**Improving performance and yield of wheat plants grown on salt affected soil.**

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**ABSTRACT**

Soil salinity is one of the biggest widespread abiotic stress severely restricting crop productivity. So, a field experiment was executed during the winter season of 2020/2021 aiming at evaluating the impact of soil addition of different organic amendments as main plots and foliar application of some stimulants as sub main plots on wheat plants grown under saline soil conditions. The combined influences of organic amendments and stimulants materials were studied by combining four organic treatments *i.e.,* control, vermicompost, compost and chicken manure and five external applications *i.e.,* control, moringa, licorice, ginger and humate potassium. 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 when wheat plants were treated with vermicompost and sprayed with moringa extract, while the lowest values of proline and enzymatic antioxidantswere recorded with untreated plants (without soil and foliar application). The same trend was found for yield and its components, where 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.

**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).** Salinity imposes harmful influences on plant growth performance through production of reactive oxygen species (ROS) which oxidate plant cells (**Khalifa *et al.* 2016** and **Abo El-Ezz *et al.* (2020)**.

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 and Mohamed *et al.*, 2020).**

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).**

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.

**MATERIALS AND METHODS**

A field trial was done during the winter season of 2020/2021 at a private farm located (31° 55′ 11.3″ N and 30° 51′ 39.94″ E) in 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 2.4 Mg h-1), compost (at rate of 24.0 Mg h-1) and chicken manure (at rate of 24.0 Mg h-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.

1. **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.

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.

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(*Glycyrrhiza* *glabra*) 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 ﬁne 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 ﬁltrate 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 Syngenta Company, 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.

1. **Experimental design.**

Twenty treatments were executed in a split plot design with three replicates with area of 6.25 m2 (2.5 m width and 2.5 m length) for each subplot.

1. **Cultivation.**

Wheat grains (**CV Egypt 1**) were sown at a rate of 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.

1. **Measurement traits.**
	1. **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 μmol of H2O2min-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).**
	2. **At harvest stage:** 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.
2. **Statistical Analysis.**

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

**RESULTS**

1. **Effect of soil application of organic amendments, foliar addition of stimulants and their interactions on physiological characters of wheat plants:**

Soil addition of some organic amendments [without (control), vermicompost (VC), compost (C) and chicken manure (ChM)] and foliar application of some stimulants [without (control), moringa, licorice and ginger extracts and potassium humate] significantly affected plant's self-production of proline (mg g-1 F.W) and enzymatic antioxidants *i.e*. catalase enzyme (CAT, A564 min-1 g-1 protein), peroxidase (POX, A564 min-1 g-1 protein) and superoxide dismutase (SOD, A564 min-1 g-1 protein) of wheat plants grown on soil having EC value of 13.2 dSm-1 at period of 70 days from sowing **(Table 4).**

Studying the Individual effect of organic amendments and foliated stimulants, data of Table 4 show that wheat plant's self-production of proline (mg g-1 F.W) and enzymatic antioxidants *i.e*. catalase enzyme (CAT, A564 min-1 g-1 protein), peroxidase (POX, A564 min-1 g-1 protein) and superoxide dismutase (SOD, A564 min-1 g-1 protein) significantly increased due to soil addition of all organic amendments compared to untreated plants under salinity conditions, where the sequence of investigated organic amendments in terms of plant's self-production from top to less was as follows; vermicompost > ChM > compost > control (without).

Wheat plant's self-production of proline (mg g-1 F.W) and enzymatic antioxidants *i.e*. catalase enzyme (CAT, A564 min-1 g-1 protein), peroxidase (POX, A564 min-1 g-1 protein) and superoxide dismutase (SOD, A564 min-1 g-1 protein) were higher with foliar application of all studied stimulants compared to untreated plants, where moringa extract was the superior and licorice extract came in the second-order and ginger extract came in the third-order, while foliar application of potassium humate outperformed only untreated wheat plants (control) which came in the last order.

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).

1. **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 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 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 inTable 5, also show that treating the wheat plants with vermicompost (VC) before sowing and spraying it with moringa extract realized the highest values of 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.

