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The Co-Addition of Soil Organic Amendments and Natural Bio-Stimulants Improves the Production and Defenses of the Wheat Plant Grown under the Dual Stress of Salinity and Alkalinity

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Abstract

Soil salinity is one of the biggest widespread abiotic stresses severely restricting crop production. Under stress, several extracts have been used as effective natural bio-stimulants. However, the combined influences of soil organic amendments and natural bio-stimulants on the production and defenses of plants grown under the dual stress of salinity and alkalinity are still only rudimentarily known. So, a field experiment was executed during the winter season of 2020/2021to assess the effectiveness of various organic amendments and the foliar application of various stimulants in reducing the detrimental effects of soil salinity on wheat plants grown under saline-alkali stress (electric conductivity = 13.2 dSm^{-1} and exchangeable sodium percentage = 15.1%).Twenty treatments were executed in a split plot design. The organic amendments[without soil addition (control), vermicompost, compost and chicken manure] were devoted in the main plots, while thebio-stimulants (without foliar application (control), moringa leave extract, licorice root extract, ginger extract, and humate potassium) were allocated in the sub plots.

The findings illustrated that the highest plant's self-production of proline and enzymatic antioxidants *i.e*. catalase enzyme, peroxidase and superoxide dismutase were realized whenwheat plants were treated with vermicompost and sprayed with moringa extract, while the lowest values of proline and enzymatic antioxidants were recorded with untreated plants (without soil and foliar application). Regarding the yield and its components, the highest value of yield was realized with wheat plants treated with vermicompost and moringa extract simultaneously.

Keywords: Vermicompost, compost and chicken manure, Moringa, Enzymatic antioxidants and wheat plants.

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1. Introduction

Nowadays, due to difficulty of finding suitable regions to be enabled the plants to achieve their optimum production potential, researchers should find practical solutions to remediate the degraded soils *e.g.,* salt-affected soil to face the big gap between population growth and their requirements (FAO, 2005). Soil salinity is one of the main factors hindering agricultural development due to the negative impact of soil salinity on production of most agricultural crops (El-Ramady *et al.,* 2018 and Abou Hussien *et al.*, 2020). The high osmotic pressure in the soil solution leads to the plant's inability to absorb the water necessary for its activities, vitality and transpiration (Abdelrahman *et al.,* 2021 and Ibrahim *et al.,* 2022). Increasing the soil salinity causes a negative effect on the hormonal balance in the plant, where it causes a decrease in the transfers from roots to leaves and the accumulation of some acids in the leaves (Abo El-Ezz *et al.* (2020). Sodic saline soil originates mainly due to little precipitation, where the destruction of soil structure is done via clay dispersion as a result of high exchangeable Na^+ on the soil colloids (Ghazi *et al.,* 2021a). Salinity imposes harmful influences on plant growth performance through production of reactive oxygen species (ROS) which oxidate plant cells and (El-Agrodi *et al.,* 2016 and Ghazi *et al.,* 2021b).

Organic manures possess the possibility of increasing soil aggregates, thus improving soil salt leach. Also it leads to provide the energy of microflora in addition to its ability to improve soil physical, chemical and biological properties and supply nutrients under salinity conditions (Al-Taey, 2017; Hafez *et al.*, 2020; El-Hadidi *et al*., 2020; Emam *et al.*, 2020 and Mohamed *et al.*, 2020). There are many researches with respect to the effect of organic amendments on plants grown on salt affected soil. Hafez *et al*. (2020) reported that vermicompost improved chemical characteristics of saline sodic soil and eliminates the detrimental influences of soil salinity. Othman (2021) assessed the influence of plant compost and animal compost on the saline soil characteristics after barley harvest and found that both plant compost and animal compost positively affected soil available nutrients (N, P and K) compared to control treatment. El-Hamdi *et al.* (2019) illustrated that the application of chicken manure significantly increased the values of wheat grains per spike, spike length (cm), weight of 1000 grains, grain and straw yields (g pot^{-1}) over control treatment.

Some papers presented the protective ways from soil salinity stress including papers discussed the usage of stimulants *e.g.,* natural herbal extracts and humate potassium, which causes increase tolerance of plants to salinity stress (Ghasemzadeh *et al.*, 2012; Kandil *et al.*, 2016;Soliman *et al.*, 2019 and Elrys *et al.*, 2020). Makkar *et al.* (2007) found that moringa leaf extract (*Moringa oleifera* L.) contains significant quantities of K, Ca, proteins and cytokinin in the form of zeatin as well as many antioxidants, ascorbates and phenols. Elrys *et al.* (2020) found that foliar application of licorice root extract led to improve wheat production as well as defenses under salt stress circumstances and attributed that to it's content of growth regulators as well as the important glycyrrhizin substance. Ghasemzadeh *et al.* (2012) reported that ginger (*Zingiber officinale Rosc*.) is rich in flavonoid components, macro and micronutrients. On the other hand, Elshaboury and Sakara (2021) reported that potassium humate increased the rate of nutrient uptake and improved plant biomass.

Wheat (*Triticum aestivum* L.) is the second most important food crop in Egypt which remains the world's largest wheat importer (Elzemrany *et al.*, 2021). Wheat grains contain protein of 6-21%, minerals of 1.8%, the starch of 60-68%, cellulose of 2.0- 2.5% and fats of 1.5-2.0% (El-Ghamry *et al.,* 2021 and Ghazi *et al.,* 2022).

