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Evaluating Nanotechnology in Raising the Efficiency of some Substances Used in Fertilizing Wheat Grown on Sandy Soil

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Abstract

Nanotechnology has the potential to increase the efficiency and quality of agricultural production. So, this research work was carried out to assess the effect of some soil conditioners at different rates and foliar application of antioxidant on the performance of wheat plants grown on sandy soil. The treatments were T_1: Control (without soil addition);T_2: 0.50%Normal compost (bulky);T_3: 0.25% Nano compost;T_4: 0.50% Nano compost;T_5: 0.50% Normal agricultural gypsum (bulky);T_6: 0.25% Nano agricultural gypsum;T_7: 0.50% Nano agricultural gypsum; T_8: 0.50% Normal sugar lime mud (bulky);T_9: 0.25% Nano sugar lime mud;T_{10}: 0.50% Nano sugar lime mud; F_1: without proline and F_2: with proline.Wheat plants treated with compostpossessed the highest values of all growth criteria (*e.g.,*fresh and dry weights, plant height and leaf area), photosynthetic pigments (after 70 days from sowing), yield, its component, and grains quality (at harvest stage) under sandy soil conditions followed by that treated with agricultural gypsum than the plants treated with sugar lime mud, while the untreated wheat plants with any soil conditioner (control treatment) possessed the lowest values of all aforementioned traits. Nano form was superior compared to the normal form with all studied soil amendments. Also, all aforementioned traits increased as the rate of Nano form increased with all studied soil amendments.Regarding the foliar application, the proline treatment was superior compared to the control treatment (without foliar application). The control treatment (without soil and foliar applications) led to raising the enzymatic antioxidants content in the straw of wheat plant after 70 days from sowing, where the cultivation without any both soil conditioners and proline caused an increase in wheat self-production from these antioxidants to scavenge the ROS (or as named free radicals) resulting due to the poverty of sandy soil, thus increase of tolerance. Generally, it can be concluded that all the studied soil conditioners (*i.e.,* gypsum, compost, and sugar lime mud) in either normal form or Nano form have a beneficial effect on improving the performance and productivity of wheat plants grown under sandy soil conditions. Also, the findings of the current work confirmed proline is one of the plant's protective ways from the poverty of sandy soil fertility, where it works as an antioxidant and leads to an increase in wheat plant tolerance to the poverty of sandy soil fertility.

Keywords: Compost, Nano, Gypsum, Sugar lime mud, Proline, and wheat plants

1. Introduction

Reclamation of degraded soils *e.g.,* sandy soil is the main target for the agricultural policy in Arab countries to face the gap between production and consumption of food for the Arabian people. Sandy soil is widespread worldwide, especially in arid and semi-arid regions like Egypt and Iraq with many issues that hinder these soils' vertical and horizontal

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expansion. These soils possess poor physical and chemical characteristics as well as a low capacity to retain irrigation water and a low supply of nutrient elements *e.g.,* N, P, and K (Tolba *et al.,* 2021 and Gaafar *et al.,* 2021). Thus, the soil conditioners addition to the production system for all crops especially wheat crops toimprove plant growth and productivity (Sadek *et al.,* 2011). Abd El-Hamid *et al.,* (2011) concluded that the utilization of agricultural gypsum and sugar lime mud could be positively affected degraded soil reclamation. While Kheir and Kamara, 2019) found that soil addition of sugar beet factory lime led to improve sandy soil properties and canola productivity. Mohamed, (2020) reported that the physical and chemical properties of sandy soil as well as its fertility were enhanced due to soil addition of compost (Abo El-Ezz *et al.,* 2020; El-Hadidi *et al.,* 2020 and Elbaalawy *et al.,* 2020). On the other hand, Nanotechnology may be a brilliant solution to many common problems in the agricultural sector (El-Sonbaty, 2021). As well as one of the plant's protective ways against the poverty of sandy soil fertility is the utilization of antioxidants such as proline that can increase plant tolerance to the poverty of sandy soil fertility (Dawood, 2021).

The top-down method is a powerful superior strategy for obtaining nanoparticles with a large surface area that are suited for a wide range of applications. A ball mill is a type of grinder that is used to grind and/or mix materials for applications such as mineral dressing, paints, pyrotechnics, ceramics, and selective laser sintering. The ball mill method is a unique method that may be used to produce a very fine powder (in micro or nanoscale) in a completely enclosed system even for highly abrasive materials without using capping or reducing chemicals that may have side effects (Abdelghany *et al.,* 2020 and Menazea *et al*.,2020).

Wheat crop is the main winter cereal crop in all countries of the world. In Arab countries, there is an urgent need for the maximization of wheat crop production because the local production isn't sufficient to equal the annual requirements (El-Ghamry *et al.,* 2021; Elzemrany *et al.,* 2021 and Yaylacı, 2021). The soil addition of some conditioners to sandy soil increases the wheat productivity. So, the objective of this work is to investigate the effect of some soil amendments in two forms i.e. normal form (non-Nano) and Nano form on the performance and productivity of wheat plants grown on sandy soil.

2. Materials and Methods

2.1 Experimental site

Pots research trials were carried out at the Farm of Agricultural Faculty, Mansoura University, Egypt during the growing season of 2021/2022.

2.2 Soil sampling

Surface soil samples (0-25 cm) were collected to represent the sandy soil from Qalapshoo Village, Belqas District, Dakahlia Governorate, Egypt. The soil sample was analyzed before sowing according to Dane and Topp (2020) and Sparks *et al.,* (2020), where their characteristics are presented in Table 1.

