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Influence of magnesium, iron, and zinc as foliar application on growth and yield of rice (*Oryza sativa L.*) in central clay plains, Sudan

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ABSTRACT

A field experiment was conducted at two locations, White Nile Research Station Farm (Kosti) and Gezira Research Station Farm (Medani). The climate in both locations is semi-arid and the soil at both locations is heavy clay vertisols. The experiment was conducted under an irrigated system during the kharif season of 2020. The study aimed to investigate the effect of adding magnesium, iron, and zinc fertilizers on vegetative growth and yield of rice (*Oryza sativa L.*). The released rice variety Wakra was used. Eight treatments were used control, Mg, Fe, Zn, Mg+Fe, Mg+ Zn, Fe+ Zn, Mg+Fe+Zn of the rate 59.5 kg/ha, 595 ml/ha respectively, and control without fertilizer. The experiment was arranged in a randomized complete block design (RCBD) with four replications. The data was analyzed using ANOVA and means separation was done using the least significant difference (LSD). The results showed that the application of these micronutrients significantly ($P \leq 0.05$) affected chlorophyll content and number of spikelets per spike at the Kosti site. While at the Medani site, plant height and 1000 grain weight showed significant differences ($P \leq 0.05$). No significant differences ($P \leq 0.05$) were found in days to 50% flowering, leaf area, number of reproductive tillers, straw yield and grain yield for both sites. The lowest and the highest yield (ton/ha) were registered for the control and Fe+ Zn treatments, respectively. The results indicated that application Fe+Zn increased grain yield by 27% and 21% at the Kosti and Medani sites, respectively. According to the results of this study, it is recommended to apply a combination of the micronutrients Fe+Zn under the Kosti and Medani sites. The study indicates that the micronutrients as foliar application are needed in the central clay plains to increase upland rice productivity in the Sudan.

Keywords: Vertisols, chlorophyll content, micronutrients, foliar application, upland rice.

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INTRODUCTION

Rice (*Oryza Sativa L.*) is one of the most important global food crops and the primary source of calories for more than half of the world's population. Rice is a tropical crop that has been cultivated in moderate regions and achieved high productivity, reaching 8 tons per hectare in Australia and Egypt and 6 tons per hectare in China and Japan. The crop is mostly grown under flooded conditions and consumes up to 43% of the world's developed irrigation resources (Bouman et al., 2007).

Rice in Sudan is grown mainly in the White Nile State, and growing upland rice type, the area and the yield are very low compared with that in other advanced countries such as China and Japan. The low production in Sudan is caused by the lack of knowledge of farmers about how to cultivate and not enough experience in the production of rice, in addition to a lack of research on the rice crop level. With the global food shortage, a need to extend rice production in Sudan has become a national strategy to meet a dual purpose as food for the growing population and as a cash crop. Sudan has a total estimated potential area for rice production of more than 300,000 hectares (Osman et al., 2022). If this area is properly utilized, it would suffice the local consumption demand. Zheng et al. (2020) suggested that Mg application improved crop yield under various field conditions across the world, along with evaluation of Mg and sugar concentration in plant tissues. Foliar application of Mg can promote photosynthesis, prevent root premature senility, increase tissue Mg concentrations and improve crop yields and quality (Rehman et al., 2018). Iron deficiency was considered a possible cause for the decline in rice yield. However, in most of the studies, foliar application has an edge over soil application (Abadia et al., 2011). According to Sidhu and Sharma (2010) in many areas, the high availability of Zn in soil is due to the increased use of Zn sulfate by farmers in recent years.

This study was undertaken to determine the influence of magnesium, iron and zinc application alone or in combination with each other as a foliar application on rice growth and grain yield under White Nile and Gezira conditions.

MATERIALS AND METHODS

A field experiment was carried out at two locations during the season of 2020. The first site was in White Nile Research Station Farm at Kosti located at latitude (37^{o} 12´N, longitude 54^{o} 31´ E) and alleviation 390.0 m above sea level. The other site was Gezira Research Station Farm at Medani located at latitude (14^{o} 24´ N, longitude 33^{o} 29´ E) and alleviation 409.0 m above sea level. The weather conditions: average maximum and minimum temperatures, rainfall and days of rain during the crop growth period at the Kosti and Medani sites are shown in Table 1.

