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# Effect of Different Micronutrient Treatments on Rice (*Oriza sativa* L.) Growth and Yield under Saline Soil Conditions

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**Abstract:** Field trials were conducted in El Serw Agricultural Research Station, Agriculture Research Center, Egypt during 2009 and 2010 summer seasons to study the effect of $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ as single or combined application in soil to the rice (Sakha101 as moderately salt tolerant rice variety) growth and yield. The treatments included $Zn^{+2}$, $Mn^{+2}$ , $Fe^{+2}$application as soil single treatments or $Zn^{+2}$ + $Mn^{+2}$, $Zn^{+2}$ + $Fe^{+2}$ , $Mn^{+2}$ + $Fe^{+2}$ and $Zn^{+2}$ +$Mn^{+2}$ + $Fe^{+2}$ as a combined applications through soil as well as a comparative treatment of commercial compound(14%$Mn^{+2}$+12%$Fe^{+2}$+16%$Zn^{+2}$) was applied twice at 20 and 45 days after transplanting (DAT) as foliar spray. The main results of the study showed that the application of the three tested micronutrients as single or a combination significantly improved rice growth of Sakha 101 rice variety in both seasons. Dry matter production, leaf area index and chlorophyll content (SPAD value) as well as plant height and panicle length were significantly higher when rice plant received the micronutrient rather compared to the control. Rice grain yield, straw yield, harvest index and yield components; panicle numbers, panicle weight, filled grains/panicle and 1000-grain weight were significantly increased by application of micronutrients application. The combination of $Zn^{+2}$ +$Fe^{+2}$ + $Mn^{+2}$ gave the highest values of most studied traits without any significant differences with those produced by foliar spray twice. It could be concluded that micronutrient application especially through foliage under saline soil conditions is beneficial for rice growth and yield under such circumstances.

**Key words:** Rice (*Oryza sativa* L.) · Micronutrients · Grain yield · Chlorophyll

## INTRODUCTION

Micronutrient deficiency is considered as one of the major causes of the declining productivity trends observed in rice growing countries. The submergence condition of rice cultivation influences electrochemical and biochemical reactions and alters pH, $PCO_2$ as well as the concentration of certain ions. Sodic, upland and calcareous coarse-textured soils with low organic matter content suffer from Fe deficiency, besides $Zn^{+2}$ and $Cu^{+2}$. Rice (*Oryza sativa*) is a staple food of million of people in Egypt and next to wheat. But it's important for Egypt as one of the most important crops cultivated in saline soil at costal area and as a soil reclamation crop. Rice is grown in Egypt in 640 thousand hectares (Production Estimates and Crop Assessment Division, FAS, USDA) and the saline soil is about 200 thousand hectares having the average yield of 7200 kg $ha^{-1}$.

The availability of micronutrients in saline soils depends on the solubility of micronutrients, the pH and redox potential of the soil solution and the nature of binding sites on the organic and inorganic particle surfaces. Thus, salinity can differently affect the micronutrient concentrations in plants depending upon crop species and salinity level [1]. Zhu *et al.* [2] reported that micronutrient deficiencies are very common under salt stress owing to high pH. Soil fertility is an important factor, which determines the growth of plant. Soil fertility is determined by the presence or absence of nutrients i.e. macro and micronutrients, which are required in minute quantities for plant growth. Micronutrients also enhances plant productivity, leaf area and grain yield as result of enhancing the enzymatic system of plants. The factors that affect the contents of such micronutrients are organic matter, soil pH, lime content, soil salinity and others, which were previously excluded from different research

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experiments. There is also correlation among the micronutrients contents and above-mentioned properties in addition to the interaction between them.

Zinc plays an important role in different metabolic processes in plant. Iron deficiency chlorosis is caused by imbalance of metallic ions as $Cu^{+2}$ and $Mn^{+2}$. The levels of micronutrients in soil is depleted due to continuous rowing of high yielding crop varieties and non addition of organic manures having these elements which are essential for normal growth and development of plants for profitable crop yield. Deb and Zeliaing [3] concluded that rice plant showed no significant response in terms of dry matter weight to $Zn^{+2}$ or $Fe^{+2}$ applications. Zinc content of the plant was not affected by the treatments while Fe content was decreased by $Zn^{+2}$ and $Fe^{+2}$ applications. Chaudhry and Wallace [4] reported that Iron completely inhibited $Zn^{+2}$ absorption by rice. Pathak *et al.* [5] found that $Fe^{+2}$ and $Mn^{+2}$ uptakes were increased with increasing $Fe^{+2}$ and $Mn^{+2}$ applications up to 18 mg $kg^{-1}$. There were positive interactions between $Fe^{+2}$ and $Mn^{+2}$ when applications were balanced but imbalance led to high levels of one element depressing uptake of the other element when the latter was applied at low level.

