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Influence of Various Additives and Nano Treatments on Corn Stalks Compost Properties and Their Impacts on Available Macronutrients in Saline Soil

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THE AIM of this greenhouse research is to optimize the use of agricultural waste by recycling it into organic fertilizer (compost). Furthermore, to increase the effectiveness of the compost produced, agricultural waste is treated with soil amendments, specifically sulfur (S) and gypsum (G), and nanotechnology is used to increase its activity and reactivity with various soil components. Convert to nano fraction (N-form). The investigation encompassed the analysis of chemical properties (pH, electrical conductivity (EC), organic matter (OM), total nitrogen, and available nutrients) and Fourier-transform infrared spectroscopy (FTIR) spectra (functional groups). Furthermore, the impact of compost, in various types and forms, on the content of available nutrients in saline soils. The results demonstrated significant variations in the chemical composition and functional group content of the produced composts, influenced by the additive type and compost size fractions. These treatments led to increased levels of OM, available nutrients, even with a decrease in compost pH. Consequently, these interventions accelerated the decomposition rate of agricultural wastes, resulting in improved compost properties. This enhancement amplified the beneficial effects of the used composts as amendments and vital resources for essential plant nutrients, as evidenced by notable increases in soil contents of available nitrogen, phosphorus, potassium, and sulfur.

Keywords: Agricultural wastes, Compost, Mineral additives, Nanotechnology, FTIR spectra, Soil properties.

1. Introduction

Corn stalks are one of the most abundant agricultural residues in the world, and they can be used as a valuable resource for composting (Fermoso.et al. 2018) Composting is a process of organic matter decomposition that produces a nutrient-rich soil amendment for crop production. However, corn stalks are high in lignin and cellulose, which make them resistant to microbial degradation and slow down the composting process (Singh et al. 2022). Therefore, different additives and treatments are needed to enhance the compost ability of corn stalks and improve the quality of the final compost. Corn stalk compost can be treated with sulfur or gypsum throughout the composting process to lower the pH of the compost and make it more acidic (Yin et al. 2021). This can help to prevent the formation of ammonia, which can cause odors and nitrogen losses in the compost. Sulfur and gypsum are both sources of sulfur, which can react with water and oxygen to form sulfuric acid, which lowers the pH of the compost. Lowering the pH of the compost can also help to improve the availability of some micronutrients, such as Fe, Mn, Zn, and Cu, which are more soluble in acidic conditions (Kijjanapanich et al. 2021). Sulfur or gypsum can also affect the chemical properties of the compost, and its nutrients content (Tubail et al., 2008 and Abou Hussien et al., 2016). Esmaeil (2018) investigated the effect of sulfur, gypsum and compost addition on soil properties and wheat productivity in saline soil. They reported that gypsum, sulfur and compost application decreased the salinity of soil and increased the yield and quality of wheat. Furthermore, sulfur or gypsum can influence the functional groups and molecular structure of the compost, as revealed by Fourier transform infrared (FTIR) spectroscopy (Li et al., 2023). However, too much sulfur or gypsum can also have negative effects on the compost quality, such as reducing microbial activity, increasing the

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salinity, and inhibiting plant growth. Bello, S. K., et al. (2021) Therefore, it is important to monitor the pH of the compost and adjust the amount of sulfur or gypsum accordingly (Day et al., 2019; Nasser et al., 2020).

Another factor that can affect the compost properties is the treatment applied to the corn stalks compost after the composting process. One of the promising treatments is the use of nanoparticles, which are particles with a diameter of less than 100 nm. Nanoparticles have unique physicochemical properties that can affect the soil-plant system in various ways. For example, nanoparticles can increase the surface area and reactivity of organic matter, modify the microbial community and activity, and influence the plant uptake and metabolism of nutrients. Rajput, V. D., et al. (2018). However, the effects of nanoparticles of compost are not well understood, and they may depend on several factors such as nanoparticle composition, size, density and ligand coverage (Medina et al., 2021). Nanotechnology can improve the quality and functionality of corn stalk compost by modifying its physicochemical properties, such as pH, electrical conductivity, nutrient content, water retention, and porosity (Chong et al., 2021). Nanotechnology can produce valuable nanomaterials from corn stalk compost, such as carbon nanotubes, graphene, cellulose Nano fibrils, and lignin-containing cellulose nano fibrils (Shi et al., 2022). On the other hand, Organic matter in soil play an important role through building up soil aggregates and enhancing proper soil physical and chemical properties. Composting transforms organic waste into a more uniform and biologically stable product that can act as slow-release source of plant nutrients (Ahmad et al. 2007). Compost is an economic and safe way for treatment of organic waste and has high concentrations of organic matter and available nutrients (Verma, 2013 and Razikordmahalleh, 2014). Composting is useful in avoiding greenhouse gas emissions, as it is an aerobic process (Nada, 2011).