TABLE 1. Some physical and chemical properties of sandy soils before adding studied soil conditioners and cultivation of wheat plants

Physical properties	Sandy soil	Chemical properties	Sandy soil
Particles size distribution, %		EC_w, dS m^{-1}	1.10
Sand	90.50	pH (1:2.5 soil suspension)	7.80
Silt	4.70	$CaCO_3$	10.0
Clay	4.80	OM (organic matter) (g kg^{-1})	3.00
Texture class	Sand	ESP	5.27
Hygroscopic water (H.W),%	1.00	Potential salinity (PS), meq L^{-1}	5.64
Saturation (SP),%	24.44	Soluble ions, cmol kg^{-1}	
Field capacity (FC),%	11.22	Ca^{++}	2.92
Wilting point (WP),%	5.61	Mg^{++}	1.09
Available water (AW), %	5.61	Na^{+}	6.56
Bulk Density (Mg m^{-3})	1.70	K^{+}	0.43
Total Porosity%	39.30	HCO_3^{-}	3.88
Real density (Mg m^{-3})	2.80	Cl^{-}	4.15
Permeability index (PI)	0.80	SO_4^{--}	2.97
Gypsum requirements(GR),Mg fed^{-1}	0.35	CEC cmol kg^{-1}	8.00

2.3 Soil conditioners used

The soil conditioners were agricultural gypsum, compost, and sugar lime mud resulting from the sugar beet industry (Dakahlia sugar beet Company) as a waste material from purification and refining processes. Table 2 shows the chemical properties of sugar lime mud, gypsum, and compost used in the experiments.The conditioners used were applied in two forms *i.e.*, normal form (non-Nano) and Nano form, which were prepared using a ball mailing machine (Spectroscopy Department, National Research Centre, Giza, Egypt) to obtain Nano-sized particles physically and without the need for chemical treatment nor adding reducing and/or capping agents.

The dried powder was ball-milled in an ordinary air atmosphere by a (planetary mill for 3 h at 50 rpm) adopting stainless steel jar and zirconium balls. Increasing temperature as a result of the milling process will be limited and has no effective impact on the HCNs especially, the mailing process was switched off each 10 min to observe and collect any residual powders.

The ball mill route utilized in this study was used for the treatment of soil conditioners including compost, agricultural gypsum, and sugar lime mud.

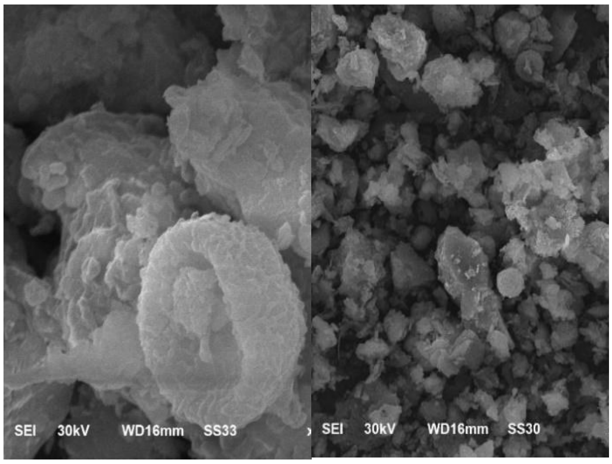
The properties of compost, agricultural gypsum, and sugar lime mud nanoparticles were characterized via Scanning electron microscopy (SEM) supported with Energy dispersive X-ray (EDAX) analysis shown in Fig. 1, 2, and 3.

TABLE 2. Chemical properties of sugar lime mud, gypsum and compost used in the experiment

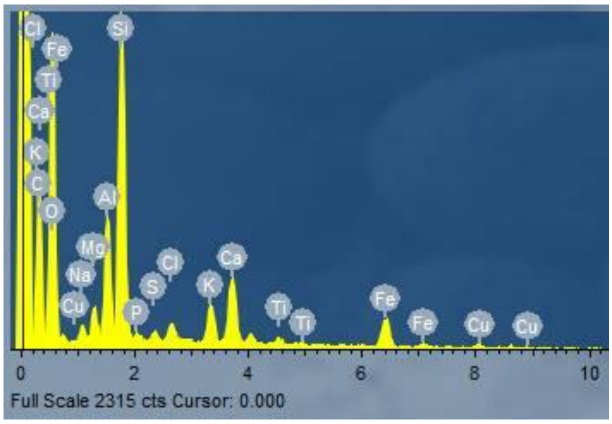
Characteristics	Values
Sugar lime mud	
$CaCO_3$%	40.80
OM%	7.200
N, g kg^{-1}	4.00
P, g kg^{-1}	6.15
K, g kg^{-1}	2.75
pH (1:2.5)	7.9
Agricultural gypsum ($CaSO_4$. $2H_2O$)	
pH (1: 5, gypsum: water)	7.30
EC [1: 5]	2.56
Ca [g Kg^{-1}]	230
S [g Kg^{-1}]	175
Compost	
pH 1:10	5.970
EC (1:10) (dSm^{-1})	3.160
OM%	56.90
Organic carbon%	22.90
C/N ratio	14.22
N, %	1.610
P, %	0. 80
K, %	0.70

Figure 1 (a, b, c) reveals scanning electron microscopic (SEM) images with two different magnifications (a, b) in combination with energy dispersive X-ray (EDAX) analysis (c) for prepared compost nanoparticles. Obtained images reveal the formation of an amorphous higher surface area of nanoparticles overlapped with higher size support. Such a form of distribution allows for higher water holding capacity (WHC).

EDAX analysis data is in agreement with the obtained chemical analysis listed in Table 2 with a more specific of the presented metals.