Soil samples were collected from the experimental sites at random from 0-30 cm depth before experimenting. These samples were analyzed to determine physical and chemical properties by adopting standard procedures. The values of physical and chemical properties are presented in Table 2.

The soil of the experimental plot is clay with a slightly alkaline reaction, low in organic carbon, available nitrogen, medium in available phosphorus, high in available potassium and deficient in zinc (Table 2).

Table 1. Annual average of maximum and minimum temperature (^{o}C), rainfall and days of rain at Kosti and Medani, season 2020.

Months	Kosti		Medani		Kosti		Medani	
	Max. temp.	Min. temp.	Max. temp.	Min. temp.	Rainfall	Days of rain	Rainfall	Days of rain
June	38.9	24.7	38.5	24.4	72.2	6	18.9	6
July	37.6	23.8	37.3	23.4	71.9	7	68.3	4
August	33.1	23.1	32.7	22.8	165.2	14	125.3	8
September	35.2	22.5	34.9	23.0	27.4	4	23.3	3
October	36.1	22.9	35.1	22.1	76.8	5	41.2	8
November	38.1	20.9	38.3	19.5	9.9	2	0	0

(Source: White Nile and Medani Metrological Station).

Table 2. Physical and chemical properties of soil at Kosti and Medani sites at 30 cm depth.

Parameter	Kosti	Medani
Clay (%)	*56.00*	59.00
Bulk density (g/cm^{3}) (dry)	1.55	1.82
Soil moisture (bar)	38.50	214.00
Porosity (%)	43.00	120.00
EC (dsm^{-1})	1.30	0.73
PH	7.50	8.10
C:N Ratio (%)	11.00	12.00
OC (%)	*0.33*	0.44
N (%)	24.00	20.00
Available P (mg/kg)	1.90	1.40
Soluble Mg^{++} (meql^{-1})	0.50	0.50
Available Fe^{++} (cmol(+)kg^{-}soil)	0.96	0.63
Exchange Zn (cmol(+) kg^{-}soil))	0.90	0.60

Treatments

The tested treatments included the addition of three nutrient fertilizers alone or in combination applied as foliar. The details of the treatments were as follows:

1. Magnesium (Mg) at 59.5 kg/ha.
2. Ferrous (Fe) at 595 ml/ha.
3. Zinc (Zn) at 595 ml/ha.
4. Mg at 59.5 kg/ha + Fe at 595 ml/ha + Zn at 595 ml/ha.
5. Control (without the addition of fertilizers).
6. Mg at 59.5 kg/ha + Fe at 595 ml/ha.
7. Mg at 59.5 kg/ha + Zn at 595 ml/ha.
8. Fe at 595 ml/ha + Zn at 595 ml/ha.

These fertilizers were applied at 37, 52 and 66 days after crop emergence.

The experimental design used was arranged in a randomized complete block design (RCBD) with four replicates. The released variety *Wakara* was sown at the recommended seed rate of 80 kg/ha (Abdalla et al., 2016). At the White Nile Research Station, sowing was done on 12th July 2020 by hand, while at the Gezira Research Station, the sowing was done on 15th July 2020 using a seed drill.

Two chemical fertilizers were added to all experimental plots at the recommended rate. Phosphorous fertilizer in the form of triple super phosphate (TSP) was applied at 43 kg P_2O_5/ha before sowing. Nitrogen fertilizer was added at 129 kg N/ha in the form of urea (Osman et al., 2016). This amount of urea was split into two equal doses, the first dose was added one week after crop emergence and the second dose was applied 21 days later.

Irrigation water was applied every week before flowering and at 4 days intervals after flowering.

Data collected

Days to 50% flowering, plant height (cm), chlorophyll content, leaf area (cm^2), number of reproductive tillers, number of spikelets per spike, 1000 grains weight (g), straw yield and grain yield (ton/ha). The data was analyzed statistically using ANOVA by software (Genstat), and the mean separation was done using the least significant differences at 5% level.