The humanity faces a great challenge representing in how to save the enough and safe foods to feed the entire the global population. Farming is the main source for such food, which may face several problems suppressing the farming productivity such as climate change, and pollution (Sári et al. 2023)

This investigation aims to study the impact of some additives (sulfur or gypsum) through the composting process and different size fraction (regular or nano) on the chemical properties and FTIR spectroscopy of corn stalks compost. The investigation will also examine the impact of sulfur or gypsum additives on the functional groups and molecular structure of compost. As well as, the soil content of available nutrients as a result of composts applications.

2. Materials and Methods

2.1 Compost properties

Under the greenhouse conditions at soil science department, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt. The used compost was prepared as described by Abou Hussien et al., (2020) as follows: three polyethylene barrels with 50 cm and 70 cm inner diameter and depth, respectively were used, where 4 kg mixture of the used organic materials (3:1 of cornstalk: farm yard manure mixed ratio) were transformed to each barrel and good mixed (**Figure 1**). An activating mixture containing of 320 g $Ca(HPO_4)_2$, 100 g $CaCO_3$, 0.32 g urea and 100 ml of fresh fertile soil-water (1:5) suspension.

2.2 Preparing nano-compost

The mixture in the first barrel untreated with any additives (C0) and the other two barrels mixed with 4% of elemental sulfur and agriculture gypsum (compost with sulfur addition "CS" and compost with gypsum addition "CG"), respectively. Each barrel was moisturized by tap water at moisture content of 50-60 % of its water holding capacity and left to decompose up to become mature. To enhance the aerobic decomposition process of the composted materials, the three barrels were turned down every 15 days standing from the top and sides into the center. Additional tap water was sprayed during the timing process to keep the moisture content in each barrel at about 50-60 % of water holding capacity. Under these decomposing conditions, the composted organic wastes were matured after 90 days. The three types of air-dried final compost were divided into two equal portions. The first was left without any further treatment (regular), while the other was physically milled to nanoscale particles of particles size less than 300 nm (nano treatment).

2.3 Analyses of composts

The composted materials (final compost) were taken separately, air dried, ground and analyzed for chemical properties (pH, EC and the content of organic matter and total nitrogen), available macronutrients (N, P, K, Ca, Mg and S) and available micronutrients (Fe, Zn, Mn and Cu) as described at the methods of Cottenie et al., (1982) and Page et al., (1982). FTIR spectroscopic analysis method was performed to detect the changes in functional groups of corn stalk compost samples. The samples were milled, sieved, mixed with KBr, and pressed into pellets. The spectra were collected on a VERTEX 70 spectrometer (Singh et al., 2017).