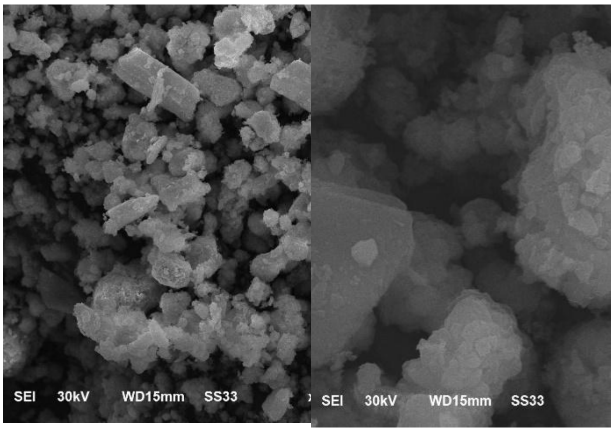
(a) (b)



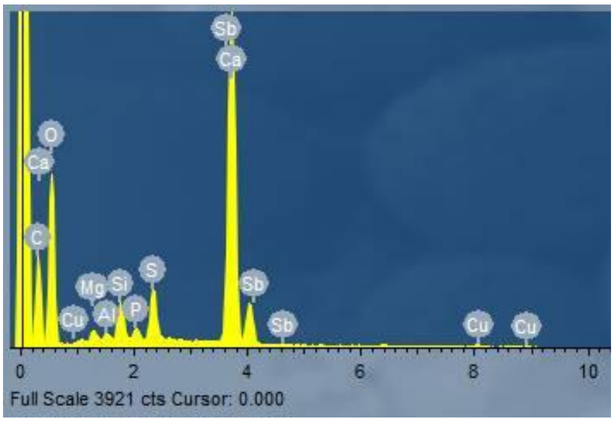
(c)

Fig. 1 (a, b, c) scanning electron microscopic (SEM) images with two different magnifications (a, b) in combination with energy dispersive X-ray (EDAX) analysis (c) for prepared compost nanoparticles

Figure 2 (a, b, c) reveals scanning electron microscopic (SEM) images with two different magnifications (a, b) in combination with energy dispersive X-ray (EDAX) analysis (c) for prepared agricultural gypsum nanoparticles. Obtained images reveal the formation of tiny nanoparticles supported over a crystalline uniform rectangular pattern with a smooth surface pointing to a lower (WHC). EDAX analysis data is in agreement with the obtained chemical analysis listed in the Table 2.



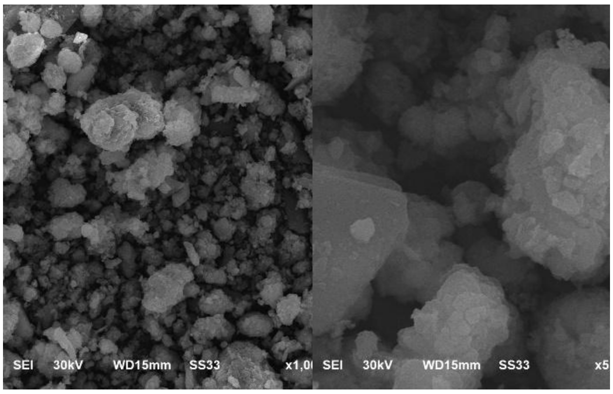
(a) (b)



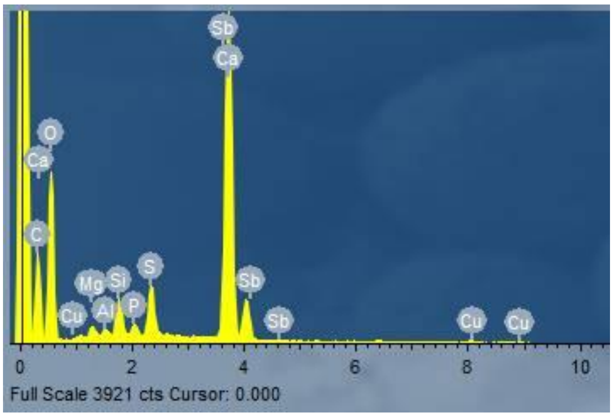
(c)

Fig. 2. (a, b, c) scanning electron microscopic (SEM) images with two different magnifications (a, b) in combination with energy dispersive X-ray (EDAX) analysis (c) for prepared agricultural gypsum nanoparticles

Figure 3 (a, b, c) reveal scanning electron microscopic (SEM) images with two different magnifications (a, b) in combination with energy dispersive X-ray (EDAX) analysis (c) for prepared sugar lime mud nanoparticles. Obtained images reveal the formation of nanoparticles supported over microparticles of the same structure while EDAX analysis support obtained chemical analysis listed in Table 2.



(a) (b)



(c)

Fig. 3 (a, b, c) Scanning electron microscopic (SEM) images with two different magnifications (a, b) in combination with energy dispersive X-ray (EDAX) analysis (c) for prepared sugar lime mud nanoparticles

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2.4 Wheat grains

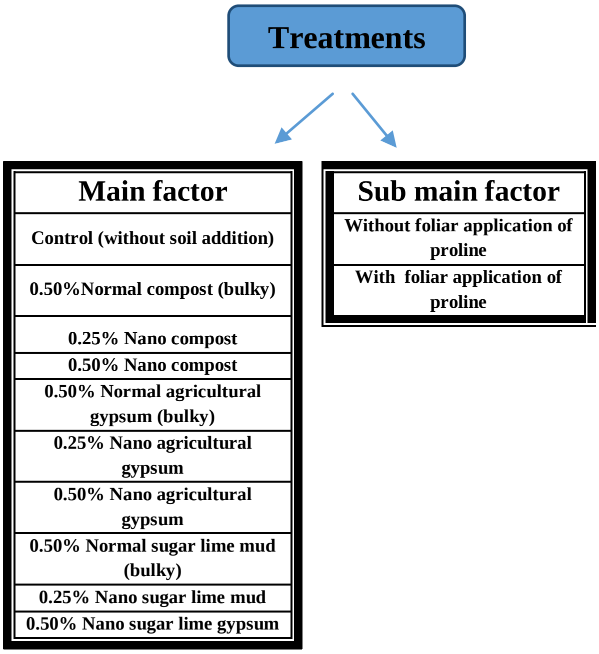
Wheat grains (*Triticum aestivum* L, var. Giza171) were obtained from the Ministry of Agricultural and Land Reclamation (MALR).