Therefore, the aim of the current work is to study the impact of salt affected soil on plant's self-production of enzymatic and non-enzymatic antioxidants as well as yield of wheat plants and evaluate the effect of different organic amendments and foliar application of some stimulants in alleviating the harmful effect of soil salinity on wheat plants grown.

2. Material and Methods

A field trial was done during the winter season of 2020/2021 at a private farm located in El-Hosayniya District, El-Sharkia Governorate, Egypt aiming at evaluating the effect of soil addition of different organic amendments as main plots and foliar spraying with some stimulants as sub main plots on wheat plants grown under salinity conditions. The combined influences of organic amendments and stimulants materials were done by combining four organic treatments [control(without soil addition), vermicompost (at rate of 1.0 Mg fed^{-1}), compost (at rate of 10.0 Mg fed^{-1}) and chicken manure (10.0 Mg fed^{-1})] and five foliar applications of stimulants [control (without), moringa, licorice and ginger (2.0%) and humate potassium (2.5 g L^{-1})] at the volume of 870 L ha^{-1} for all them. Thestudied rates of the treatments (main and sub-main) were almost the same as the one used by Yasmeen, (2011); Othman, (2021); Ghazi, (2020); Ghazi and El-Sherpiny (2021); Doklega and Imryed, (2020) Elrys *et al.* (2020).

- *Soil Sampling*

Before soil addition of studied organic amendments, a composite soil sample was taken at a depth of 0-20 cm from the experimental site then analyzed according to Sarkar (2005),where the studied soil had a clayey texture with 21.03% of sand, 30.30% of silt, 48.67% of clay having pH value of 8.13, EC value of 13.20 dSm^{-1}, ESP value of 15.08% and CEC value of 25.28 cmol kg^{-1}.

- *Preparation and addition of organic manures*

Compost (50% plant residues + 50% horses and cows excrements) was prepared as described by El-Hammady *et al.* (2003), then it was transported immediately to the experimental site, where it was added to soil before sowing (during soil preparation) at rate of 24.0 Mg h^{-1}. Chicken manure (ChM) was added to soil before sowing (during soil preparation) at rate of 24.0 Mg h^{-1} while Vermicompost was added to soil before sowing (during soil preparation) at rate of 2.4 Mg h^{-1}. The characteristics of organic amendments used are shown in Table 1.

- *Foliar applications*

Moringa extract (*Moringa oleifera*) was done through mixing 20 g of moringa leaves with 675 ml of 80 % ethanol according to **Mvumi*et al.* (2013)** and then the suspension was stirred then filtered. Licorice root(*Glycyrrhizaglabra*) was extracted at 50°C for 24 h through soaking 10.0 g of roots in a liter of water according to Ghazi (2020) and then filtered and supplement the final volume to liter. Ginger extract was prepared through washing manually followed by peeling with a sharp knife then drying in a hot air oven at 55°C followed by grinding to a ne powder. 10.0 g of ground ginger (*Zingiber officinale*) was extracted with 100 ml of ethanol overnight in a shaker at room temperature (32 ± 2 ºC). The combined ltrate was evaporated in a rotary evaporator below 40°C. The extract obtained after evaporation of ethanol was used (**Salariya and Habib, 2003)**. Potassium humate was purchased from SyngentaCompany, Cairo city, Egypt.

Solutions of natural stimulants (moringa, licorice, ginger) were prepared with a concentration of 2.0 %, while solution potassium humate was prepared with a concentration of 2.5 g L^{-1}. Some stimulants characteristic are shown in Tables 2 and 3.

- *Experimental design*

Twenty treatments were executed in a split plot design with three replicates with area of 6.25 m^2 (2.5 m width and 2.5 m length) for each subplot.

- *Cultivation*

Wheat grains (CV Misr 1) were sown at a rateof 160 kg ha^{-1} on 29th of November. One month before wheat sowing, the studied organic amendments were applied to the studied soil in a single application at the aforementioned rates, where each experimental subplot received organic amendments then irrigated after adding. Foliar application of the studied stimulants was implemented at three periods *i.e.,* 30, 45, and 60 days from sowing. The traditional agricultural practices including mineral fertilization and irrigation were done for the wheat production according to the Egyptian Ministry of Agriculture. On 30th of April, harvest process was done.

- *Measurement traits*

At a period of 70 days after wheat sowing: Proline was determined according to Ábrahám *et al.* (2010). Catalase enzyme activity (CAT) was calculated using a molar extinction coefficient of 36 mol L^{-1} cm^{-1} and expressed by mol of H_2O_2 min^{-1} mg^{-1} of protein (Anderson *et al.*, 1995). Peroxidase Activity (POX) was assessed through the production rate of purpurogallin at 420 nm according to the proposed method of Nakano and Asada (1981).Superoxide Dismutase (SOD) was assessed according to the proposed method of Giannopolitis and Ries (1977).

At harvest stage: Spike weight (g),spike length(cm), No. of grain $spike^{-1}$,weight of 1000 grain (g), grain yield (Mg h^{-1}), straw yield (Mg h^{-1}), biological yield (Mg h^{-1}) and harvest index (grain yield / biological yield x100) were measured. N, P and K (%) contents of wheat grain were determined using micro-kjeldahl, spectrophotometer and flame photometer apparatus, respectively according to Chapman and Pratt (1961). As well N, P, K and Na uptake (kg ha^{-1}) in straw and grain.

- *Statistical Analysis.*

It was done according to Gomez and Gomez, 1984, using CoStat (Version 6.303, CoHort, USA, 1998–2004)].

TABLE 1. Some characteristics of organic amendments used.