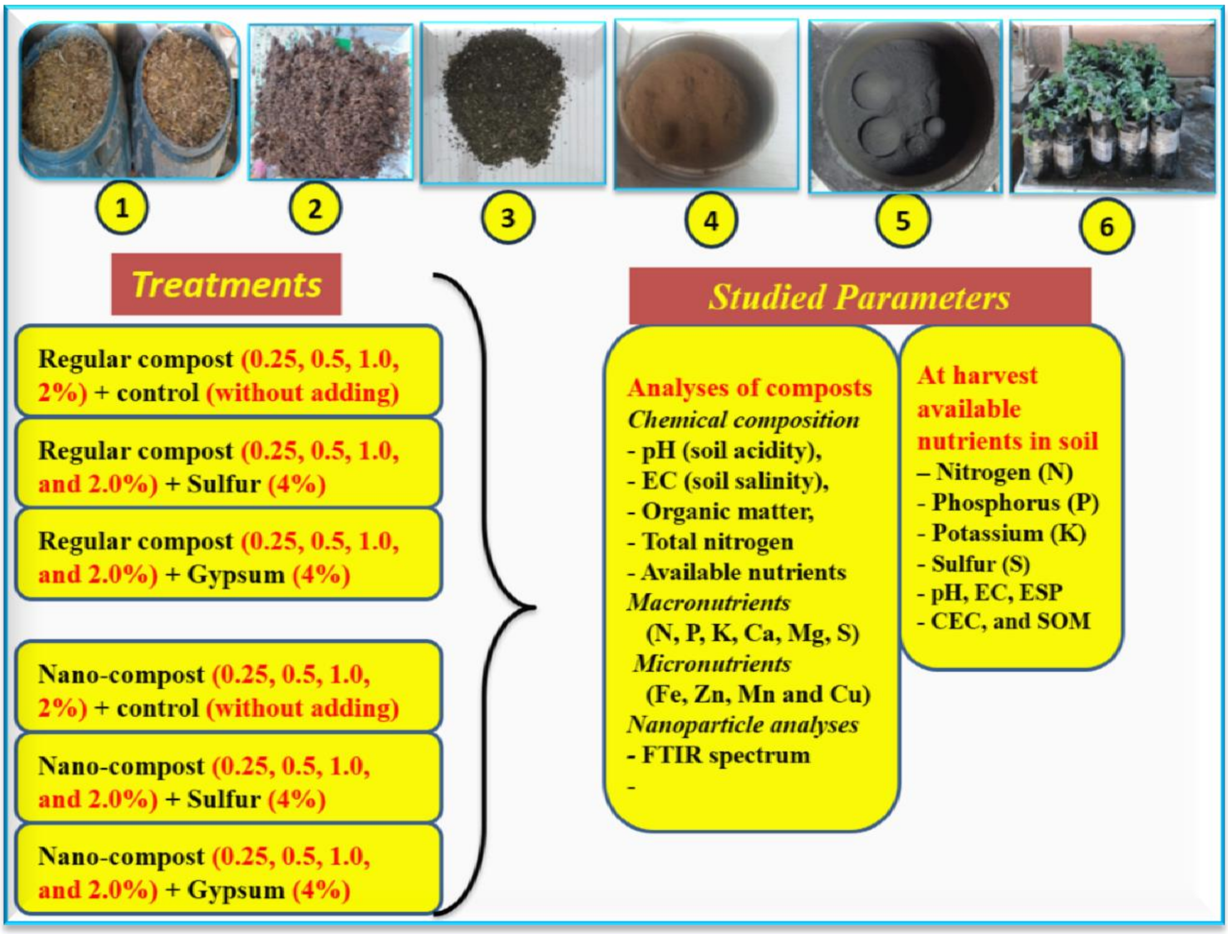

Fig. 1. Summary of the experimental performance, where photo (1) represents the row compost material, (2) maize stalks during composting process, (3) mature compost, (4) nano form, (5) the used polemale, and (6) tomato plants treated with different types, forms and added rate of compost.

Table 1. Some physical and chemical properties of the experimental saline soil and its content of available nutrients

Particle size distribution (%)				**Texture class**	**WHC**
Coarse sand	Fine sand	Silt	Clay		(%)
7.50	13.70	23.30	55.50	Clayey	48.50
pH (1:2.5) Suspension	**EC** (in paste extract, dS m^{-1})		**OM** (%)	**CEC** (cmolc kg^{-1})	
8.90	11.70		0.95	34.13	
		Available nutrients (mg/kg^{-1})			
	N	P	K	S	
	28.55	3.08	68.51	40.40	
	Fe	Mn	Zn	Cu	
	4.33	5.70	2.87	1.15	

WHC= Water holding capacity**, pH** = Soil reaction measured in 1:2.5, soil: distilled water suspension**), EC**= Electrical conductivity of soil salinity, **OM**= Organic matter and **CEC=** Cation exchange capacity.

2.4 Greenhouse experiment

The used salt affected soil in this study was brought from Edku regions beside Edku Lake, Behaira Governorate, Egypt (31°16'01.9" N, 30°12'50.6"E) where five surface soil samples (0-20 cm) were collected from different five sites of the selected area, air-dried, ground, good mixed, sieved through a 2mm sieve and kept for further analysis. A portion of the fine prepared soil sample was taken and analyzed for its physical, chemical properties and the content of available macro and micro nutrients as described by Cottenie et al., (1982), Page et al., (1982) and Kute (1986). The obtained data are recorded in Table (1).

A pot experiment was conducted in the greenhouse, throughout the summer growing season. A total of 90 plastic pots with dimensions of 20 cm inner diameter and 25 cm depth were utilized. Two kg of prepped salt-affected soil placed in each pot. The pots were categorized into two main groups, denoted as main group^{-1} (45 pots), representing compost fraction size (regular and nano forms). Within each main group, the pots were further subdivided into three subgroups (15 pots each), representing the types of used compost [C0, CS, and CG]. Additionally, each subgroup was divided into five sub-subgroups (3 pots for each one), representing different compost application rates (0, 0.25, 0.5, 1.0, 2.0%). Thus, the experimental design was arranged in completely randomized blocks with three replicates. Sixty days before transplanting, all compost treatments were applied and thoroughly mixed with the potted soil. Simultaneously, all pots received ordinary superphosphate fertilizer at recommended rate (100 kg of 15.5 P_2O_5.fed^{-1}) at a rate of 0.2 g per pot, blended into the soil. The pots were then moistened using tap water to achieve a moisture content equivalent to 60% of the soil water holding capacity and were incubated at room temperature (25±2°C) for 60 days. After this incubation period, each pot was transplanted with three seedlings of tomato plants (*Solanum lycopersicum* L.) on July 4, 2021, with a seedling length of 15 cm. Fifteen days post-transplanting, the plants in each pot were thinned to one plant. Subsequently, all pots received 150 kg fed^{-1} of ammonium nitrate (33% N) and 100 kg fed^{-1} of potassium sulphate (48% K_2O), equivalent to 0.3 and 0.2 g per pot, respectively. Both nitrogen and potassium fertilizers were applied in two equal doses, 20 and 40 days after transplanting, along with irrigation water. Throughout the cultivation period, the moisture content in all pots was maintained at 60% of the soil holding capacity. At the flowering stage (70 days), the plant in each pot was cut above the soil surface, and the fresh weight was recorded (g plant^{-1}). After plant harvesting, the soil of each pot was taken, ground, good mixed, sieved through at 2 mm sieve and analysed for its content of available essential nutrients and statistical analysis as described by Cottenie et al. (1982) and page et al. (1982).