RESULTS

The results showed that days to 50% flowering ranged between 62-64 days at the Kosti site and between 56-60 days at the Medani site. No significant (P≤ 0.05) differences were found between the different treatments due to micronutrient fertilization at both sites. All fertilizer treatments registered fewer days to 50% flowering as compared to control at both sites (Table 3).

At the Kosti site, the mean plant height showed no significant (P≤ 0.01) differences between fertilizer treatments, and the plant height ranged between 116 cm for the Mg treatment and 102 cm for the control. At the Medani site, there were significant (P≤ 0.05) differences between the control and the other micronutrient fertilizer treatments, which were not significantly (P≤ 0.05) different from each other. The treatment Mg + Fe + Zn produced the tallest plants (122cm), and the least plant height was registered for the control (99.4 cm). At Kosti, the mean of chlorophyll content at treatment Mg was significantly (P≤ 0.05) different compared to that of treatment Fe and the control, but was not statistically different from the remaining treatments, which in turn did not differ significantly (P≤ 0.05) from each other or treatment Fe and the control. At the Medani site, no significant (P≤ 0.01) differences between the treatments mean were found. The results showed that the straw yield ranged between 3.77-4.48 ton/ha at the Kosti site and between 2.92-3.44 ton/ha at the Medani site. No significant (P≤ 0.01) differences were found between the different treatments due to micronutrient fertilization at both sites. The results showed that grain yield ranged between 1.77-1.84 ton/ha at the Kosti site and between 1.29-1.56 ton/ha at the Medani site. No significant (P≤ 0.01) differences were found between the different treatments due to micronutrient fertilization at both sites. All fertilizer treatments registered greater grain yield as compared to control at both sites. Hence, correlation analysis is necessary to determine the effect of minerals provided and the number of characteristics that need to be considered in improving grain yield. Results in Table 4 showed that there was a positive and significant correlation between grain yield with several effective tillers (r = 0.42), chlorophyll content(r = 0.23) and straw yield (r =0.46). However, days to heading, plant height, leaf area (r = 0.12), and number of spikelets per spike (r = 0.12) demonstrated that there is no relationship with grain yield with (r = 0.06, r = 0.13, r = 0.12 and r =0.12) respectively. It seems that characters did not give any attribute to grain yield.

DISCUSSION

The increase in plant height due to zinc application might be due to the accelerated activity of enzyme and auxin production, an important growth promoter regulating stem elongation and cell enlargement. The present results are in agreement with the findings of Uddin et al. (2002).

The combined application of Mg + Zn recorded a significant effect on LAI, and in the presence of these nutrients, the growth of rice was enhanced resulting in higher LAI. Mg is the key component of chlorophyll and

Table 3. Combined analysis of Days to heading, plant height (cm), leaf area (cm^2), chlorophyll contents, spike length, number of spikelet per spike, thousand grain weight, straw yield and yield of aerobic rice as affected by Mg, Fe and Zn application.