2.5 Pots used

Plastic pots (30 cm diameter and 35 cm depth) were filled with air-dry soils equalled to 10 kg oven-dry soil of tested sandy soils.

2.6 Experimental setup

This research work was carried out to assess the effect of some soil conditionersat different rates as amain factor as well as foliar application of proline [without foliar (control), proline] as a sub main factor on the performance of wheat plants grown on sandy soil. The following schematic diagram shows the studied treatments.



Each soil conditioner was applied in pots in normal form (Non-Nano) as control at a rate of 0.5% (5.0g kg^{-1}) and Nano form at two rates (0.25% and 0.5%, 2.5 and 5.0g kg^{-1}) one month before sowing. While foliar application of proline was done at periods of 21, 28, and 35 days from sowing at rate of 80 mg L^{-1}. Proline was purchased from El-Gamhoria Company, Egypt.

With three replicates, the experiment was arranged in a split plot design. All pots were irrigated using fresh water up to saturation limit by weight after mixing conditioners with sandy soil.

On 10th November 2021, thirty grains were sown in each pot then thinning process to 20 plants pot^{-1} was done after 20 days from sowing. The grown plants were irrigated every 4 days according to the needs of the plant. The normal agricultural practices and mineral fertilization were done for wheat production according to Ministry of Agricultural and Soil Reclamation (MASR). Three weeks before sowing, all pots received calcium superphosphate (6.6% P) at a rate of 1.0 g pot^{-1}(100.0 kg fed^{-1}). Ammonium nitrate (33.5 %N) was applied in one dose at 20 days from sowing after thinning process at a rate of 1.3 g N pot^{-1}(130.0 kg fed^{-1}). Potassium sulfate was applied at a rate of 0.41 g K pot^{-1}(41.0 kg fed^{-1}) with an N-fertilizer dose. The harvest process was done on the 11th of March.

2.7 Measurements traits

2.7.1 At a period of 70 days after wheat sowing

Random samples of ten wheat plants were taken from each sub plot to determine the following criteria;

i. Growth parameters: Fresh and dry weights (g $plant^{-1}$) and plant height (cm) as well as leaf area (cm^2) of flag leaf using the following equation L.A= L **x** W **x** 0.7; where L=length and W is the width of the flag leaf.
ii. Photosynthetic pigments: Chlorophyll content (SPAD, value) and carotenoid content (mg g^{-1}) according to Ranganna (1997).
iii. Some enzymatic antioxidants:peroxidase enzyme (POD), catalase enzyme (CAT), and superoxide Dismutase (SOD) were determined using the spectrophotometric method as described by Alici and Arabaci, (2016).

2.7.2 At the harvest stage

Random samples of ten wheat plants were taken from each sub plot to estimate wheat yield and its components as well as some qualitative traits as follows:

2.7.3 Yield and its components:

Spike length, spike weight, No. of grain $spike^{-1}$, the weight of 1000 grain, grain yield, straw yield, biological yield, and harvest index (grain yield / biological yield x100).

2.7.4 Qualitative traits of grains:

Protein content in wheat grain was calculated by using the following formula: Protein % = (N) × 5.75 as described by Anonymous, (1990), while total carbohydrates in wheat grain were determined according to Hedge and Hofreiter (1962).

2.8 Statistical analysis

The obtained data were subjected to analysis of variance according to Gomez and Gomez (1984).

3. Results and Discussion

Plant growing after 70 days from sowing

Soil addition of some conditioners [agricultural gypsum, compost, and sugar lime mud, in normal form (non-Nano) at a rate of 0.5% and another form (Nano) at rates of 0.25% and 0.5%] and foliar application of proline [without foliar (control), proline (80 mg L^{-1})]significantly affected wheat growth criteria *i.e.* plant height (cm), fresh and dry wheat (g $plant^{-1}$) and leaf area (cm^2) (Table 3) as well as photosynthetic pigments*i.e.*, chlorophyll (SPAD, reading) and carotenoid content (mg g^{-1} F.W) and some enzymatic antioxidants in the straw of wheat plant *i.e.*,peroxidase enzyme (POD, unit g^{-1} $protein^{-1}$), catalase enzyme (CAT, unit g^{-1} $protein^{-1}$) and superoxide Dismutase (SOD, unit g^{-1} $protein^{-1}$) after 70 days from wheat sowing (Table 4).

Effect of treatments on the growth and photosynthetic pigments of wheat plants

a- *Growth criteria and chlorophyll content*

The wheat plants treated with compostpossessed the highest values of plant height, fresh and dry wheat, leaf area (Table 3) as well as chlorophyll and carotenoid content (Table 4) under sandy soil conditions followed by that treated with agricultural gypsum than the plants treated with sugar lime mud, while the untreated wheat plants with any soil conditioner (control treatment) possessed the lowest values of all aforementioned traits. On the other hand, the Nano form was superior compared to the normal form with all studied soil amendments. Also, all aforementioned traits increased as the rate of Nano form increased with all studied soil amendments.