3. Results and Discussion

3.1 Compost chemical composition

Table (2) shows the chemical properties of the studied composts with different treatments (regular and *n*ano) different types (without additives "C" with sulfur "CS" and with gypsum "CG"). The pH values of the composts ranged from 6.11 to 7.44, which indicate that these composts have slightly acidic to neutral.

Table 2. The chemical properties of the studied composts with different treatments (regular and nano) different types (without additives "C", with sulfur "CS", and with gypsum "CG").

Compost properties	Regular compost treatments			Nano compost treatments		
	Compost	Sulfur/ Compost	Compost-Gypsum	Compost	Sulfur/ Compost	Compost-Gypsum
pH (1:5 suspension)	7.33	6.34	6.66	7.44	6.11	7.13
EC (dS m^{-1}) (1:10 extract)	2.50	2.80	2.98	2.87	2.95	3.11
Organic Carbon (OC, %)	29.33	27.57	28.36	30.28	28.37	27.94
OM (%) (OC*1.57)	46.04	43.29	44.52	47.53	44.55	43.86
Total N (%)	1.6	1.82	1.68	1.73	1.98	1.8
C/N Ratio (OC/TN)	18.33	15.15	16.88	17.5	14.33	15.52
Available N (mg/kg)	8105	9503	8880	8707	9934	9454
Available P (mg/kg)	595	680	632	628	720	665
Available K (mg/kg)	1850	1920	1897	2005	2115	2078
Available S (mg/kg)	1977	3118	2770	2056	3280	3025
Available Fe (mg/kg)	603	670	635	642	705	672
Available Zn (mg/kg)	415	460	437	427	480	451
Available Mn (mg/kg)	64	72	66	70	85	76
Available Cu (mg/kg)	22	29	24	25	36	29

C= Compost without additives, CS= Sulfur compost and CG= Compost with gypsum addition.

The pH values are lower for the sulfur composts (CS) than the compost without additives (C) or gypsum composts (CG) because sulfur is an acidifying agent that lowers the soil pH when soil bacteria oxidize it. This sulfur breakdown (oxidation) produces sulphate, a form of soluble sulfur that plants can absorb as essential nutrient. (El-Sayed et al., 2020). Therefore, adding sulfur to the compost can make it more acidic than compost without additives or gypsum, which are neutral or alkaline substances.

The pH values are also slightly higher for the nano-treated composts than the regular ones, which may indicate that nano-treatment increases the pH of the compost. The pH values are slightly higher for the nano-treated composts than the regular ones because nano-treatment may affect the chemical reactions and microbial activities in the compost. Nano-treatment can enhance the oxidation of sulfur and organic matter in the compost, which can increase the production of acidic substances such as sulfuric acid and carbonic acid (Sanders, 2021). These substances can lower the pH of the compost, but they can also be neutralized by the alkaline components of the compost, such as calcium carbonate and magnesium carbonate. The balance between these acidic and alkaline substances may determine the final pH of the compost. Nano-treatment may increase the rate of neutralization, resulting in a slightly higher pH than regular treatment (El-Sayed et al. 2020). The EC values of the composts ranged from 2.50 to 3.11 dS/m, which indicates that they have moderate to high salinity levels (Table 1). The EC values are higher for the CG composts than the C or CS composts, which suggests that gypsum increases the salinity of the compost. One possible reason is that gypsum can dissociate into ions when dissolved in water. These ions can increase the electrical conductivity of the solution by enabling the flow of electric current. According to Louie et al. (2012), gypsum is a nonconductor compound in its natural form, but it can become conductive if it is combined with a polymer called the C/N ratio values of the composts range from 14.22:1 to 18.33:1, which indicates that they have optimal to high carbon-to-nitrogen ratios. The C/N ratio values are lower for the CS than the C or CG, which suggests that sulfur lowers the carbon-to-nitrogen ratio of the compost (Amuah et al., 2022). The C/N ratio values are also slightly lower for the nano-treated composts than the regular ones, which may indicate that nano-treatment lowers the carbon-to-nitrogen ratio of the compost polyaniline in a composite form. This composite can also have its electrical conductivity controlled by oxidation and reduction. Therefore, adding gypsum to composts may enhance their electrical properties by introducing more ions and conductive polymers into the mixture. The EC values of the compost with additives are higher than those without additives, suggesting that adding sulfur or gypsum increases the salinity of the compost. This may be because sulfur and gypsum are both sources of sulfate, which is a soluble salt (Khater, 2015).

The EC values are also slightly higher for the nano-treated composts than the regular ones, which may indicate that nano-treatment increases the salinity of the compost. This may be due to the smaller particle size and higher surface area of Nano compost, which can enhance the dissolution and retention of salts (Karnchanawong and Nissaikla, 2014). The OC and OM values of the composts ranged from 27.57 to 30.28% and 43.29 to 47.53% (Table 1), respectively, which indicates that they have high organic matter content.