Parameter	Location	Mg	Fe	Zn	Mg+Fe	Mg+Zn	Fe+Zn	Mg+Fe+Zn	Control	LSD	MSE (+)	CV%
Days to heading	**Kosti**	57.3a	57.5a	57.5a	58.8a	58.0a	59.0a	59.0a	60.0a	4.57	0.51	5.33
	Medani	64.0a	63.3a	62.3a	63.0a	64.0a	63.3a	62.0a	63.5a	2.83	0.45	3.05
	Combined	60.6a	60.8a	59.9a	60.9a	61.0a	61.1a	60.5a	61.8a	2.71	0.45	4.44
Plant height (cm)	**Kosti**	114.4a	116.3a	117.5a	117.3a	115.5a	116.0a	122.3a	99.5b	8.81	1.42	5.22
	Medani	116.8a	106.0ab	110.5ab	107.3ab	113.5a	111.0ab	110.3ab	102.8b	12.5	1.54	7.59
	Combined	115.4a	111.1a	114.0a	112.3a	114.5a	113.5a	116.3a	101.1a	7.31	0.90	6.47
Number of tillers	**Kosti**	264.8a	273.8a	262.5a	268.8a	261.8a	204.0b	232.8ab	254.5a	46.3	11.51	12.45
	Medani	292.3a	286.5a	273.5a	288.0a	298.5a	277.0a	301.0a	239.3a	78.0	9.95	18.81
	Combined	278.5a	280.1a	268.0a	278.4a	240.5a	280.1a	266.9a	246.9a	50.2	7.77	18.66
Leaf area (cm^2)	**Kosti**	29.9ab	28.3ab	34.2a	33.9a	35.3a	32.4a	32.6a	24.4b	7.67	1.05	16.63
	Medani	33.6a	31.15a	36.3a	32.4a	37.8a	33.2a	32.6a	31.9a	17.6	2.06	3.44
	Combined	31.8b	29.7b	35.3ab	33.1ab	41.5a	32.8ab	32.6ab	28.1b	9.33	1.17	2.79
Chlorophyll content	**Kosti**	39.2a	39.0a	40.1a	38.1a	38.9a	39.1a	39.1a	38.5a	2.59	0.29	4.50
	Medani	41.8a	38.8b	40.3ab	40.2ab	40.4ab	39.8ab	40.2ab	38.9b	2.18	0.27	3.70
	Combined	40.5a	38.9ab	40.2ab	39.1ab	39.6ab	39.5ab	39.7ab	38.7b	1.63	0.21	4.11
Number of spikelet/spike	**Kosti**	8.3a	8.5a	8.0a	8.5a	8.3a	7.5a	8.5a	8.0a	1.24	0.15	10.28
	Medani	10.0ab	10.5ab	12.0a	11.5a	10.5ab	11.5a	11.8a	8.5b	2.13	0.32	13.41
	Combined	9.1ab	9.5a	10.0a	10.0a	9.4ab	9.5a	10.1a	8.3b	1.20	0.24	12.61
1000 grain weight (g)	**Kosti**	31.0a	27.4b	25.3cb	27.1b	23.9c	26.4cb	27.4b	25.9cb	3.18	0.57	8.06
	Medani	32.6a	31.7a	29.9a	29.9a	29.9a	31.8a	30.8a	33.1a	5.81	0.65	12.67
	Combined	31.8a	29.8ab	27.6b	28.5b	26.9b	29.1ab	29.1ab	29.5ab	3.30	0.51	11.29
Biomass (ton/ha)	**Kosti**	2.87a	2.84a	3.39a	3.20a	2.48a	2.70a	3.07a	3.07a	0.97	0.13	2.22
	Medani	3.80ab	3.18b	2.95b	3.55ab	3.18b	3.52ab	4.35a	3.80ab	0.97	0.17	18.53
	Combined	3.33ab	3.00b	3.17ab	3.37ab	2.83b	3.11ab	3.71a	3.44ab	0.69	0.11	2.12
Yield (ton/ha)	**Kosti**	1.42a	1.40a	1.56a	1.55a	1.37a	1.46a	1.29a	1.34a	0.31	0.04	14.96
	Medani	1.78a	1.50ab	1.63ab	1.65ab	1.63ab	1.65ab	1.72a	1.40b	0.99	0.06	12.59
	Combined	1.60a	1.45a	1.60a	1.60a	1.50a	1.55a	1.50a	1.37a	0.25	0.04	16.65

the Mg application resulted in better photosynthesis and caused increased leaf width. This finding is in agreement with Zayed et al. (2011).

Application of $FeSO_4$ in aerobic rice as the foliar application had failed to claim a significant effect on the number of reproductive tillers per m^2. This might be due to the involvement of Fe in plant physiochemical activity, but it might not be a strong element to induce a drastic change in plant growth and may be due to the availability of nutrients in sufficient quantities, which is per the findings of Venugopal (2005). Filled grain in this experiment might have resulted from increased nutrient uptake and translocation within the plant. As magnesium plays a key role in chlorophyll synthesis, the higher chlorophyll content might have led to faster grain filling through an increased photosynthetic rate. The contribution of carbohydrates from the photosynthetic activity for a longer period might have resulted in efficient translocation of food material into the sink (grain), thereby increasing the number of filled grains per spike. These results conform with the findings of Ravikiran and Reddy (2004).