Regarding the foliar application, the proline treatment was superior compared to the control treatment (without foliar application). In other words, the wheat plants sprayed with proline had high values of plant height, fresh and dry wheat, leaf area, chlorophyll, and carotenoid content in compression with the corresponding plants grown without foliar application.

Generally, the highest values of all aforementioned traits were realized when wheat plants were treated with 0.50 %Nano compost and sprayed with proline, while the lowest values were recorded when wheat plants were not treated with both soil conditioners and proline (control treatment).

The high organic materials found in compost are a good explanation for its superior impact on the performance growth of wheat at 70 days from sowing compared to other studied soil conditioners (agricultural gypsum and sugar lime mud) (Ghazi, 2020 and Othman, 2021). Agricultural gypsum superiority after the compost is due to that calcium leads to increase soil aggregates, while the beneficial effect of sugar lime mud compared to the corresponding untreated soil may be attributed to its content of organic matter (7%), which has a great role in improving sandy soil fertility as mentioned in a similar study by Ghazi *et al., (*2021a) on wheat plants. On the other hand, the Nano form is better than the normal form and this may be due to increased surface area under the Nano form (both studied rates), thus it is useful to add less amount of conditioner and safe for the environment. The superiority of Nanoparticles may be due to that Nano-fertilizers were more advantageous compared with conventional fertilizers because Nanoparticles can triple the effectiveness of soil conditioners, thus reducing the requirement from these. Also, it can be said that Nanoparticles can increase the resistance of wheat plants to environmental stress in addition to being less hazardous to the environment (El-Sonbaty, 2021).

The superiority of proline may be attributed to that foliar application of proline promoted sandy soil stress tolerance during wheat plant development in addition to its role in cell division and cell wall expansion (Othman, 2021).

TABLE 3. Effect of some soil conditioners and foliar application of proline on growth criteria of wheat plant grown on sandy soil at a period of 70 days from planting date

Treatments		Plant height, cm	Fresh weight, g plant^{-1}	Dry weight, g plant^{-1}	Leaf area, cm^2 plant^{-1}
Conditioners form and rates					
T_1		75.81j	31.92g	8.07j	90.28j
T_2		78.79f	32.61d	8.63f	93.31e
T_3		81.87c	33.14b	9.20c	96.39c
T_4		84.77a	33.97a	9.76a	99.45a
T_5		88.09g	34.67e	10.34g	102.57f
T_6		91.53d	35.38c	10.96d	105.69d
T_7		94.74b	36.06b	11.49b	108.80b
T_8		96.21i	36.36fg	11.71i	109.96i
T_9		97.56h	36.67f	11.92h	110.83j
T_{10}		99.14e	36.98d	12.14e	111.84g
LSD5%		0.74	0.53	0.19	0.41
Foliar applications					
F_1		93.46b	35.62b	11.05b	104.21b
F_2		95.11a	36.13a	11.34a	105.26a
LSD5%		0.30	0.21	0.06	0.26
Interaction					
T_1	F_1	75.35o	31.84k	8.01m	89.96r
	F_2	76.26o	31.99k	8.13m	90.59qr
T_2	F_1	93.28i	35.95i	11.40f	108.31i
	F_2	96.20h	36.16hi	11.58f	109.28h
T_3	F_1	102.08e	37.80def	12.69d	114.39e
	F_2	105.09d	38.37cde	12.68d	115.76d
T_4	F_1	109.55b	39.36b	13.23b	119.15b
	F_2	110.87a	41.50a	13.61a	120.56a
T_5	F_1	87.09k	34.99j	10.62h	105.25k
	F_2	88.37j	35.52ij	11.02g	107.14j
T_6	F_1	98.13g	37.18fg	11.94e	110.81g
	F_2	99.19f	37.70ef	12.58d	111.88f
T_7	F_1	105.96d	38.38cd	13.04c	117.07c
	F_2	106.99c	38.56c	13.04c	117.80c
T_8	F_1	80.60n	32.14k	8.53l	91.11pq
	F_2	82.64m	32.39k	8.76k	91.46op
T_9	F_1	85.37l	32.42k	9.13j	91.97o
	F_2	88.30j	32.50k	10.11i	92.82n
T_{10}	F_1	97.21g	36.19hi	11.86e	94.11m
	F_2	97.18g	36.63gh	11.87e	95.30l
LSD5%		0.95	0.68	0.19	0.83

T_1: Control (without soil addition);**T_2:** 0.50%Normal compost (bulky);**T_3:** 0.25% Nano compost;**T_4:** 0.50% Nano compost;**T_5:** 0.50% Normal agricultural gypsum (bulky);**T_6:** 0.25% Nano agricultural gypsum;**T_7:** 0.50% Nano agricultural gypsum; **T_8:** 0.50% Normal sugar lime mud (bulky);**T_9**: 0.25% Nano sugar lime mud;**T_{10}**: 0.50% Nano sugar lime mud; **F_1:** Without proline and **F_2:** With proline.