The OC and OM values are higher for the C composts than the CS or CG composts, which suggests that sulfur and gypsum reduce the organic matter content of the compost. The OC and OM values are also slightly higher for the nano-treated composts than the regular ones, which may indicate that nano-treatment enhances the organic matter content of the compost.

The total N values of the composts, as listed in Table (1), ranged from 1.60 to 1.98%, which indicates that they have moderate to high nitrogen content. The total N values are higher for the CS composts than the C or CG composts, which suggests that sulfur increases the nitrogen content of the compost. This may suggest that adding sulfur to the composts increases the nitrogen content, possibly by stimulating the activity of nitrogen-fixing bacteria or by reducing nitrogen losses through volatilization or leaching. The total N values are also slightly higher for the nano-treated composts than the regular ones, which may indicate that nano-treatment enhances the nitrogen content of the compost.

The C/N ratio values of the composts ranged from 14.22:1 to 18.33:1, which indicates that they have optimal to high carbon-to-nitrogen ratios. The C/N ratio values are lower for the CS than the C or CG, which suggests that sulfur lowers the carbon-to-nitrogen ratio of the compost (Amuah et al., 2022). The C/N ratio values are also slightly lower for the nano-treated composts than the regular ones, which may indicate that nano-treatment lowers the carbon-to-nitrogen ratio of the compost.

The available P, K, S, Fe, Zn, Mn, and Cu content as mg/kg of the composts vary depending on the type and treatment of the compost (Table 1). Generally, these values are higher for the CS and CG composts than the C composts, which suggests that sulfur and gypsum increase these nutrients in the compost. These values are also generally higher for the nano-treated composts than the regular ones, which may indicate that nano-treatment enhances these nutrients in the compost.

3.2 FTIR spectrum

The FTIR spectrum for regular and nano maize stalk compost treated without additives (C0), sulfur (CS) and gypsum (CG) during the composting process is illustrated in Fig (1). The O-H stretching vibration band ranged between 3900-3000 cm^{-1} and indicates the presence of water, alcohols, phenols, and carboxylic acids in the compost. The intensity of this band reflects the degree of hydrogen bonding and the moisture content of the compost. The higher the intensity, the higher the moisture content and the lower the stability of the compost. For regular or Nano compost, the treatment without additives (CR0 and CN0) has the highest intensity of O-H stretching vibration, followed by the treatment with sulfur or gypsum. For the regular compost, the intensities of O-H stretching vibration are 1.1286 (without additives), 0.3867 (plus sulfur), and 0.3697 (plus gypsum). For the Nano compost, the intensities of O-H stretching vibration are 0.5002 (without additives), 0.48869 (plus sulfur), and 0.4118 (plus gypsum). This suggests that the treatment without additives has the highest moisture content and the lowest stability among the three treatments (Carballo et al., 2008).

The stretching vibration band of C-H appears in the range of 3000-2800 cm^{-1} and indicates the presence of aliphatic chains, such as fatty acids, waxes, and lipids, in the compost. The intensity of this band reflects the degree of aliphaticity and the amount of easily degradable organic matter in the compost. The lower the intensity, the higher the degree of humification and stability of the compost (Eid, 2022). In this case, none of the treatments show a significant peak in this region, which suggests that they have a low amount of aliphatic chains and a high degree of humification.

The stretching vibration band of C=O appears in the range of 1800-1600 cm^{-1} and indicates the presence of carboxylic acids, esters, ketones, aldehydes, and amides in the compost. The intensity of this band reflects the degree of oxidation and acidification of the compost. The higher the intensity, the higher the degree of oxidation and acidification and the lower the pH of the compost.

The regular or Nano compost in all three treatments shows a peak at around 1601 cm^{-1}, which corresponds to the C=O stretching vibration of carboxylic acids or amides. For the regular compost, the treatment without additives (CR0) has the highest intensity (0.7373), followed by the treatment with sulfur (CRS) and the treatment with gypsum, which has the intensity of 0.3820 and 0.3370, respectively. This suggests that adding sulfur or gypsum decreases the oxidation and acidification of the regular compost.

For the Nano compost, the treatment with sulfur (CNS) has the highest intensity (0.4345), followed by the treatment without additives (CN0) and the treatment with gypsum (CNG), which have intensity of 0.3765 and 0.283, respectively. This suggests that adding sulfur increases the oxidation and acidification of the Nano compost while adding gypsum decreases it (Carballo et al., 2008). The C-O stretching vibration band appears in the range of 1300-1000 cm^{-1} and indicates the presence of carbohydrates, such as cellulose, hemicellulose, starch, and sugars, in the compost.