Organic fertilizers	EC**, dSm^{-1}	pH*	Organic matter, %	Total nutrients,%			C/N ratio	Moisture, %	Weight of m^3 kg^{-1}
				N	P	K			
Compost	3.65	7.98	39.87	1.80	0.60	1.53	12.87	31.0	325
Vermicompost	3.01	7.87	40.63	2.93	0.93	1.87	8.06	33.0	580
Chicken manure	4.64	7.93	42.87	2.44	0.86	1.73	10.21	32.0	645

*Organic residues -water suspension 1: 5 ** Organic residues water extract 1: 10

TABLE 2. Chemical analyses of natural extract used

Components	Natural extracts		
	Water extract	Ethanolic extracts	
	Licorice root	Moringa leaves	Ginger
Ca,%	2.500	2.500	2.700
Fe, mg kg^{-1}	512.0	550.0	370.0
N,%	1.900	2.000	0.800
Mg,%	0.010	0.012	0.010
K,%	1.700	2.100	1.100
P,%	0.250	0.300	0.095
Super oxide dismutase (SOD),IU min^{-1} mg $^{-1}$ protein.	170.0	193.2	130.4
Peroxidase (POD), IU min^{-1} mg $^{-1}$ protein.	17.80	21.90	15.30
Catalase (CAT), IU min^{-1} mg $^{-1}$ protein.	6.920	7.050	5.640

TABLE 3. Characteristic of potassium humate used.

Solubility,%	pH	Humic acid,%	Fulvic acid,%	Moisture,%	N,%	K_2O,%	P_2O_5,%
100	**8.60**	**62.0**	**3.20**	**5.92**	**0.47**	**11.0**	**1.00**

Concerning ginger extract, it was a superior treatment compared to both potassium humate and control treatments and its superiority may be due to its contents of phenolic acids such as gallic, salicylic, cinnamic, ferulic, vanillic and tannic acids as mentioned by Ghasemzadeh *et al.* (2010).

Potassium humate had a remarkable effect against salinity stress compared to control treatment. This ameliorative effect may be owing to the entrance of humic substances into the wheat tissues carrying both water and micronutrients. Also, the ameliorative effect may be attributed to its ability in increasing the water permeability of wheat plant membranes and water holding capacity. The findings are in agreement with the obtained results of Osman *et al.* (2017) who reported that potassium humate could indirectly and directly affect the physiological processes of wheat plant growth under salinity conditions by providing minerals uptake and biochemical substances as well as carrying trace elements and growth regulators for improving wheat plant's growth.

Going along with combination treatments between organic amendments and foliar application of stimulants, it was obvious that the highest plant's self-production of all aforementioned traits were realized when wheat plants were treated with vermicompost (VC) and sprayed with moringa extract, while the lowest values of proline and enzymatic antioxidantswere recorded with untreated plants (without soil and foliar application).

It is known that plant's self-production of antioxidants increases in tissues of the plants grown on salt-affected soil to protect the plant from the deleterious effect resulting from overproduction of free radicals or reactive oxygen species (ROS) owing to salinity stress but with the continuing salinity stress for a long time, the plant's self-production of these antioxidants declines. On the contrary, the findings showed that the wheat plant's self-production of antioxidants *i.e.* proline catalase enzyme, peroxidase and superoxide dismutase didn't decline but increased due to all studied organic amendments and this may be attributed to that studied organic substances promoted plants to produce these antioxidants to reduce the oxidative damage in stressed plants by modulating oxidative balance. The obtained findings are in harmony with the results of Othman, (2021) who indicated that salinity of soil (6.25 dSm^{-1}) negatively affected all growth criteria of barley plants.On the other hand, the superiority of moringa extract in scavenging ROS may be due to its high content from antioxidants **(Ghasemzadeh *et al.* 2010)** compared to other stimulants, where licorice followed it in its content then ginger extract and lately potassium humate (Makkar *et al.* 2007; Osman *et al.* 2017 and Elrys *et al.* 2020).

- *Effect of soil application of organic amendments, foliar addition of stimulants and their interactions on wheat yield and its components*

Data of Table 5 show that wheat plants grown on salt affected soil and amended by vermicompost possessed the highest values of spike lengths and weights, weight of 1000 grains , No. of grains $spike^{-1}$ as well as grain, straw and biological yield and harvest index followed by that amended by chicken manure (ChM),then plants treated with compost (C), while untreated wheat plants showed the lowest values of yield and its components. The obtained results are in harmony with those of Mohammed *et al*. (2012);Mahmoud *et al.* (2015); Liu *et al.* (2019); Shaban *et al.* (2019); Tahir*et al.* (2020) and Othman, (2021).

Data of the same Table clearly indicate that foliar application of stimulants caused a noticeable increment in productivity of wheat plants grown on saline soil as compared to that of the corresponding control plants, where the plants sprayed with moringa extract showed the highest values of spike lengths and weights, weight of 1000 grains , No. of grains $spike^{-1}$ as well as grain, straw and biological yield and harvest index followed by licorice extract, ginger extract and potassium humate, respectively, while untreated plants (control) had the lowest values of all aforementioned yield traits. The findings are in accordance with those of Yasmeen, (2011); Tuba *et al*. (2015); Shabana *et al.* (2017); Ismail *et al*. (2018); Elrys *et al.* (2020); Merwad (2020).

Results in Table 5, also show that treating the wheat plants with vermicompost (VC) before sowing and spraying it with moringa extract realized the highest values of spike lengths and weights, weight of 1000 grains , No. of grains spike^{-1} as well as grain, straw and biological yield and harvest index, while the lowest values were recorded with untreated ones (without soil and foliar application), where the deleterious effect of salinity was severely clear on yield of corresponding untreated plants.