Foliar sprays are widely used to apply micronutrients, especially iron and manganese, for many crops. Soluble inorganic salts are generally as effective as synthetic chelates in foliar sprays, so the inorganic salts are usually chosen because of lower costs. Correction of deficiency symptoms usually occurs within the first several days and then the entire field could be sprayed with the appropriate micronutrient source. It was found that micronutrients showed towards to increasing the yield of different crops [6,7]. The soil with higher pH values and lower organic matter, micronutrients deficiencies are expected [8]. Savithri *et al.* [7] obtained a maximum increase in rice yield of 4.8 t $ha^{-1}$ with the foliar spray (1-2% FeSO4 solution) or soil incorporation of $Fe^{+2}$ (50 kg $FeSO_4$ $ha^{-1}$) with bulky organic manure (12.5 t $ha^{-1}$). Ali *et al.* [9] showed that the highest significant paddy yield of 6087 kg $ha^{-1}$ was found from NPK + $Zn^{+2}$ + $Cu^{+2}$ + $Fe^{+2}$ + $Mn^{+2}$ against 4073 kg $ha^{-1}$ yield from NPK treatment. Johnson *et al*. [10] reported that micronutrient application significantly increased rice grain yield. Furthermore, Sultana *et al*. [11] found that foliar spray of $MnSO_4$ partially minimized the salt-induced nutrient deficiency, increased photosynthesis, dry matter accumulation, number of fertile spikelet in the panicle and grain yield.

The present study was undertaken to determine the effect of micronutrients ($Zn^{+2}$, $Fe^{+2}$; $Mn^{+2}$;) application alone as well as in combination with each other either as a foliar or as soil application on the rice grain yield under saline soil conditions.

## MATERIALS AND METHODS

Field trials were conducted at El Serw Agricultural Research Station, Agriculture Research Center, during 2009 and 2010 summer seasons. The trials were laid out in a randomized complete block design with four replications. The treatments included $Zn^{+2}$,Mn ,$^{+2}$ $Fe^{+2}$application as soil single treatments or $Zn^{+2}$ + $Mn^{+2}$, $Zn^{+2}$ + $Fe^{+2}$ , $Mn^{+2}$ + $Fe^{+2}$ and $Zn^{+2}$ +$Mn^{+2}$ + $Fe^{+2}$ as a combined applications through soil as well as a comparative treatment of commercial compound (14%$Mn^{+2}$+12%$Fe^{+2}$+16%$Zn^{+2}$) was applied twice at 20 and 45 days after transplanting (DAT) as foliar spray. Nitrogen, phosphorous and potassium @ 69- 15.5-25 kg N, $P_2O_5$, $K_2O$ $fed^{-1}$ were applied in the form of urea, calcium supper phosphate and potassium sulfate while $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ were applied @ the rates 10, 4.2 and 2.9 kg/fed, respectively, in the form of sulfate salts . The net plot size was 10 $m^2$. Transplanting date was April 20 with plant spacing of 20 x 20 cm. All PK were applied at land preparation. Nitrogen was applied into four equal doses at 15, 30, 50 and 90 DAT as recommended under saline soil. The transplantation of rice was done on May 22 and 26 while harvesting was on Oct. 4$^{th}$ and 9$^{th}$ in 2009 and 2010, respectively. Composite soil sample was taken before fertilizer application and was analyzed for various chemical characteristics $Zn^{+2}$, $Cu^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ were determined by DTPA method of Lindsay and Norvel [12]. Soil texture was determined using method of Moodie *et al.* [13]. Available P was determined by using Olsen P by $NaHCO_3$ extraction [14], while available K was determined by Olsen method using ammonium acetate extraction [14].

At heading stage, plant samples were randomly taken and transferred to the lab to determine dry matter, leaf area index and chlorophyll content (SPAD Value).Leaf area was measures using leaf area meter ion the lab then leaf area index was estimated by divided the leaf area of plant on the occupied ground d area of plant. The chlorophyll content was measured by SPAD meter. At maturity stage, yield and yield contributing parameters such as plant height, number of productive tillers, straw weight, panicle length, number of grains/panicle, filled grain percentage, 1000-grain weight and grain yield were measured

## RESULTS AND DISCUSSION

**Growth Parameters:** Data presented in Tables 2 and 3 showed that application of $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ as a single or in different combinations significantly affected the studied growth parameters. Data confirm the importance of micronutrient application to rice under saline soil conditions because it seems to have effective and