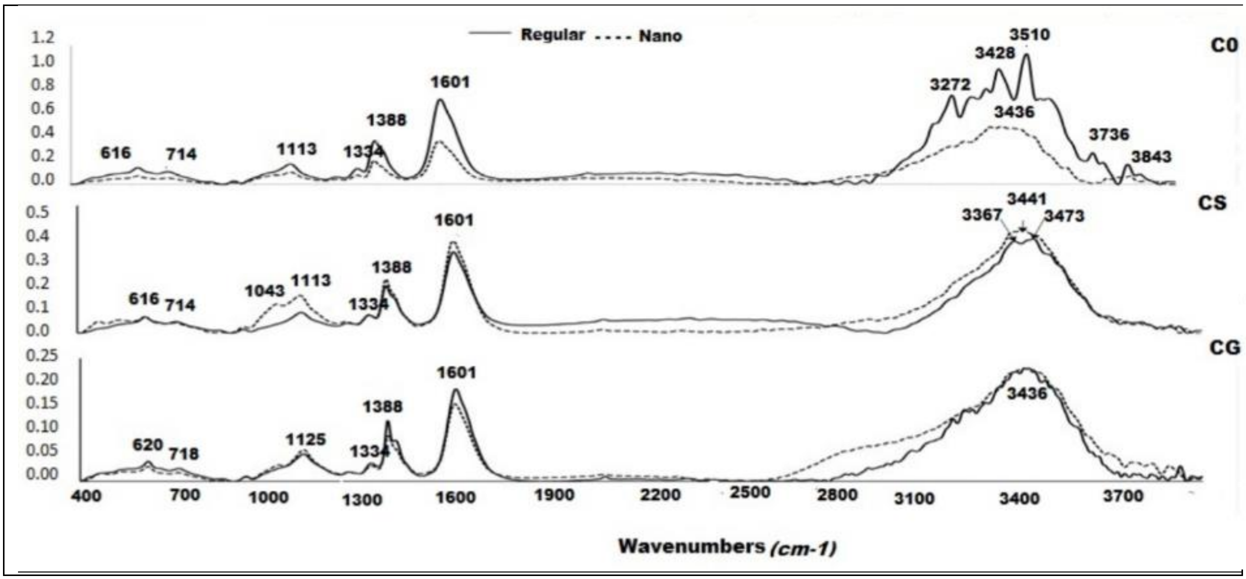

Fig. 1. FTIR spectrum for regular and nano corn stalk compost treated without additives (C0), sulfur (CS) and gypsum (CG) during composting process.

The intensity of this band reflects the degree of degradation and decomposition of carbohydrates in the compost. The lower the strength, the higher the degree of degradation and decomposition. For each type of compost (regular or nano), all three treatments (without additives, plus sulfur, and plus gypsum) show a peak at 1388 cm^{-1}, which corresponds to C-O stretching vibration of cellulose or hemicellulose. This peak suggests that both types of compost contain this type of carbohydrate. For the regular compost, all three treatments also show similar peaks at 1334 and 1113 cm^{-1}, which correspond to C-O stretching vibration of cellulose or hemicellulose and polysaccharides or glycosidic bonds, respectively. These peaks suggest that the regular compost contains mainly these types of carbohydrates. The regular compost without additives also shows peaks at 714 and 616 cm^{-1}, which correspond to C-O stretching vibration of esters or ethers. This implies that the regular compost also has some additional carbohydrate compounds. The regular compost plus sulfur shows a slight shift of the peak at 616 to 620 cm^{-1}, which may indicate a minor change in the structure or composition of the esters or ethers. The regular compost plus gypsum shows no significant difference from the regular compost without additives. These results suggest that adding sulfur or gypsum does not affect the degradation and decomposition of carbohydrates in the regular compost significantly. For the nano compost, the treatments show different peaks depending on the additives. The CN0 shows a peak at 1265 cm^{-1}, which corresponds to C-O stretching vibration of starch or sugar. This peak suggests that the nano compost contains some simple carbohydrates as well. The CNS shows peaks at 1334 and 1039 cm^{-1}, which correspond to C-O stretching vibration of cellulose or hemicellulose and esters or ethers, respectively. These peaks suggest that the nano compost contains more diverse and complex carbohydrates than the nano compost without additives. The CNG shows peaks at 1334 and 1260 cm^{-1}, which correspond to C-O stretching vibration of cellulose or hemicellulose and starch or sugar, respectively. These peaks suggest that the nano compost contains similar carbohydrates as the Nano compost without additives. These results imply that adding sulfur increases the diversity and complexity of carbohydrates in the Nano compost, while adding gypsum does not affect them significantly. The band of C-H bending vibration appears in the range of 900-600 cm^{-1} and indicates the presence of aromatic rings, such as lignin, in the compost. The intensity of this band reflects the degree of aromaticity and the amount of recalcitrant organic matter in the compost. The higher the intensity, the higher the degree of aromaticity and the lower the degradability of the compost. For regular or nano compost, all three treatments (without additives, plus sulfur, and plus gypsum) show similar peaks at 714 and 616 cm^{-1}, which are attributed to C-H bending vibration of aromatic rings or alkenes. These peaks suggest that both types of compost contain these types of compounds.