- *Effect of soil application of organic amendments, foliar addition of stimulants and their interactions on Nutrients content and uptake of straw and grain.*

At harvest stage, the data of Tables 6 and 7 show that both straw and grain of the wheat plants fertilized with vermicompost (VC) possessed the highest values of N, P and K concentration (%) and their uptake (kg ha^{-1}) followed by that fertilized with chicken manure (ChM) then plants fertilized with compost (C), while straw and grain of the wheat plants untreated with organic amendments possessed the lowest values of N, P and K (%) as well as their uptake (kg ha^{-1}). This trend attributed to the high content of vermicompost (VC) from N, P and K. Also, both compost and chicken manure contained these nutrients but in smaller quantities, where chicken manure amendment was better than compost.

Regarding Na concentration (%) and its uptake (kg ha^{-1}) in both straw and grain, the highest values were obtained with plants grown on untreated soil, where Na^+ was high in soil solution and on soil colloids which made wheat roots absorbed a high quantity of sodium. On the other hand, Na concentration (%) and its uptake (kg ha^{-1}) in both straw and grain declined as a result of soil addition of all organic amendments, where the lowest values were realized with VC followed by ChM and C, respectively and this may be attributed to application of organic fertilizers in salt-affected soil promotes flocculation of clay minerals, which is an essential condition for the aggregation of soil particles, thus get rid of Na^+ which found on soil colloids and decline of ESP value and this role will more explain in the partition of soil analyses after harvest (Lakhdar *et al.* 2009).

Regarding the individual effect of stimulants, the data of the same Tables (6 and 7) indicate that the foliar application of moringa extract was the superior one followed by licorice extract then ginger extract then potassium humate and lately control treatment (without foliar application). This trend was for all studied nutrients concentration and their uptake in both straw and grain of the wheat plants except sodium. On the contrary, the lowest values of Na concentration (%) and its uptake (kg h^{-1}) in both straw and grain were recorded when wheat plants were sprayed with moringa extract, while the highest values were realized with unsprayed plants. The findings are in accordance with those of Yasmeen, (2011); Tuba *et al*. (2015); Shabana *et al.* (2017); Ismail *et al*. (2018); Elrys *et al.* (2020); Merwad (2020).

Concerning the interaction among studied treatments, the highest values of N, P and K (%) as well as their uptake (kg ha^{-1}) were realized when wheat plants were treated with vermicompost (VC) and sprayed with moringa extract, while the lowest values of these aforementioned traits were recorded with untreated plants (without soil and foliar application). On the contrary, the highest values of Na (%)as well as its uptake (kg ha^{-1}) were recorded with untreated plants (without soil and foliar application) as a normal result of soil salinity. While the combination of soil additions and foliar applications caused reduce salinity harmful, where the lowest values of Na (%)as well as its uptake (kg ha^{-1}) were realized when wheat plants were treated with vermicompost

(VC) and sprayed with moringa extract and this may be due to the ability of these substances as combined treatment in scavenging ROS. Similar results were obtained by Ghasemzadeh *et al.* 2010; Makkar *et al.* 2007; Osman *et al.* 2017; Elrys *et al.* 2020 and Othman, (2021).

TABLE 4. Effect of soil addition of organic amendments, foliar application of stimulants on performance of wheat plants grown under salinity condition at period of 70 days from sowing.

Treatments	Proline ($\mu g\ g^{-1}$ DW)	CAT	POX	SOD
			($A564\ min^{-1}\ g^{-1}$ protein)	
Organic amendments				
T_1	28.43d	53.97d	1.03d	4.44d
T_2	39.51a	69.54a	1.42a	7.08a
T_3	34.41c	58.39c	1.17c	5.77c
T_4	36.73b	61.56b	1.31b	6.36b
LSD $_{at\ 5\%}$	**0.46**	**0.25**	**0.02**	**0.05**
Foliar application				
F_1	28.77e	52.60e	1.01e	4.42e
F_2	40.35a	69.73a	1.46a	7.54a
F_3	38.69b	64.50b	1.36b	6.71b
F_4	34.58c	60.77c	1.22c	5.89c
F_5	31.47d	56.72d	1.11d	5.01d
LSD $_{at\ 5\%}$	**0.49**	**0.66**	**0.01**	**0.10**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.

T_1: Without soil addition; **T_2:** Vermicompost (1.0 Mg fed^{-1}); **T_3:** Compost (10.0 Mg fed^{-1}); **T_4**: Chicken manure (10.0 Mg fed^{-1}); **F_1:** Without foliar application; **F_2:** Moringa extract(2.0%); **F_3:** Licorice extract(2.0%); **F_4:** Ginger extract(2.0%); **F_5:** Potassium humate(2.5 g L^{-1}); **CAT:** Catalase enzyme activity; **POX:** Peroxidase Activityand **SOD:** Superoxide Dismutase.

