, the use of treatments F, S or C did not produce any statistically significant differences in nutrient contents (Table 4).

Although the differences are not statistically significant, it is interesting to mention that the Na, Fe and Cu grain contents were higher in the subplots treated with F. Finally, the subplots treated with C had more B in grain. With straw, significant differences in Fe, Zn and Cu contents only occurred with higher values of these metals for treatment S.

The calculations made to estimate the harvest results were for planting doses (180 kg ha^{-1}), weight of 100 grains in fresh (4.5 g) and 1 spike per plant (400 spikes m^2). The final average yield in the control plots was 3,056 kg ha^{-1}. The best harvest result, with statistically significant differences (Figure 1), was achieved with treatment C (3,423 kg ha^{-1}), followed by S (3315 kg ha^{-1}).

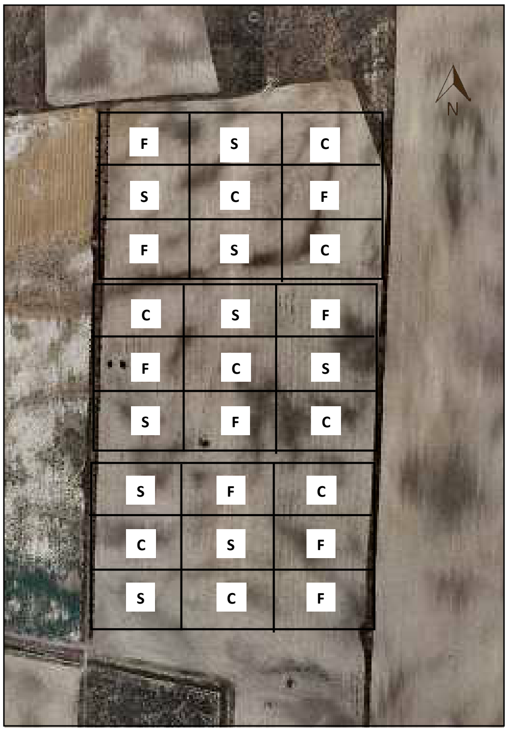

Figure 1: Schematic illustration of experimental site. Distribution of sub-plots and treatments: F (commercial fertilizer), S (sewage sludge), C (compost). (*Image adapted from google maps*).

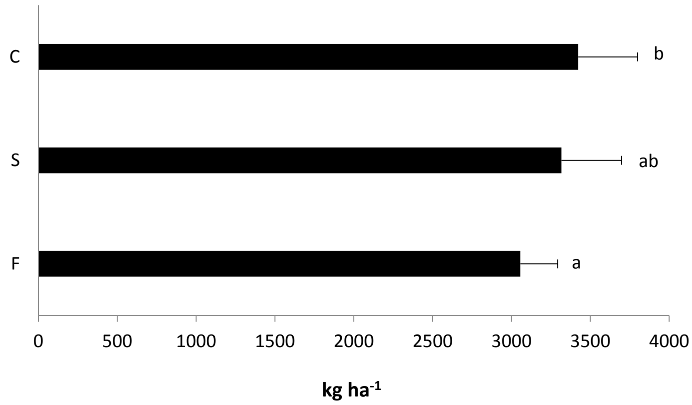

Figure 2: Differences among treatments for yield (kg ha^{-1}). Different letters mean groups with significant differences at P<0.05 according to the LSD test. Data are expressed as average ± standard deviation.

So, the yield obtained with the organically amended compost (C) was 12% higher than that obtained with the commercial fertiliser (F).

Discussion

Up to know, sewage sludge is a very problematic material managed in different ways in accordance with the law of each country [22]. In our study, we have applied it in two ways authorized by Spanish legislation: air-dried (S) and composted (C). The main difference among treatments after harvest was the increase in nitrogen, organic matter and zinc content in soil after applying compost compared with air-dried sewage sludge and commercial fertiliser treatments. The composting of the sludge is a key factor to apply it safely, eliminating risks derived from its microbiological composition since, once the process is finished, and the elimination of pathogens is achieved [23].

High electrical conductivity and salinity, as is the case of the soil studied, has been known to be a major challenge reducing crop yield [10]. In this sense, soil organic matter acts as an important regulator of numerous environmental constraints to crop productivity [24]. The use of organic amendments is considered one of the biological methods to reclaim salt-affected soils [25]. It is important to mention that, in our study compost application to soil allowed the same level or organic matter as the original one to maintain (more than 2%), while the level of organic matter in soil lowered compared with the initial moment after the two other treatments, F and S. Added organic matter helps glue tiny soil particles together to form larger water-stable aggregates by increasing biopore spaces, which increases the soil air circulation needed for plants and microorganism growth [26]. It has been studied that compost-amended soil exhibit increases in terms of the quantity and quality of total organic carbon, nitrogen and phosphorus nutrients, microbial biomass and enzymatic activities[25].