Table 1: Soil chemical properties of experimental sites during 2009 and 2010 seasons

| | | | Cation meq $L^{-1}$ | | | Anion meq $L^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|
| Seasons | pH | $ECdSm^{-1}$ | $Ca^{++}$ +$Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $So_4$ | $Cl^{-}$ | $HCO^{-}_3$ |
| 2009 | 8.23 | 7.50 | 31 | 56 | 0.32 | 50.5 | 30.3 | 8.0 |
| 2010 | 8.18 | 7.35 | 29 | 50 | 0.31 | 32 | 40.0 | 7.0 |

| | Available nutrients meq $L^{-1}$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | N | P | K | Zn | Mn | Fe | Cu |
| 2009 | 28 | 12 | 350 | 1.12 | 10.0 | 11 | 6.2 |
| 2010 | 26 | 14 | 360 | 1.02 | 10.5 | 12 | 6.0 |

Table 2: Dry matter, LAI and Chlorophyll of Sakha 101 rice variety as affected by $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ and their combinations under saline soil during 2009 and 2010 seasons

| | Dry matter (g $hill^{-1}$ ) | | LAI | | Chlorophyll (SPAD value) | |
|---|---|---|---|---|---|---|
| Treatments | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Control | 26.57 | 26.85 | 4.72 | 4.82 | 37.60 | 37.80 |
| $Zn^{+2}$ | 29.70 | 30.35 | 5.12 | 5.20 | 39.70 | 39.60 |
| $Fe^{+2}$ | 29.20 | 29.80 | 4.80 | 4.90 | 40.20 | 40.00 |
| $Mn^{+2}$ | 29.57 | 29.90 | 4.60 | 4.70 | 39.60 | 39.90 |
| $Zn^{+2}$+$Fe^{+2}$ | 30.10 | 30.80 | 5.40 | 5.52 | 40.30 | 40.10 |
| $Zn^{+2}$+$Mn^{+2}$ | 29.05 | 29.00 | 4.87 | 4.97 | 39.30 | 38.00 |
| $Fe^{+2}$+$Mn^{+2}$ | 30.35 | 30.57 | 4.95 | 5.07 | 40.80 | 40.10 |
| $Zn^{+2}$+$Mn^{+2}$+$Fe^{+2}$ | 32.95 | 31.80 | 5.62 | 5.75 | 41.00 | 42.00 |
| Foliar(Comparative treatment ) | 32.80 | 31.65 | 5.60 | 5.70 | 42.80 | 42.75 |
| L.S.D 0.05 | 2.00 | 1.62 | 0.50 | 0.42 | 1.80 | 1.50 |

Table 3: Panicle length, plant height and panicle numbers $hill^{-1}$ of Sakha 101 rice variety as affected by $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ and their combinations under saline soil during 2009 and 2010 seasons

| | Panicle length (cm) | | Plant height cm | | Panicle numbers | |
|---|---|---|---|---|---|---|
| Treatments | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Control | 19.35 | 19.57 | 86.87 | 87.80 | 15.0 | 14.91 |
| $Zn^{+2}$ | 20.45 | 20.60 | 96.95 | 96.65 | 16.30 | 16.12 |
| $Fe^{+2}$ | 20.42 | 20.60 | 95.27 | 95.12 | 16.47 | 16.17 |
| $Mn^{+2}$ | 20.12 | 20.37 | 94.57 | 94.82 | 16.22 | 15.92 |
| $Zn^{+2}$+$Fe^{+2}$ | 20.50 | 20.60 | 93.40 | 93.12 | 16.82 | 16.65 |
| $Zn^{+2}$+$Mn^{+2}$ | 19.92 | 20.30 | 93.10 | 92.97 | 15.80 | 15.82 |
| $Fe^{+2}$+$Mn^{+2}$ | 20.52 | 20.62 | 92.05 | 92.02 | 16.60 | 16.43 |
| $Zn^{+2}$+$Fe^{+2}$+$Mn^{+2}$ | 20.30 | 20.97 | 97.00 | 96.92 | 17.00 | 17.27 |
| Foliar(Comparative treatment ) | 21.30 | 21.67 | 96.60 | 96.10 | 16.80 | 16.09 |
| L.S.D 0.05 | 0.42 | 0.48 | 3.11 | 2.94 | 1.19 | 1.05 |

favorable role in improve rice growth under saline soil and subsequently resulted in high tolerance of rice to salt. It seems that $Fe^{+2}$ and Mn improved rice growth parameters, as they encouraged rice plants to produce more dry matter as a result of increasing chlorophyll content and optimizing rice canopy with appropriate leaf area index with magnified NAR. However, the double combinations of $Zn^{+2}$ + $Mn^{+2}$ or $Fe^{+2}$+ $Mn^{+2}$ and $Fe^{+2}$+ $Zn^{+2}$ did not provide so much improvement on rice growth under saline soil conditions. The triple combination significantly surpassed other combinations as seen in Tables 2 and 3. The obtained data regarding the impact of foliar application of the three micronutrients provided the superiority of foliar application compared to single or other soil applied micronutrients. Such positive response to foliar application of $Zn^{+2}$ +$Fe^{+2}$ + $Mn^{+2}$ on rice growth