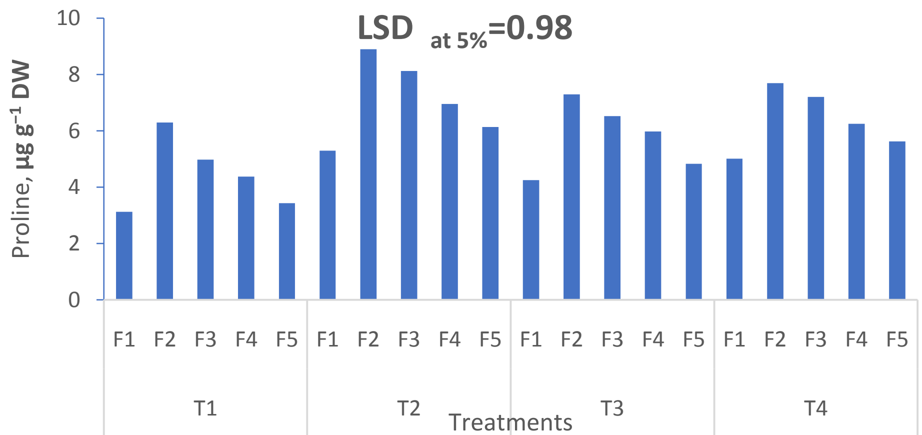

Fig 1. Interaction effect of the studied treatments on proline content in straw of wheat plants grown under salinity condition at period of 70 days from sowing.

T_1: Without soil addition; **T_2:** Vermicompost (1.0 Mg fed^{-1}); **T_3:** Compost (10.0 Mg fed^{-1}); **T_4**: Chicken manure (10.0 Mg fed^{-1}); **F_1:** Without foliar application; **F_2:** Moringa extract(2.0%); **F_3:** Licorice extract(2.0%); **F_4:** Ginger extract(2.0%) and **F_5:** Potassium humate(2.5 g L^{-1}).

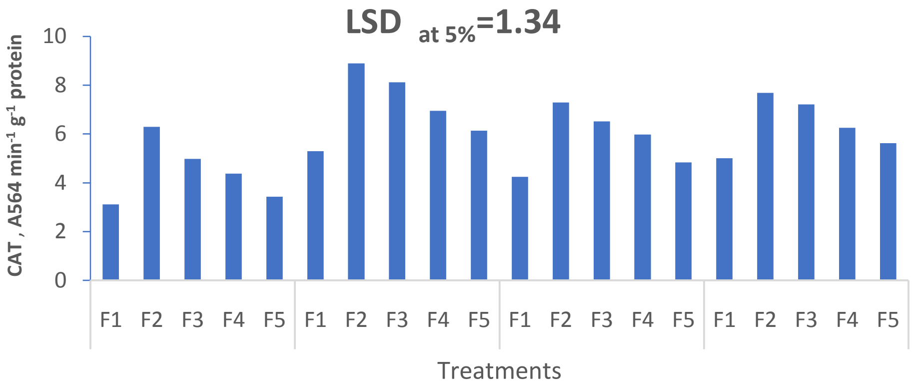

Fig 2. Interaction effect of the studied treatments on catalase enzyme activity in straw of wheat plants grown under salinity condition at period of 70 days from sowing.

T_1: Without soil addition; **T_2:** Vermicompost (1.0 Mg fed^{-1}); **T_3:** Compost (10.0 Mg fed^{-1}); **T_4**: Chicken manure (10.0 Mg fed^{-1}); **F_1:** Without foliar application; **F_2:** Moringa extract(2.0%); **F_3:** Licorice extract(2.0%); **F_4:** Ginger extract(2.0%); **F_5:** Potassium humate(2.5 g L^{-1}) and **CAT:** Catalase enzyme activity.

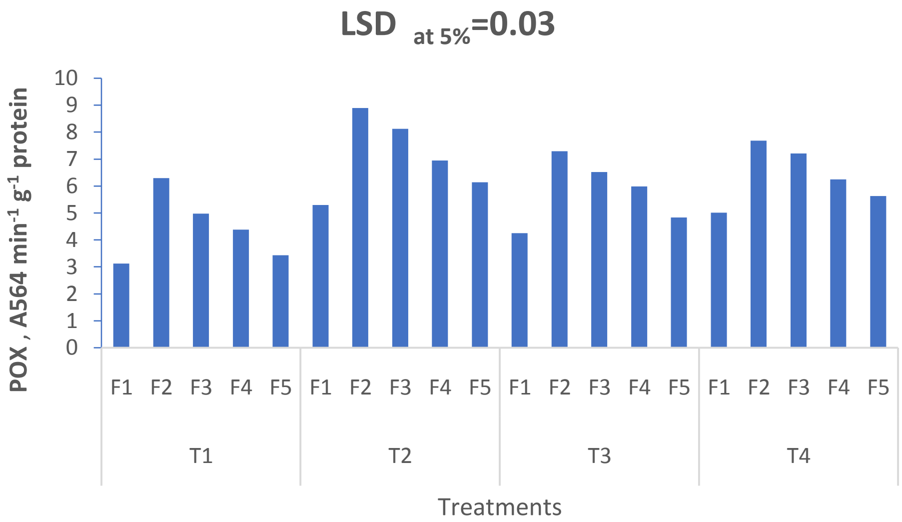

Fig 3. Interaction effect of the studied treatments on peroxidase activity in straw of wheat plants grown under salinity condition at period of 70 days from sowing.

T_1: Without soil addition; **T_2:** Vermicompost (1.0 Mg fed^{-1}); **T_3:** Compost (10.0 Mg fed^{-1}); **T_4**: Chicken manure (10.0 Mg fed^{-1}); **F_1:** Without foliar application; **F_2:** Moringa extract(2.0%); **F_3:** Licorice extract(2.0%); **F_4:** Ginger extract(2.0%); **F_5:** Potassium humate(2.5 g L^{-1}) and **POX:** Peroxidase activity.