The levels of nutrients and hazardous elements in sewage sludge's are often reported, but most works were limited to few sludge samples, which constrain results interpretation [27]. Using sludge as a source of nutrients in agriculture can save non-renewable sources of energy for more sustainable production [12]. Although it has not been the object of our study, it has been seen that compost produced from sewage sludge and straw may improve hydraulic soil properties [28]. Our study indicates that treatments S, and especially C, may be a potential source of nitrogen and organic matter for plants. Sewage sludge amendment could be an innovative solution for new arable land resources and solid waste disposal. Research has shown that, as an initial fertility driver, and combined with planted and tilled green manures, it favours reduced salinity and pH, and increases organic matter and N and P concentrations in mudflat soil [29]. This agrees with part of the results of the present work (organic matter and N). It is well-known the pH influence in plant nutrients availability. Under acidic conditions ($\leq$ 4.5) plants would show signs of nutrients deficiencies [30], nevertheless, that was not our case since, on the contrary, pH soil was very basic. It is advisable to be cautious with the accumulation of some heavy metals because Cu and Zn can pose serious risks in agricultural use [1]. After harvest the amounts of Zn, Cu and Mn soil contents maintained after applying commercial fertiliser.

If there were a risk that pollutant compounds from the sewage sludge in any of the two applied forms (composted or air-dried) would enter into the food chain, their application to soil would be rejected. But we have verified that grain nutrient content was not affected by the treatment received in any of the plots. Hence, the application of sewage sludge or compost compared to traditional fertilisation with commercial fertilisers did not lead to nutritional imbalances in wheat grain filling. The benefits of adding any sludge as fertilizer to cropland must be compared with the risks of any contamination of the food chain; moreover, sludge has resulted in improved growth and yield of different crops (*Medicago sativa* L., *Triticum aestivum* L., (*Vicia faba* L., *Zoysia japonica* L., *Zea mays* L., *Cannabis sativa* L., *Brassica napus* L., *Salix viminalis* L. or *Sorghum bicolor* L.) [12]. Enhancing the nutritional value of food crops is a means to improve human nutrition and health. While a significant increase in the Zn concentration in soil was observed, it had no significant effect on vegetal tissue contents. Some research works by other authors have coincided with this point and had applied sewage sludge as an organic amendment. They found increased trace elements in soil, such as Zn, but no increase in the studied plant tissues, agricultural crops [30] or forest species [31]. As sewage sludge contains considerable amounts of organic matter and nutrients, specially when composted, it has been recognized that can minimize environmental risks[28]. The high nitrogen content in sewage sludge, along with its availability according to soil characteristics, can explain the beneficial effect on both growth and biomass. Compared to the plants fertilised chemically with a recommended commercial fertiliser, the C-amended plants displayed better growth and yields. Similar results have been obtained by other researchers [32-34].

Materials and methods

Part of the methodology used in this study is comparable to that used in another similar study [35].

Study area and experimental design: The field trial was carried out in a 15-hectare dry-land farming agricultural plot located in Quero (39º33'7.16'' N; 3º15'37.17''W) in the province of Toledo (central Spain). This field plot has always been cultivated traditionally for winter cereals and periodically crops have been intercalated with fallow.

According to the climate data reported from the Alcázar de San Juan weather station (XUTM: 482750; YUTM: 4340164, altitude 658 m), throughout the study period, the mean minimum, mean maximum and mean average temperatures were respectively 0.53ºC, 26.38ºC and 11.2ºC, and total precipitation was 282.3 mm.

Three different fertiliser treatments were considered: sewage sludge (S), commercial fertiliser (F) used as the control, and composted sewage sludge (C). The test plot was divided (Figure 2) into 27 sub-plots (9 replicates per fertiliser treatment randomly distributed: F, S and C).

In all cases doses was 18 t ha^{-1}. Early in December, the plot was prepared with farm machinery, and treatments F, S and C were applied to soil. Twenty days later, 180 kg ha^{-1} of durum wheat (*Triticum turgidum* L. cv. Vitron) seeds were sown since this is the reference durum wheat variety recommended for early harvesting areas.