Table 4: Panicle weight, filled grains and 1000-grain weight g of Sakha 101 rice variety as affected by $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ micronutrients fertilizer under saline soil during 2009 and 2010 seasons

| | Panicle weight (g) | | Filled grains / panicle | | 1000 grains weight (g) | |
|---|---|---|---|---|---|---|
| Treatments | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Control | 2.53 | 2.55 | 104.50 | 105.25 | 26.35 | 26.62 |
| $Zn^{+2}$ | 2.66 | 2.64 | 113.80 | 113.00 | 27.45 | 27.55 |
| $Fe^{+2}$ | 2.62 | 2.63 | 111.00 | 110.50 | 27.20 | 27.40 |
| $Mn^{+2}$ | 2.60 | 2.61 | 111.70 | 112.30 | 27.00 | 27.15 |
| $Zn^{+2}$+$Fe^{+2}$ | 2.68 | 2.69 | 116.80 | 115.50 | 27.90 | 23.10 |
| $Zn^{+2}$+$Mn^{+2}$ | 2.64 | 2.60 | 114.90 | 113.80 | 27.63 | 27.60 |
| $Fe^{+2}$+$Mn^{+2}$ | 2.69 | 2.68 | 115.80 | 115.30 | 27.87 | 27.95 |
| $Zn^{+2}$+$Fe^{+2}$+$Mn^{+2}$ | 2.75 | 2.72 | 116.50 | 115.50 | 27.75 | 27.35 |
| Foliar(Comparative treatment ) | 2.80 | 2.82 | 120.50 | 119.50 | 28.50 | 28.75 |
| L.S.D 0.05 | 0.088 | 0.069 | 4.77 | 5.62 | 0.77 | 0.64 |

Table 5: Grain yield and straw yields and harvest index of Sakha 101 rice variety as affected by $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ fertilizers under saline soil during 2009 and 2010 seasons.

| | Grain yield (ton/ fed*.) | | Straw yield (ton/ fed.) | | Harvest index | |
|---|---|---|---|---|---|---|
| Treatments | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Control | 1.77 | 1.85 | 2.92 | 3.07 | 0.378 | 0.376 |
| $Zn^{+2}$ | 1.94 | 2.02 | 3.13 | 3.23 | 0.383 | 0.385 |
| $Fe^{+2}$ | 1.92 | 1.96 | 3.05 | 3.14 | 0.383 | 0.383 |
| $Mn^{+2}$ | 1.90 | 1.96 | 2.99 | 3.11 | 0.389 | 0.386 |
| $Zn^{+2}$+$Fe^{+2}$ | 1.98 | 2.18 | 3.23 | 3.21 | 0.400 | 0.412 |
| $Zn^{+2}$+$Mn^{+2}$ | 2.10 | 2.25 | 3.08 | 3.14 | 0.390 | 0.400 |
| $Fe^{+2}$+$Mn^{+2}$ | 2.07 | 2.22 | 3.15 | 3.21 | 0.394 | 0.408 |
| $Zn^{+2}$+$F^{+2}e$+$Mn^{+2}$ | 2.27 | 2.37 | 3.31 | 3.41 | 0.40 | 0.410 |
| Foliar(Comparative treatment ) | 2.24 | 2.30 | 3.04 | 3.14 | 0.420 | 0.422 |
| L.S.D 0.05 | 0.08 | 0.11 | 0.18 | 0.15 | 0.015 | 0.019 |

*fed. = One feddan = 4200 $m^2$

under saline soil may be attributed to micronutrient uptake problems mitigation for some nutrients under salinity or high alkalinity and could be avoided by such method of application. Other benefit for foliar application that it might be more economically than those by topdressing or soil application. The control treatment without any micronutrients application gave the lowest values of dray matter per hill, LAI, chlorophyll content, shortest panicle and plant height. All studied micronutrients and their combination significantly improved the above mentioned growth traits but most of them were at a par. The comparative foliar application treatment of $Zn^{+2}$ +$Fe^{2+}$ + $Mn^{+2}$ twice at 20 and 45 days after transplanting (DAT) gave the highest values of chlorophyll content and panicle length without any significant differences with those produced by the combination of $Zn^{+2}$ +$Fe^{2+}$ + $Mn^{+2}$ as a soil application .The opposite was true regarding dry matter, leaf area index (LAI) and plant height.