The CRS shows a slight shift of the peak at 616 to 620 cm^{-1}, which may indicate a minor change in the structure or composition of the aromatic rings or alkenes. The CRG shows no significant difference from the treatment without additives. These results suggest that adding sulfur or gypsum does not affect the aromaticity and degradability of the regular compost significantly. For the nano compost, there is no significant difference among the three treatments in terms of their peaks and intensities. These results show that adding sulfur or gypsum does not affect the aromaticity and degradability of the Nano compost significantly.

3.3 Soil content of available macronutrients

Soil characteristics were improved considerably owing to this combined application i.e. residual organic matter content increased significantly (Ihab et al. 2023). Compost application without and with subsoiling tillage significantly increased soil available macronutrients (N, P, K and S) (Abou Hussien et al. 2020).

Table (3) Effect of compost additive types and forms (regular "R" and nano "N" size fractions) on saline soil content of available macronutrients "mg/kg"

Type	Added Rate (%)	N		G Means	P		G Means	K		G Means	S		G Means
		R	N		R	N		R	N		R	N	
C0	0	28.6	28.6	35.45 ^{c}	3.08	3.08	4.71 ^{c}	68.5	68.5	78.88 ^{c}	40.4	40.4	42.875 ^{c}
	0.25	30.3	38.6		3.7	4.66		71.3	76.5		40.8	41.3	
	0.5	33.5	39.5		4.22	5.5		73.8	80.8		41.92	42.65	
	1	34.8	41.2		4.92	5.8		76.7	89.9		43.5	45.1	
	2	36.7	42.7		5.8	6.37		80.4	102.4		45.45	47.25	
	Mean	32.78	38.12		4.34	5.08		74.14	83.62		42.41	43.34	
CS	0	28.6	28.6	40.35 ^{b}	3.08	3.08	5.375 ^{a}	68.5	68.5	85.52 ^{b}	40.4	40.4	64.32 ^{a}
	0.25	35.2	44.2		4.05	5.37		74.2	83.7		48.8	50.35	
	0.5	36.5	46.8		4.93	5.98		80.8	89.6		55.5	60.68	
	1	37.1	53.2		5.96	6.77		85.3	99.6		70.8	78.13	
	2	38	55.3		6.62	7.9		94.9	110.1		92.92	105.22	
	Mean	35.08	45.62		4.93	5.82		80.74	90.3		61.68	66.96	
CG	0	28.6	28.6	41.49 ^{a}	3.08	3.08	5.04 ^{b}	68.5	68.5	87.84 ^{a}	40.4	40.4	58.965 ^{b}
	0.25	36.5	46.5		3.85	4.82		76.1	86.9		45.3	48.1	
	0.5	38.4	49.3		4.78	5.95		79.1	98.3		50.5	55.55	
	1	39.2	52.6		5.48	6.42		82.5	108.8		61.13	67.3	
	2	39.7	55.5		6.11	6.85		88.2	121.5		85.8	95.17	
	Mean	36.48	46.5		4.66	5.42		78.88	96.8		56.63	61.3	
G Mean		34.78 ^{b}	43.41 ^{a}		4.6 ^{a}	5.44 ^{a}		77.92 ^{b}	90.24 ^{a}		53.6 ^{a}	57.2^{a}	

C0=Compost without additives,CS= Sulfur compost and CG= Compost with gypsum addition

Ratea	N			P			K			S		
	R	N	G Mean	R	N	G Mean	R	N	G Mean	R	N	G Mean
0	28.6	28.6	**28.6 ^{e}**	3.1	3.1	**3.1 ^{e}**	68.5	68.5	**68.5 ^{e}**	40.4	40.4	**40.4 ^{d}**
0.25	34.0	43.1	**38.6 ^{d}**	45.0	5.0	**25 ^{d}**	73.9	82.4	**78.1 ^{d}**	45.0	46.6	**45.8 ^{c}**
0.5	36.1	45.2	**40.7 ^{c}**	49.8	5.8	**27.8 ^{c}**	77.9	89.6	**83.7 ^{c}**	49.3	53.0	**51.1 ^{b}**
1	37.0	49.0	**43.02 ^{b}**	59.1	6.3	**32.73 ^{b}**	81.5	99.4	**90.5 ^{b}**	58.5	63.5	**61 ^{b}**
2	38.1	51.2	**44.7 ^{a}**	73.7	7.0	**40.4 ^{a}**	87.8	111.3	**99.6 ^{a}**	74.7	82.5	**78.6 ^{a}**
Mean	34.78	43.41	39.10	46.14	5.44	25.79	77.92	90.24	84.08	53.57	57.20	55.39