Test materials: Sewage sludge, compost and commercial fertiliser: Sewage sludge used in the experiment came from the Alcázar de San Juan WWTP (29,000 inhabitants) in central Spain (391 240 N; 31 120 W, altitude 644 m and the chemical composition is reported in Table 1. In this table it can be seen that the metal content was lower than the limits set by Spanish Royal Decree 1310/90. Sewage sludge should be composted with another co-substrate to improve the porosity of composted matter and ensure proper conditions for the exchange of oxygen and carbon dioxide, as well as improving the structure [22]. The raw materials used to prepare compost were barley straw and the Alcázar de San Juan WWTP sewage sludge used at a ratio of two parts straw-one part sludge (v/v). The straw used had 80% dry matter, 4.4% crude protein, 75% fiber (cellulose, hemicellulose and lignin), 0.37% Ca, 0.11% P and 2.38% K. A wind-row composting system was used. Straw was applied without grinding as a carbon source and a bulking agent since it helps to improve the compost structure thanks to its fibrous texture. Sewage sludge was previously air-dried and used as the main nitrogen source. The piles dimensions were 30 x 8 x 15 m. Temperature and humidity were controlled by sensors. The straw+sludge mixture was periodically flipped 3 times a month for 4 months. Details of the final composition are displayed in Table 1.

The common characteristics of the commercial fertiliser used in the control plots with the other substrates are detailed in Table 1. Other relevant information on the commercial label was humic acids content (1%), organic N (1.50 %), ammoniacal N (6.50%), and organic C (12.50%).

Soil sampling and measurement: Soil samples were tested twice. An initial soil sample was collected at 30 different points and at a depth of 0-25 cm to obtain the average soil composition and the mixture was analysed in laboratory. The tested parameters and their values are shown in Table 2.

One month after harvesting, a 25 cm-deep soil sample was collected from 10 random points of each replicate. Hence nine soil samples (1 composite sample x 9 replicates) per treatment (F, S and C) were collected, and analysed (Table 3).

Each soil sample was air-dried and sieved to < 2 mm, and was analysed by the following techniques: texture by the Bouyoucos hydrometer method, pH by the potentiometric method (saturated soil paste 1:2, 5), electrical conductivity, N by the Kjeldahl procedure and extractable P. Soil samples were prepared for the analysis with acid digestion to determine Ca, Mg, Na and K (atomic emission); Fe, Zn, Cu, and Mn (atomic absorption spectroscopy).

Crop sampling and measurement: Random pre-harvested (213 days after sowing) bunches of 24 plants were cut from the base close to the soil in the middle of the subplot (replicate) to avoid board effects. As with soil sampling, there were nine groups of collected plants per treatment (1 bunch per treatment and replicate). In the laboratory, grain and straw were separated, and the micro- and macronutrients of grain and straw were analysed.

Yield method measurements were based on grab samples. To estimate the harvest results, it was taken into account that 1 spike per plant is usual for the variety studied (*Triticum turgidum* L. cv. Vitron) in the study area and in rainfed cultivation. The planting dose (180 kg ha^{-1} of seeds) and the weight of 100 fresh grains (30 weighing of groups of 100 grains were done to ensure reliable results).

Statistical procedure: A statistical analysis was run with the statistical Statgraphics Centurion XV.1 programme. The experimental design used three factors or treatments (F, S and C) and nine replicates per treatment. To ensure that the data came from a normal distribution, the standardised skewness and standardised kurtosis values were checked. Data were subjected to a simple factorial ANOVA and Fisher's least significant difference (LSD) was used to discriminate among means was for $P<0.05$. P-values lower than 0.05 indicated that these factors had a statistically significant effect on each parameter at the 95.0% confidence level.

Conclusions

Our study demonstrated beneficial effects of composting sewage sludge as treatment C promoted high Cu, Mn and Fe levels in soil in usable forms by plants and better yields than the other two treatments, S and F. The use of compost in soil allowed organic matter to be maintained and, in contrast, this parameter decreased at the end of the study after using a commercial fertiliser or air-dried sewage sludge without composting. Regarding grain and straw composition, nutrient content was not affected by the use of sewage sludge as a fertiliser treatment.

This study demonstrates that when properly treated and applied to farmland, air-dried and specially composted sewage sludge is not only economically feasible, but also improves soil characteristics and yield.

Of the three fertiliser treatments studied, the composting of sewage sludge proved the most beneficial from an agronomic point of view. This statement stems from three main conclusions:

1. After applying composted sewage sludge as an organic amendment for the wheat crop, nitrogen content, organic matter and assimilable zinc in soil increased.

2. The best harvest was obtained after applying compost.

3. None of the three studied treatments obtained significant differences in nutrient content in either grain or straw.

From the above conclusions, we can state that using sewage sludge from the Alcázar de San Juan WWTP is a feasible alternative as a fertiliser product, especially if it has been previously composted before being applied to soil.

Finally, our findings suggest that sewage sludge compost may be safely applied to salt-affected soils with no adverse effects on plants. Hence our starting hypothesis is true and sludge composting is useful for improving the agronomical aptitude of saline soil without damaging crops.

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