The tallest plants were produced by the combination of $Zn^{+2}$ +$Fe^{+2}$ + $Mn^{+2}$ application to soil without any significant differences between the rest treatment except control. The favorable effect of above-mentioned nutrients $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ might be due to their role in improving rice growth, photosynthesis, chlorophyll formation and cell elongation and division. The obtained results on micronutrient foliar application twice was efficiency and economy was reported by Savithri *et al.* [7], Singaraval *et al.* [8], Ali *et al*. [9], Johnson *et al*. [10] and Sultana *et al.* [11].

**Yield and its Components:** Data in Tables 3 and 4 showed that application of $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ as single or in combination as soil or comparative foliar treatment significantly improved yield components as compared to control treatment. Most of the studied treatments of nutrient application were similar on their effect on panicle numbers except the combination of $Zn^{+2}$ + $Mn^{+2}$. The latter combination increased panicle number of rice but without significant differences with those produced by control treatment (none of micronutrient application). $Zn^{+2}$ and $Mn^{+2}$ applications as an individual have better effect than their combination because of the antagonistic effect. The highest value of panicle numbers of Sakha 101 was produced by the combination of $Zn^{+2}$ +$Fe^{+2}$ + $Mn^{+2}$ as soil application in both seasons. On the other hand, the control treatment of non-micronutrient application exerted the lowest values of panicle numbers per hill. Application of the three micronutrients as a single or in a combination and their foliar spray twice positively improved panicle weight in both years of study.

The effect of treatments on panicle weight and 1000-grain weight was similar to the trend obtained with panicle number under the current treatments. Certainly, the comparative foliar application of the three macronutrients in combination proved its superiority and it gave the highest values of panicle weight and 1000-grain weight. The combination of $Zn^{+2}$ +$Fe^{+2}$+ $Mn^{+2}$ as soil application occupied the second order after foliar application regarding panicle weight and 1000-grain weight. Similar findings were reported by Savithri *et al.* [7], Singaraval *et al.* [8], Ali *et al.* [9], Johnson *et al.* [10] and Sultana *et al.* [11].

**Grain Yield:** Data in Table 5 showed that the three micronutrients $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ and their combinations significantly affected grain yield, straw yield and harvest index in both years of study. Foliar application of the comparative treatment with the three studied micronutrients twice significantly improved and increased grain and straw yields of Sakha 101 rice variety. Interestingly, $Zn^{+2}$, $Fe^{+2}$, $Mn^{+2}$, $Zn^{+2}$ + $Fe^{+2}$, $Zn^{+2}$ + $Mn^{+2}$ and $Fe^{+2}$ + $Mn^{+2}$ were similar in straw yield in both season. Meanwhile, the differences among $Zn^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ application as single and $Zn^{+2}$ +$Mn^{+2}$ as combination were insignificance regarding rice grain yield and harvest index in both seasons. The triple combination of $Zn^{+2}$ + $Fe^{+2}$ + $Mn^{+2}$ as soil application gave the highest values of grain yield followed by the comparative foliar application treatment of the three nutrients twice in both seasons. The lowest values of rice grain yield of Sakha 101 rice variety was recorded when rice plant did not receive any of the applied micronutrients. As for harvest index, the micronutrients application as single or combination significantly improved harvest index in both seasons and foliar application proved its superiority rather than soil application as single or combination.

Foliar application of the three studied micronutrients under saline soil might encourage more grain formation against straw during pre and post heading. In addition, it was observed that foliar application was effective in improving rice growth and subsequently main yield components such as filled grains per panicle, panicle weight and 1000-grain weight. In addition, foliar application of micronutrients might raise dry matter transformation from store parts to sink part. Foliar application might be better than soil application because ion imbalance and uptake problem happened under saline soil condition. Advantages of foliar sprays might be due to (1) application rates are much lower than those of soil application; (2) a uniform application is easily obtained; and (3) response to the applied nutrient is almost immediate, so deficiencies can be corrected during the growing season[8]. Savithri *et al.* [7], Ali *et al.* [9], Johnson *et al.* [10] and Sultana *et al.* [11] showed some similarity with those obtained under the current study. These results suggested that soil or foliar application of the three micronutrient partially alleviates the adverse effects of salinity on yield and yield components of salt-stressed plants

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