TABLE 4. Effect of some soil conditioners and foliar application of proline on photosynthetic pigments and enzymatic antioxidants in the straw of wheat plant grown on sandy soil at a period of 70 days from planting date

Treatments		Photosynthetic pigments		Enzymatic antioxidants		
		Chlorophyll (SPAD, reading)	Carotenoid (mg g^{-1})	POD	CAT (unit g^{-1} protein $^{-1}$)	SOD
Conditioners form and rates						
T_1		31.81i	0.297j	1.275a	48.24a	7.75a
T_2		35.67e	0.367f	1.157e	46.23b	6.41e
T_3		38.09c	0.404c	0.999h	43.33d	6.21gh
T_4		39.26a	0.429b	0.908j	39.13e	6.06i
T_5		35.09f	0.348g	1.183d	47.66a	7.13d
T_6		37.47d	0.392d	1.085g	44.14c	6.26fg
T_7		38.69b	0.468a	0.928i	39.43e	6.16h
T_8		32.64h	0.315i	1.253b	48.10a	7.53b
T_9		33.98g	0.333h	1.223c	47.96a	7.24c
T_{10}		37.05d	0.381e	1.121f	44.45c	6.31f
LSD5%		0.54	0.004	0.013	0.70	0.08
Foliar applications						
F_1		35.72b	0.365b	1.127a	45.06a	6.75a
F_2		36.23a	0.382a	1.099b	44.67b	6.66b
LSD5%		0.26	0.003	0.008	0.29	0.06
Interaction						
T_1	F_1	31.25l	0.292q	1.288a	48.22a	7.78a
	F_2	32.36k	0.302pq	1.262b	48.25a	7.73a
T_2	F_1	35.31gh	0.363j	1.165de	47.28b	6.42d
	F_2	36.03g	0.371ij	1.148ef	45.17c	6.40d
T_3	F_1	37.94de	0.401de	1.065i	43.36e	6.22ef
	F_2	38.25cd	0.407ec	0.933j	43.30e	6.20ef
T_4	F_1	39.08ab	0.426b	0.913jk	39.23f	6.10fg
	F_2	39.44a	0.432b	0.902k	39.02f	6.01g
T_5	F_1	34.92hi	0.344kl	1.190d	47.87ab	7.18bc
	F_2	35.26gh	0.352k	1.175d	47.44ab	7.07c
T_6	F_1	37.23ef	0.388fg	1.092gh	44.18de	6.27def
	F_2	37.71def	0.396ef	1.078hi	44.10de	6.26def
T_7	F_1	38.39bcd	0.415c	0.931j	39.48f	6.17efg
	F_2	38.99abc	0.521a	0.924jk	39.39f	6.14fg
T_8	F_1	32.46k	0.311op	1.263ab	48.14ab	7.71a
	F_2	32.82k	0.319no	1.242bc	48.05ab	7.35b
T_9	F_1	33.76j	0.329mn	1.228bc	48.06ab	7.29b
	F_2	34.20ij	0.338lm	1.217c	47.86ab	7.19bc
T_{10}	F_1	36.90f	0.378hi	1.137f	44.75cd	6.33de
	F_2	37.19ef	0.384gh	1.104g	44.15de	6.28def
LSD5%		0.83	0.011	0.026	0.93	0.18

T_1: Control (without soil addition); **T_2:** 0.50%Normal compost (bulky); **T_3:** 0.25% Nano compost; **T_4:** 0.50% Nano compost; **T_5:** 0.50% Normal agricultural gypsum (bulky); **T_6:** 0.25% Nano agricultural gypsum; **T_7:** 0.50% Nano agricultural gypsum; **T_8:** 0.50% Normal sugar lime mud (bulky); **T_9**: 0.25% Nano sugar lime mud; **T_{10}**: 0.50% Nano sugar lime mud; **F_1:** Without proline; **F_2:** With proline; **POD:** Peroxidase enzyme; **CAT:** Catalase enzyme and **SOD:** Superoxide dismutase.

***b-** Enzymatic antioxidants*

Table 4 illustrates the wheat plant's self-production from enzymatic antioxidants in the straw of wheat plant *i.e.,* peroxidase enzyme (POD, unit g^{-1} protein $^{-1}$), catalase enzyme (CAT, unit g^{-1} protein $^{-1}$) and superoxide dismutase (SOD, unit g^{-1} protein^{-1}) after 70 days from wheat sowing.

Not using soil and foliar applications (control treatment) caused an increase of wheat self-production from these antioxidants to scavenge the ROS (or as named free radicals) resulting due to the poverty of sandy soil to increase of tolerance at 70 days from sowing. In contrast, the plants that were treated with the studied substances did not need a large self-production from these antioxidants because the studied substances may have played the role played by the antioxidants, and this is in different proportions according to the rates studied.

In other words, untreated wheat plants with any soil conditioners (control) contained the highest values of studied enzymatic antioxidants, while the lowest values were realized when wheat plants were treated with nano compost at a rate of 0.50 %. Also, the wheat plants treated with proline produced the lowest values of these enzymatic antioxidants in the wheat straw after 70 days from sowing compared to untreated plants (without proline) which have the highest values. Thus it can be said that proline played an adaptive role in the tolerance of wheat plants to sandy soil poverty.

Generally, it can be concluded that all studied soil conditioners either in normal form or nano form as well as proline have a beneficial effect on reducing the wheat plant's requirements from antioxidants self-production compared control treatments.

This is attributed to the vital role of studied treatments, which played the role played by the antioxidants, in scavenging ROS (responsible for cell damage) in the chloroplast as well as their role in regulating wheat plant physiology, photosynthesis, and immunological enhancement. The obtained results showed that all studied stimulants have a positive effect on scavenging ROS compared to untreated plants. The obtained findings are in harmony with the results of Ghazi (2020) and Othman (2021).

***c-** Performance at Harvest Stage*

Soil addition of some conditioners [agricultural gypsum, compost, and sugar lime mud, in normal form (non-Nano) at a rate of 0.5% and another form (Nano) at rates of 0.25% and 0.5%] and foliar application of proline [without foliar (control), proline (80 mg L^{-1})]significantly affected wheat yield and its components *i.e.* spike length (cm), spike weight (g), No. of grain spike^{-1}, the weight of 1000 grain (g), grain, straw and biological yield (Mg ha^{-1}) (Fig 4) and harvest index as well as qualitative traits of grains *i.e.,* carbohydrates and protein content (%) (Table 5).