**DISCUSSION**

The superiority of vermicompost compared to other studied organic amendments may be due to it had the lowest C/N ratio in addition to its high content from nutrients more than others organic amendments. For the same reasons, the ChM was superior to compost fertilizer. The obtained findings are in harmony with the results of **Lakhdar *et al.* (2008 and 2009);** **Abera *et al.* (2018) and Adebifar, (2018).**The superiority of foliar application of moringa extract more than other stimulants may be attributed to increased salinity stress tolerance and led to wheat plant development through increasing chlorophyll and carotene contents due to antioxidants properties of moringa leaf extract as mentioned by **Makkar *et al.* (2007)** who found that moringa leaf extract contains high quantities of antioxidants proteins, ascorbates and phenols in addition to calcium, potassium, and cytokinin.

As shown in the presented results, the superiority of foliar application of licorice extract was clear more than both ginger extract and potassium humate and this trend may be attributed to its contents of many different important compounds *i.e*. mevalonic acid glycyrrhizin, vitamins, glycyrrhizin, polysaccharide that is the initiator in the synthesis of gibberellins in plants, and many nutrients which are mainly needed in wheat plant growth as reported by **Elrys *et al.* (2020).**

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.

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)**.

**CONCLUSION**

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.

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**Table 1. Some characteristics of organic amendments used.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Organic fertilizers** | EC\*\*, dSm-1 | pH\* | Organic matter, % | Total nutrients,% | C/N ratio |
| N | P | K |
| **Compost** | 3.65 | 7.98 | 39.87 | 1.80 | 0.60 | 1.53 | 12.87 |
| **Vermicompost** | 3.01 | 7.87 | 40.63 | 2.93 | 0.93 | 1.87 | 8.06 |
| **Chicken manure** | 4.64 | 7.93 | 42.87 | 2.44 | 0.86 | 1.73 | 10.21 |

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

**Table 2. Chemical analyses of natural extract used.**

|  |
| --- |
| **Natural extracts** |
| **Components** | **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,%** | **K2O,%** | **P2O5,%** |
| **100** | **8.60** | **62.0** | **3.20** | **5.92** | **0.47** | **11.0** | **1.00** |

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments**  | **Proline**  | **CAT**  | **POX**  | **SOD**  |
| **(μg g−1 DW)** | **(A564 min-1 g-1 protein)** |
| **Organic amendments** |  |
| **Without soil addition** | 28.43d | 53.97d | 1.03d | 4.44d |
| **Vermicompost**  | 39.51a | 69.54a | 1.42a | 7.08a |
| **Compost**  | 34.41c | 58.39c | 1.17c | 5.77c |
| **Chicken manure** | 36.73b | 61.56b | 1.31b | 6.36b |
| **LSD at 5%** | **0.46** | **0.25** | **0.02** | **0.05** |
| **Foliar application** |  |
| **Without foliar application**  | 28.77e | 52.60e | 1.01e | 4.42e |
| **Moringa extract** | 40.35a | 69.73a | 1.46a | 7.54a |
| **Licorice extract** | 38.69b | 64.50b | 1.36b | 6.71b |
| **Ginger extract**  | 34.58c | 60.77c | 1.22c | 5.89c |
| **Potassium humate** | 31.47d | 56.72d | 1.11d | 5.01d |
| **LSD at 5%** | **0.49** | **0.66** | **0.01** | **0.10** |
| **Interactive effect**  |  |
| **Without**  | **Without**  | 24.04m | 46.48m | 0.82n | 3.12n |
| **Moringa extract** | 33.23i | 64.27f | 1.31ef | 6.29g |
| **Licorice extract** | 30.82j | 57.21i | 1.18hi | 4.98k |
| **Ginger extract**  | 27.69k | 52.03k | 0.95l | 4.38l |
| **Potassium humate** | 26.37l | 49.90l | 0.89m | 3.43m |
| **Vermi-compost** | **Without**  | 32.98i | 60.34h | 1.19gh | 5.30j |
| **Moringa extract** | 46.06a | 76.17a | 1.60a | 8.90a |
| **Licorice extract** | 44.47b | 73.95b | 1.51b | 8.12b |
| **Ginger extract**  | 38.58f | 72.21c | 1.46c | 6.95e |
| **Potassium humate** | 35.47h | 65.02f | 1.33e | 6.14gh |
| **Compost** | **Without**  | 28.00k | 49.47l | 0.94l | 4.25l |
| **Moringa extract** | 39.85e | 67.68e | 1.40d | 7.29d |
| **Licorice extract** | 38.28f | 61.73g | 1.33e | 6.52f |
| **Ginger extract**  | 35.18h | 58.13i | 1.16i | 5.98h |
| **Potassium humate** | 30.76j | 54.92j | 1.02k | 4.83k |
| **Chicken manure** | **Without**  | 30.04j | 54.13j | 1.09j | 5.01k |
| **Moringa extract** | 42.28c | 70.81d | 1.51b | 7.69c |
| **Licorice extract** | 41.18d | 65.12f | 1.41d | 7.21d |
| **Ginger extract**  | 36.86g | 60.71gh | 1.30f | 6.25g |
| **Potassium humate** | 33.30i | 57.06i | 1.22g | 5.63i |
| **LSD at 5%** | **0.98** | **1.34** | **0.03** | **0.21** |