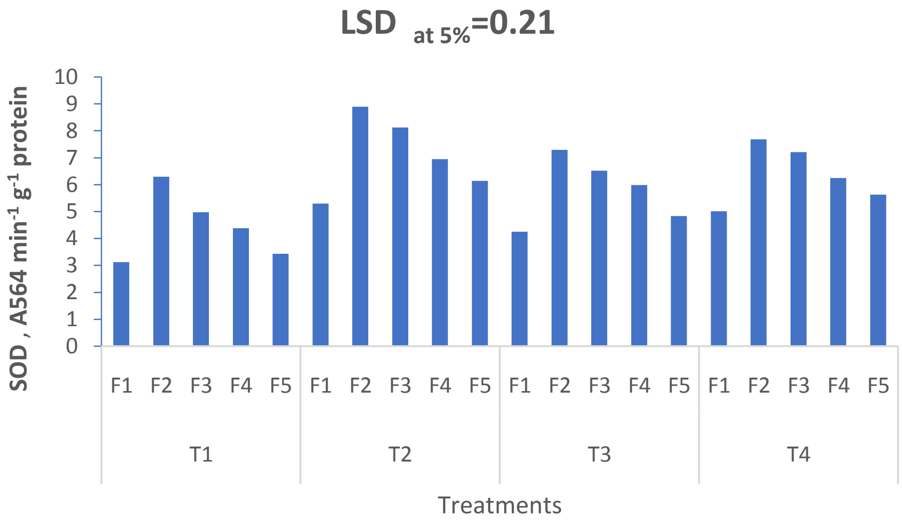

Fig 4. Interaction effect of the studied treatments on superoxide dismutase activity in straw of wheat plants grown under salinity condition at period of 70 days from sowing.

T_1: Without soil addition; **T_2:** Vermicompost (1.0 Mg fed^{-1}); **T_3:** Compost (10.0 Mg fed^{-1}); **T_4**: Chicken manure (10.0 Mg fed^{-1}); **F_1:** Without foliar application; **F_2:** Moringa extract(2.0%); **F_3:** Licorice extract(2.0%); **F_4:** Ginger extract(2.0%); **F_5:** Potassium humate(2.5 g L^{-1}) and **SOD:** Superoxide dismutase.

TABLE 5. Effect of soil addition of organic amendments, foliar application of stimulants and their interactions on wheat yield and its components under salinity condition at harvest stage.

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, %
Organic amendments									
T_1		16.19d	3.43d	53.33b	46.06d	4.75d	7.67d	12.42d	38.18d
T_2		18.41a	4.98a	56.87a	51.02a	6.08a	8.63a	14.71a	41.21a
T_3		17.31c	4.21c	55.53a	48.50c	5.37c	8.17c	13.54c	39.53c
T_4		17.95b	4.68b	56.07a	50.07b	5.79b	8.47b	14.26b	40.46b
LSD $_{at\ 5\%}$		**0.10**	**0.04**	**N.S**	**0.08**	**0.03**	**0.06**	**0.07**	**0.20**
Foliar application									
F_1		15.72e	3.13e	52.67c	45.20e	4.54e	7.50e	12.04e	37.70e
F_2		18.93a	5.33a	57.42a	52.16a	6.35a	8.86a	15.21a	41.70a
F_3		18.21b	4.84b	56.33ab	50.54b	5.93b	8.56b	14.50b	40.80b
F_4		17.56c	4.41c	56.00ab	49.16c	5.55c	8.28c	13.82c	40.03c
F_5		16.91d	3.90d	54.83b	47.50d	5.11d	7.98d	13.09d	38.99d
LSD $_{at\ 5\%}$		**0.19**	**0.05**	**1.83**	**0.18**	**0.08**	**0.11**	**0.11**	**0.52**
Interactive effect									
	F_1	15.07n	2.73t	51.00h	43.65t	4.19q	7.22n	11.41o	36.73k
	F_2	17.70fg	4.40j	55.67b-g	49.09j	5.47h	8.25fg	13.72h	39.86ef
T_1	**F_3**	16.60ij	3.77n	54.67c-h	47.04n	4.95kl	7.89ij	12.83k	38.55ghi
	F_4	16.07kl	3.37p	53.33e-h	46.20p	4.76mn	7.63kl	12.40lm	38.43ghi
	F_5	15.50m	2.87s	52.00gh	44.30s	4.39p	7.36mn	11.75n	37.33jk
	F_1	16.30jk	3.58o	54.00d-h	46.62o	4.85lm	7.77jk	12.62kl	38.41ghi
	F_2	19.73a	5.91a	60.00a	54.10a	6.87a	9.23a	16.10a	42.68a
T_2	**F_3**	19.37a	5.59c	55.67b-g	53.01c	6.68b	9.05ab	15.73b	42.47ab
	F_4	18.47cd	5.09f	57.67a-d	51.25f	6.17d	8.68d	14.85e	41.53bc
	F_5	18.20de	4.73h	57.00a-e	50.10h	5.83f	8.41ef	14.24g	40.97cd
	F_1	15.70lm	3.02r	52.67fgh	44.99r	4.50op	7.46lm	11.96n	37.63ijk
	F_2	18.80bc	5.26e	58.00abc	51.87e	6.34c	8.80cd	15.14d	41.87abc
T_3	**F_3**	17.90ef	4.58i	56.33a-f	49.57i	5.66g	8.39ef	14.04g	40.28de
	F_4	17.40gh	4.24k	55.67b-g	48.53k	5.26i	8.20fgh	13.46i	39.09fg
	F_5	16.77i	3.94m	55.00b-g	47.53m	5.07jk	8.01hi	13.08j	38.76gh
	F_1	15.80lm	3.21q	53.00fgh	45.56q	4.64no	7.55lm	12.19m	38.04hij
	F_2	19.50a	5.73b	56.00b-f	53.55b	6.72b	9.13ab	15.85b	42.39ab
T_4	**F_3**	18.97b	5.44d	58.67ab	52.51d	6.45c	8.93bc	15.38c	41.91abc
	F_4	18.30d	4.93g	57.33a-d	50.66g	5.99e	8.60de	14.59f	41.08cd
	F_5	17.17h	4.07l	55.33b-g	48.06l	5.16ij	8.12gh	13.28ij	38.88fgh
LSD $_{at\ 5\%}$		**0.38**	**0.10**	**n.s**	**0.35**	**0.15**	**0.22**	**0.23**	**1.03**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.
T_1: Without soil addition; **T_2:** Vermicompost (1.0 Mg fed^{-1}); **T_3:** Compost (10.0 Mg fed^{-1}); **T_4**: Chicken manure (10.0 Mg fed^{-1}); **F_1:** Without foliar application; **F_2:** Moringa extract(2.0%); **F_3:** Licorice extract(2.0%); **F_4:** Ginger extract(2.0%) and **F_5:** Potassium humate(2.5 g L^{-1}).