Data from Tables 5 and 6 illustrated that the highest values of spike length, spike weight, No. of grain spike^{-1}, the weight of 1000 grain, grain, straw and biological yield, harvest index, carbohydrates, and protein content of plants grown on sandy soil were recorded when the wheat plants were treated with compost followed by that treated with agricultural gypsum than the plants treated with sugar lime mud, while the untreated wheat plants with any soil conditioner (control treatment) had the lowest values of all aforementioned traits. On the other hand, the Nano form was superior compared to the normal form with all studied soil amendments. Also, all aforementioned traits increased as the rate of nano form increased with all studied soil amendments. Regarding the foliar application, the wheat plants sprayed with proline had high values of all aforementioned yield and grain traits in compression with the corresponding plants grown without foliar application.

Generally, the highest values of spike length, spike weight, No. of grain spike^{-1}, the weight of 1000 grain, grain, straw and biological yield, harvest index, carbohydrates, and protein content were recorded when wheat plants were treated with 0.50 %Nano compost and sprayed with proline, while the lowest values were recorded when wheat plants were not treated with both soil conditioners and proline (control treatment).

Generally, it can be noticed that the increase of wheat plant growth and photosynthetic pigments content due to either soil conditioners or foliar applications of proline positively reflected wheat yield and grain quality. These findings are in the line with those obtained byKheir and Kamara, (2019); Abo El-Ezz *et al.,* (2020); El-Hadidi *et al.,* (2020) who recognized the importance of sugar lime mud , gypsum and compost in reclaiming sandy soil. Beside, El-Sonbaty, 2021) who reported the superiority of Nano fertilizers compared to traditional fertilizers.

TABLE 5. Effect of some soil conditioners and foliar application of proline on yield and its components of wheat plants grown on sandy soil as well as some biochemical traits of wheat grains

Treatments		Spike length, cm	Spike weight, g	No. of grain spike^{-1}	Weight of 1000 grain, g	Grain yield (Mg ha^{-1})	straw yield (Mg ha^{-1})	Biological yield (Mg ha^{-1})	Harvest index, %	Biochemical traits of wheat grains	
										Carboh-ydrates,%	Protein,%
Conditioners form and rates											
T_1		12.96j	2.95j	44.09j	23.33h	4.15j	7.38j	11.53j	36.02h	61.82g	8.50i
T_2		16.73f	3.58f	45.67f	28.67de	5.23f	8.81f	14.04f	37.27e	65.15e	9.20f
T_3		18.37c	3.94c	47.38c	32.33b	5.90c	9.61c	15.51c	38.01c	67.13bc	9.82c
T_4		19.53a	4.30a	49.12a	34.67a	6.43a	10.10a	16.53a	38.90a	68.78a	10.07a
T_5		15.00g	3.29g	44.99g	27.50ef	4.98g	8.21g	13.18g	37.73d	64.77e	8.94g
T_6		17.65d	3.78d	47.08d	31.00c	5.67d	9.35d	15.01d	37.74d	66.48cd	9.55d
T_7		19.05b	4.18b	48.00b	33.33b	6.13b	9.83b	15.96b	38.42b	67.77ab	9.93b
T_8		13.94i	3.05i	44.58i	24.83g	4.32i	7.57i	11.89i	36.36g	62.49fg	8.65h
T_9		14.42h	3.10h	44.75h	26.33f	4.62h	7.89h	12.51h	36.93f	63.34f	8.72h
T_{10}		17.12e	3.68e	46.49e	29.83cd	5.54e	9.14e	14.68e	37.76d	65.60de	9.39e
LSD5%		0.18	0.03	0.14	1.19	0.05	0.07	0.08	0.21	1.06	0.08
Foliar applications											
F_1		16.32b	3.55b	46.00b	28.87b	5.24b	8.70b	13.94b	37.49a	65.19	9.21b
F_2		16.63a	3.62a	46.43a	29.50a	5.35a	8.87a	14.22a	37.54a	65.47	9.34a
LSD5%		0.13	0.02	0.13	0.51	0.03	0.05	0.07	N.S	N.S	0.05
Interaction											
T_1	F_1	12.81j	2.89n	43.90j	23.00q	4.09m	7.35n	11.44o	35.76i	61.53k	8.45j
	F_2	13.10j	3.01m	44.28ij	23.67q	4.22l	7.41n	11.62no	36.28h	62.11jk	8.55ij
T_2	F_1	16.69f	3.55i	45.22g	28.33jkl	5.20fg	8.56i	13.77h	37.80cd	65.25fg	9.13g
	F_2	16.78f	3.62hi	46.11f	29.00ijk	5.26f	9.05h	14.31g	36.74g	65.04fg	9.26fg
T_3	F_1	18.22cd	3.91d	47.35cd	32.00def	5.85c	9.57ef	15.42d	37.92cd	66.97bc	9.77de
	F_2	18.53bc	3.97d	47.41cd	32.67cde	5.94c	9.65de	15.60d	38.11bc	67.28bc	9.86cd
T_4	F_1	19.39a	4.23b	48.53b	34.33ab	6.38a	10.03ab	16.41b	38.89a	68.69a	10.04ab
	F_2	19.67a	4.36a	49.70a	35.00a	6.48a	10.17a	16.65a	38.92a	68.86a	10.10a
T_5	F_1	14.66h	3.24k	44.87gh	27.33lm	4.85h	8.10k	12.95j	37.43ef	64.70gh	8.75h
	F_2	15.33g	3.35j	45.12g	27.67kl	5.10g	8.31j	13.42i	38.04bc	64.84gh	9.12g
T_6	F_1	17.38e	3.76ef	47.06de	30.67fgh	5.62de	9.22g	14.84f	37.86cd	66.18c-f	9.41f
	F_2	17.93d	3.81e	47.09de	31.33efg	5.71d	9.47f	15.18e	37.63de	66.77b-	9.68e
T_7	F_1	18.82b	4.14c	47.56c	33.00bc	6.09b	9.76cd	15.85c	38.42b	67.72ab	9.88bcd
	F_2	19.28a	4.21bc	48.44b	33.67abc	6.17b	9.90bc	16.07c	38.41b	67.82ab	9.97abc
T_8	F_1	13.90i	3.04m	44.57hi	24.33pq	4.30kl	7.50mn	11.81mn	36.45gh	62.49ijk	8.62hij
	F_2	13.98i	3.06lm	44.58hi	25.33op	4.34k	7.63m	11.97m	36.28h	62.50ijk	8.67hi
T_9	F_1	14.27hi	3.08lm	44.65hi	26.00no	4.51j	7.81l	12.32l	36.58gh	62.87ij	8.69hi
	F_2	14.57h	3.13l	44.85gh	26.67mn	4.73i	7.96kl	12.69k	37.27f	63.81hi	8.75h
T_1	F_1	17.06ef	3.67gh	46.27f	29.67hij	5.54e	9.10gh	14.64f	37.82cd	65.51ef	9.36f
	F_2	17.18e	3.70fg	46.71e	30.00ghi	5.55e	9.17gh	14.72f	37.70c-	65.68d-	9.42f
LSD5%		0.40	0.07	0.40	1.62	0.11	0.16	0.23	0.43	1.33	0.17