**CAT:** Catalase enzyme activity; **POX:** Peroxidase Activityand **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**  | **Grain yield**  | **straw yield**  | **Biological yield**  | **Harvest index, %** |
| **( Mg ha-1)** |
|  **Organic amendments**  |
| **Without soil addition** | 4.75d | 7.67d | 12.42d | 38.18d |
| **Vermicompost**  | 6.08a | 8.63a | 14.71a | 41.21a |
| **Compost**  | 5.37c | 8.17c | 13.54c | 39.53c |
| **Chicken manure** | 5.79b | 8.47b | 14.26b | 40.46b |
| **LSD at 5%** | **0.03** | **0.06** | **0.07** | **0.20** |
|  **Foliar application** |
| **Without foliar application**  | 4.54e | 7.50e | 12.04e | 37.70e |
| **Moringa extract** | 6.35a | 8.86a | 15.21a | 41.70a |
| **Licorice extract** | 5.93b | 8.56b | 14.50b | 40.80b |
| **Ginger extract**  | 5.55c | 8.28c | 13.82c | 40.03c |
| **Potassium humate** | 5.11d | 7.98d | 13.09d | 38.99d |
| **LSD at 5%** | **0.08** | **0.11** | **0.11** | **0.52** |
| **Interactive effect** |
| **Without**  | **Without**  | 4.19q | 7.22n | 11.41o | 36.73k |
| **Moringa extract** | 5.47h | 8.25fg | 13.72h | 39.86ef |
| **Licorice extract** | 4.95kl | 7.89ij | 12.83k | 38.55ghi |
| **Ginger extract**  | 4.76mn | 7.63kl | 12.40lm | 38.43ghi |
| **Potassium humate** | 4.39p | 7.36mn | 11.75n | 37.33jk |
| **Vermi-****compost** | **Without**  | 4.85lm | 7.77jk | 12.62kl | 38.41ghi |
| **Moringa extract** | 6.87a | 9.23a | 16.10a | 42.68a |
| **Licorice extract** | 6.68b | 9.05ab | 15.73b | 42.47ab |
| **Ginger extract**  | 6.17d | 8.68d | 14.85e | 41.53bc |
| **Potassium humate** | 5.83f | 8.41ef | 14.24g | 40.97cd |
| **Compost** | **Without**  | 4.50op | 7.46lm | 11.96n | 37.63ijk |
| **Moringa extract** | 6.34c | 8.80cd | 15.14d | 41.87abc |
| **Licorice extract** | 5.66g | 8.39ef | 14.04g | 40.28de |
| **Ginger extract**  | 5.26i | 8.20fgh | 13.46i | 39.09fg |
| **Potassium humate** | 5.07jk | 8.01hi | 13.08j | 38.76gh |
| **Chicken manure** | **Without**  | 4.64no | 7.55lm | 12.19m | 38.04hij |
| **Moringa extract** | 6.72b | 9.13ab | 15.85b | 42.39ab |
| **Licorice extract** | 6.45c | 8.93bc | 15.38c | 41.91abc |
| **Ginger extract**  | 5.99e | 8.60de | 14.59f | 41.08cd |
| **Potassium humate** | 5.16ij | 8.12gh | 13.28ij | 38.88fgh |
| **LSD at 5%** | **0.15** | **0.22** | **0.23** | **1.03** |