The presented data in table (3) show that, in general, compost applications in the three types and two forms resulted in the content (mg/kg) of saline soil available N, P, K and S, where these contents were increased with the increase rate of added composts. For example, the soil content of available N, P, K and S without compost applications in regular form were 26.60, 3.08, 68.50 and 40.40 mg/kg which increased to 38.70, 5.80, 80.40 and 45.45 mg/kg with C0 application at rate 2% in regular form and to 42.70, 6.37, 102.40 and 47.25 mg/kg with the same compost type (C0) and application rate (2%), These results were supported by Saher and Said (2023) but in nano form: This also show that, compost applications in nano form resulted in more increase in the soil content of available nutrients. These findings attributed mainly to improve effect of added compost on soil characters such as reducing in both soil pH and ESP and increase in its content of OM as mentioned as explained before that by Abou Hussien et al. (2020). Also, compost in nano form has a high content of functional groups compared with these in regular form (Cobollo et al., 2008; Eid, 2023). As well as, data in table (3) show the clear effect of compost type (additive type) on the saline soil content of available N, P, K and S, where these additives played in a major role in the compost properties (table,2) and its content of functional groups (Fig,1). According to the found values in the soil content of available N, P, K and S, the used three types of compost takes the order CG > CS >

C0 for N content and CS > CG > C0 for the contents of P, K and S. These variations are in related with the chemical composition of added compost type and its effect on soil chemical properties such as soil pH, ESP and its content of OM. As well as compost chemical composition have a great effect on soil biological activity (Abou Hussien et al., 2019).

3.4 Impacts of compost on rates and soil salinity

Compost may decrease soil EC (salinity), which is a measure of soil salinity or salt content (**Table 4**). Compost contains various acids that dissolve in soil water and increase the solubility and leaching salts from soil. Saline soils are soils that have high soluble salts that affect the growth of most crops. Saline soils have ECe > 4 dS m-1 and low exchangeable sodium percentage (ESP) < 15. One of the management practices for saline soils is to use organic amendments such as compost, which can improve the soil physical and chemical properties and enhance the leaching of salts. Compost can also provide nutrients and organic matter to the soil, which can increase the soil fertility and crop yield. However, compost alone may not be enough to reclaim saline soils, especially if they are also sodic (high ESP > 15). In such cases, chemical amendments such as gypsum ($CaSO_4$) or sulfur (S) may be needed to provide soluble calcium (Ca^{2+}) and lower the soil pH, which can displace sodium (Na^+) from the soil exchange sites and increase the permeability and infiltration of water (Osman 2018).

The table (4) shows the effect of different types of compost (regular and nano) without additives (C), with sulfur (CS) and with gypsum (CG) on the electrical conductivity (EC) of saline soil at different rates (%). The results in Table (4) reveal that compost application reduced soil EC compared to the control (no compost). This is consistent with the fact that compost can dilute the salt concentration in soil and enhance the leaching of soluble salts from the root zone. Compost can also improve the soil structure and porosity, which can increase the water infiltration and drainage, and thus reduce the salt accumulation in soil. Compost can also provide organic matter and nutrients to soil microorganisms, which can enhance the biological activity and decomposition of organic matter, and thus lower the EC values of soil. These results are in agreement with Li et al. (2020) and El-Sharkawy et al. (2021).

Table 4. Effect of different types of compost (regular and nano) without additives (C), with sulfur (CS) and with gypsum (CG) at different rates (%) on (EC) of saline soil.

Compost Treatments	Types	Rates %					G Means
		0.00	0.25	0.50	1.00	2.00	
Regular	C	11.70	11.42	10.62	10.50	9.15	10.68
	CS	11.70	10.82	10.08	9.63	9.50	10.35
	CG	11.70	10.97	10.28	9.87	9.78	10.52
R Means		**11.70**	**11.07**	**10.33**	**10.00**	**9.48**	**10.51 b**
Nano	C	11.70	11.50	10.92	10.50	9.55	10.83
	CS	11.70	10.93	10.75	10.22	9.75	10.67
	CG	11.70	11.18	10.87	10.30	9.41	10.69
Nano Means		**11.70 a**	**11.20 b**	**10.85 c**	**10.34 d**	**9.57 f**	**10.73 a**
G Means		**11.70**	**11.14**	**10.59**	**10.17**	**9.52**	**10.62**
Compost types	**Means**				**LSD 0.05**		
C	**10.76 a**				**Treat**	**0.0422**	
CG	**10.61 b**				**Types**	**0.0517**	
CS	**10.51 c**				**Rates**	**0.0668**	

4. Conclusion

The FTIR spectrum for maize stalk compost with different treatments shows that adding sulfur or gypsum affects the functional groups and chemical bonds of the organic matter in different ways. For each type of compost (regular or nano), adding sulfur or gypsum does not have a significant effect on the aliphatic, humification, aromaticity, and degradability of the compost. For the regular compost, adding sulfur or gypsum decreases the oxidation, acidification, moisture content, and hydrogen bonding of the compost while having no significant effect on the degradation, decomposition, and diversity of carbohydrates in the compost. Adding sulfur to nano compost increases the oxidation, acidification, and diversity of carbohydrates in the compost while adding gypsum decreases the oxidation and acidification of the compost. Applying sulfur or gypsum does not have a significant effect on the degradation and decomposition of carbohydrates in the compost.

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