T_1: Control (without soil addition);**T_2:** 0.50%Normal compost (bulky);**T_3:** 0.25% Nano compost;**T_4:** 0.50% Nano compost;**T_5:** 0.50% Normal agricultural gypsum (bulky);**T_6:** 0.25% Nano agricultural gypsum;**T_7:** 0.50% Nano agricultural gypsum; **T_8:** 0.50% Normal sugar lime mud (bulky);**T_9**: 0.25% Nano sugar lime mud;**T_{10}**: 0.50% Nano sugar lime mud; **F_1:** Without proline and **F_2:** With proline.

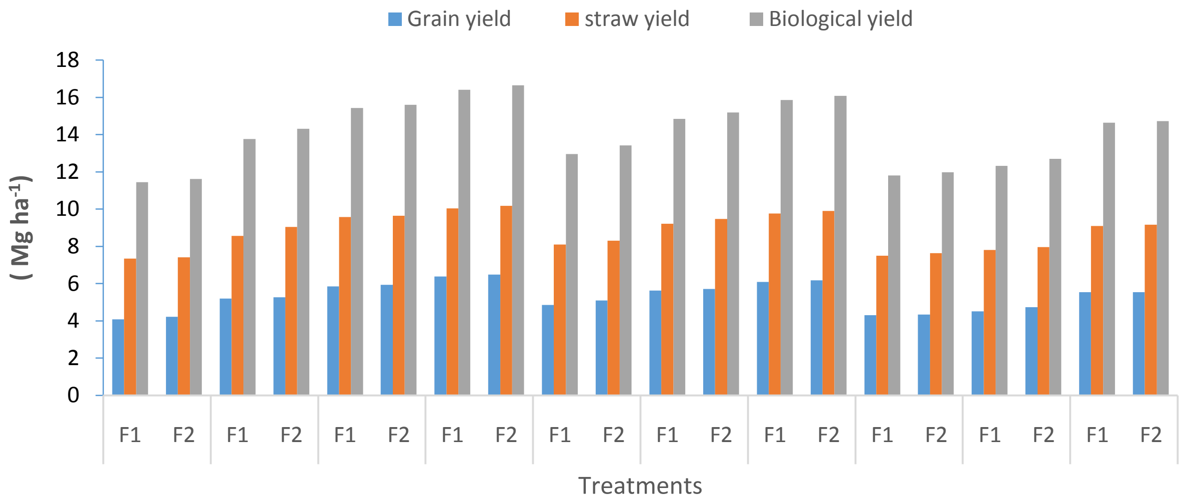


Fig. 4. Effect of some soil conditioners and foliar application of proline on grain,straw and biological yields of wheat plants grown on sandy soil

T_1: Control (without soil addition);**T_2:** 0.50%Normal compost (bulky);**T_3:** 0.25% Nano compost;**T_4:** 0.50% Nano compost;**T_5:** 0.50% Normal agricultural gypsum (bulky);**T_6:** 0.25% Nano agricultural gypsum**;T_7:** 0.50% Nano agricultural gypsum; **T_8:** 0.50% Normal sugar lime mud (bulky);**T_9**: 0.25% Nano sugar lime mud;**T_{10}**: 0.50% Nano sugar lime mud; **F_1:** Without proline and **F_2:** With proline.

4. Conclusions

Generally, it can be concluded that all the studied soil conditioners (*i.e.*, gypsum, compost, and sugar lime mud) in either normal form or Nano form have a beneficial effect on improving the performance and productivity of wheat plants grown under sandy soil conditions. Also, the findings of the current work confirmed proline is one of the plant's protective ways from the poverty of sandy soil fertility, where it works as an antioxidant and leads to an increase in wheat plant tolerance to the poverty of sandy soil fertility.

- Conflicts of interest

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge.

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