TABLE 6. Effect of soil addition of organic amendments, foliar application of stimulants and their interactions on N, P, K and Na (%) in straw and grain of wheat plants grown under salinity condition at harvest stage.

Treatments		N,%		P,%		K,%		Na,%	
		Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
Organic amendments									
T_1		0.79d	1.46d	0.149d	0.207d	1.21d	1.15d	1.44a	1.34a
T_2		1.56a	1.75a	0.333a	0.397a	1.62a	1.55a	1.03d	0.82d
T_3		1.28c	1.61c	0.289c	0.292c	1.35c	1.18c	1.30b	1.19b
T_4		1.41b	1.68b	0.315b	0.363b	1.37b	1.32b	1.16c	1.03c
LSD $_{at\ 5\%}$		**0.01**	**0.01**	**0.003d**	**0.004**	**0.02**	**0.01**	**0.01**	**0.01**
Foliar application									
F_1		1.03e	1.43e	0.204e	0.172e	1.19e	1.08e	1.42a	1.31a
F_2		1.49a	1.81a	0.330a	0.403a	1.62a	1.54a	1.04e	0.88e
F_3		1.38b	1.72b	0.304b	0.367b	1.47b	1.42b	1.14d	0.99d
F_4		1.26c	1.62c	0.271c	0.325c	1.37c	1.31c	1.24c	1.09c
F_5		1.16d	1.54d	0.250d	0.307d	1.28d	1.15d	1.31b	1.20b
LSD $_{at\ 5\%}$		**0.01**	**0.01**	**0.004**	**0.004**	**0.02**	**0.01**	**0.01**	**0.01**
Interactive effect									
	F_1	0.67p	1.28p	0.107p	0.133n	0.86k	0.82k	1.65a	1.53a
	F_2	0.96l	1.63i	0.183l	0.260i	1.49d	1.41d	1.26h	1.19g
T_1	F_3	0.84m	1.57k	0.170m	0.237j	1.35fg	1.31e	1.36ef	1.25f
	F_4	0.78n	1.48m	0.153n	0.207k	1.23i	1.24f	1.43d	1.33d
	F_5	0.71o	1.35o	0.130o	0.200k	1.11j	0.98i	1.51b	1.42b
	F_1	1.22i	1.52l	0.263i	0.203k	1.41e	1.32e	1.20ij	1.06j
	F_2	1.87a	1.99a	0.407a	0.523a	1.88a	1.78a	0.81p	0.61p
T_2	F_3	1.72b	1.87c	0.370c	0.473b	1.71b	1.70b	0.95o	0.67o
	F_4	1.58d	1.74f	0.330e	0.400d	1.61c	1.55c	1.06m	0.79m
	F_5	1.43f	1.67g	0.303f	0.383e	1.49d	1.42d	1.15kl	0.96l
	F_1	1.06k	1.46n	0.200k	0.160m	1.20i	0.94j	1.48kl	1.40c
	F_2	1.50e	1.76e	0.350d	0.357f	1.50d	1.41d	1.13l	1.01k
T_3	F_3	1.39g	1.65h	0.327e	0.340g	1.44e	1.30e	1.21ij	1.10h
	F_4	1.27h	1.61j	0.293g	0.303h	1.35fg	1.24f	1.30g	1.20g
	F_5	1.21i	1.57k	0.277h	0.300h	1.28h	1.04h	1.38e	1.27ef
	F_1	1.18j	1.47mn	0.247j	0.190l	1.31gh	1.25f	1.34f	1.28e
	F_2	1.63c	1.89b	0.380b	0.473b	1.62c	1.55c	0.98n	0.74n
T_4	F_3	1.56d	1.79d	0.350d	0.420c	1.41e	1.40d	1.07m	0.94l
	F_4	1.41fg	1.68g	0.310f	0.390e	1.31gh	1.24f	1.17k	1.04j
	F_5	1.30h	1.60j	0.290g	0.350f	1.24i	1.18g	1.23hi	1.16h
		0.03	**0.02**	**0.009**	**0.008**	**0.04**	**0.03**	**0.03**	**0.02**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.
T_1: Without soil addition; **T_2:** Vermicompost (1.0 Mg fed^{-1}); **T_3:** Compost (10.0 Mg fed^{-1}); **T_4**: Chicken manure (10.0 Mg fed^{-1}); **F_1:** Without foliar application; **F_2:** Moringa extract(2.0%); **F_3:** Licorice extract(2.0%); **F_4:** Ginger extract(2.0%) and **F_5:** Potassium humate(2.5 g L^{-1}).

TABLE 7. Effect of soil addition of organic amendments, foliar application of stimulants and their interactions on N, P, K and Na uptake (kg ha^{-1}) in straw and grain of wheat plants grown under salinity condition at harvest stage

Treatments		N, kg h^{-1}		P, kg h^{-1}		K, kg h^{-1}		Na, kg h^{-1}	
		Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
Organic amendments									
T$_1$		60.8d	69.8d	11.5d	10.0d	93.3d	55.6d	109.8a	63.2a
T$_2$		135.9a	107.8a	29.0a	24.8a	140.4a	95.5a	88.3d	48.5c
T$_3$		105.5c	86.8c	23.8c	16.0c	110.9c	64.4c	105.4b	63.1a
T$_4$		120.5b	98.7b	27.0b	21.8b	116.9b	77.2b	97.1c	58.3b
LSD at 5%		**0.1.4**	**1.0**	**0.2**	**0.2**	**1.5**	**1.1**	**1.5**	**0.6**
Foliar application									
F$_1$		77.6e	65.2e	15.4e	7.8e	89.8e	49.5e	105.9a	59.2b
F$_2$		133.0a	115.9a	29.5a	26.1a	144.0a	98.1a	91.7d	55.0d
F$_3$		119.2b	102.6b	26.4b	22.4b	126.6b	85.3b	97.2c	57.4c
F$_4$		105.2c	90.6c	22.7c	18.4c	114.0c	73.3c	101.9b	59.2b
F$_5$		93.4d	79.5d	20.2d	16.0d	102.4d	59.7d	104.3a	60.5a
LSD at 5%		**1.7**	**1.3**	**0.4**	**0.4**	**2.4**	**1.4**	**1.6**	**1.0**
Interactive effect									
	F$_1$	48.0o	53.6p	7.8p	5.5p	62.1o	34.4n	119.1a	63.9ab
	F$_2$	79.2k	88.9i	15.2l	14.1k	122.6fg	77.1g	103.6ef	64.8a
T$_1$	**F$_3$**	65.9l	77.4k	13.5m	11.7l	106.5ij	64.8i	106.9cd	61.8cd
	F$_4$	59.2m	70.3m	11.6n	9.8m	93.9lm	58.8jk	108.8bcd	63.1abc
	F$_5$	51.9n	59.0o	09.5o	8.7n	81.3n	42.8m	110.8b	62.3bcd
	F$_1$	94.5i	73.4l	20.3j	9.9m	109.2hi	63.7i	93.3ij	51.1g
	F$_2$	172.6a	136.4a	37.4a	35.9a	173.5a	122.4a	74.5m	41.9j
T$_2$	**F$_3$**	155.6b	124.6b	33.4c	3.4b	154.2b	113.2b	85.6l	44.9i
	F$_4$	136.8d	107.3e	28.4e	24.6d	139.8d	95.6d	92.0jk	48.7h
	F$_5$	120.3f	97.1g	25.5g	22.4f	125.3f	82.5f	96.3hi	55.8f
	F$_1$	78.7k	65.5n	14.9l	7.2o	89.5m	42.1m	110.0bc	62.8bc
	F$_2$	131.6e	111.3d	30.7d	22.7ef	132.0e	89.1e	99.5gh	63.7abc
T$_3$	**F$_3$**	116.6g	93.1h	27.3f	19.1g	120.3g	73.3h	101.1fg	62.2bcd
	F$_4$	104.1h	84.4j	24.1h	16.0i	110.2hi	65.0i	106.6de	62.9bc
	F$_5$	96.5i	79.6k	22.1i	15.0j	102.5jk	52.7l	110.1bc	64.1ab
	F$_1$	89.1j	68.2mn	18.6k	8.6n	98.6kl	57.7k	101.2fg	59.1e
	F$_2$	148.4c	127.0b	34.7b	31.8b	147.9c	103.8c	89.3k	49.6gh
T$_4$	**F$_3$**	138.9d	115.4c	31.3d	27.1c	125.5f	89.9e	95.1ij	60.7de
	F$_4$	120.8f	100.4f	26.6f	23.2e	112.2h	74.0h	100.2g	62.3bcd
	F$_5$	105.1h	82.4j	23.6h	18.0h	100.2k	60.7j	99.8g	59.6e
LSD at 5%		**3.3**	**2.7**	**0.8**	**0.7**	**5.0**	**2.8**	**3.3**	**1.9**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.

T$_1$: Without soil addition; **T$_2$:** Vermicompost (1.0 Mg fed^{-1}); **T$_3$:** Compost (10.0 Mg fed^{-1}); **T$_4$:** Chicken manure (10.0 Mg fed^{-1}); **F$_1$:** Without foliar application; **F$_2$:** Moringa extract(2.0%); **F$_3$:** Licorice extract(2.0%); **F$_4$:** Ginger extract(2.0%) and **F$_5$:** Potassium humate(2.5 g L^{-1}).

3. Conclusions

The obtained results confirmed that combining between soil addition of organic amendments and foliar application of stimulants is one of the most important strategies for amending salt-affected soil, where organic materials and stimulants play a vital role in the enhancement of plant performance and maintaining crop yields.

Generally, it can be concluded that treating the saline soil with vermicompost before sowing wheat and spraying it with moringa extract is the best treatment that could be recommended for wheat plants grown under salinity conditions.

Conflicts of interest

Authors have declared that no competing interests exist.

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