Combined foliar application of (Mg+Fe+Zn) at both sites recorded better thousand-grain weight compared to the control. This might be due to the increased transportation of photosynthesis from source to sink due to Zn application as reported

Table 4. Correlation coefficient among agronomic characters in three types of mineral elements on rice growth and grain yield.

	DH	PH	NET	LA	CC	SS	TGW	SY	GY
DH	1								
PH	-0.12	1							
NET	-0.11	-0.06	1						
LA	0.23*	0.27*	-0.07	1					
CC	0.29*	-0.13	0.17	0.09	1				
SS	0.38**	0.60*	0.1	0.17	0.24*	1			
TGW	0.29*	-0.2	0.21	0.002	0.11	0.31*	1		
SY	0.06	-0.01	0.43**	-0.17	0.13	0.07	0.26*	1	
GY	0.06	0.13	0.42**	0.12	0.23*	0.12	0.16	0.46***	1

* and **, significant and highly significant at the 0.05 and 0.01 level of probability, respectively.
DH = Days to Heading, **PH** = Plant Height, **NET** = Number of Effective Tillers, **LA** = Leaf Area, **CC** = Chlorophyll Content, **SS** = No of Spikelets per Spike, **TGW** = Thousand Grain Weight, **SY** = Straw Yield, **GY** = Grain Yield.

by Singh and Singh (2012).

The increase in straw yield was mainly due to the availability of nutrients in sufficient quantities increased in number of tillers per m^2 and the straw yield of aerobic rice. These findings are per those of Reddy and Kumar (1999).

CONCLUSION

From the result of this study, it can be concluded that the foliar application of micronutrients enhanced the growth parameters and yield attributes and increased the yield of rice when compared with the control but did not reach a significant level.

REFERENCES

Abadia J, Vazquez S, Alvarez R, Jendoubi EI, Abadia A, Fernandez A, Millan AF, **2011.** Towards a knowledge-based correction of iron chlorosis. Plant Physiol Biochem, 49: 471-482.

Abdalla AA, Elsiddig A, Alawia OH, **2016.** Effect of seed rate on yield and yield components of aerobic rice under White Nile State Conditions. Univ Khartoum J Agric Sci, 24(1): 27-41.

Bouman BAM, Xiaoguang Y, Huaqi W, Zhimin W, Junfang Z, Bin C, **2007.** Performance of aerobic rice varieties under irrigated conditions in North China. Field Crops Res, 97: 53-65.

Osman AA, Elsiddig AA, Hassan AO, 2016. Response of aerobic rice to nitrogen and phosphorus fertilizers under Gezira Condition. Proceeding the 59th Meeting *(NCHC)* 25-32.

Osman KA, Abdalla SM, Ismail AI, Lee S-B, Mohamed AE, Yousif SA, Ahmed YM, **2022.** Yield Stability and Adaptability of Elite Doubled Haploid (DH) Rice Genotypes in Different Locations in Central Clay Plains of the Sudan Am J Plant Sci, 13: 1282-1295.

Ravikiran S, **Reddy** GLN, **2004**. Effect of ZnSO4 foliar spray on yield of rice cultivars. Andhra Agric J, 51(3&4): 438-440.

Reddy MD, **Kumar** KA, **1999.** Effect of levels and time of N application on performance of late sown rice. Indian J Agron, 44(2): 297-300.

Rehman HU, Alharby HF, Alzahhrani Y, Rady MM, **2018**. Magnesium and organic biostimulant integrative application induces physiological and biochemical changes in sunflower plants and its harvested progeny on sandy soil. Plant Physiol Biochem, 126: 97-105.

Sidhu GS, **Sharma** BD, **2010**. Diethylene triaminepetaacetic acid extractable micronutrients status in soil under a rice- wheat system and their relationship with soil properties in different agroclimatic zone of indo- genetic of India. Common Soil Sci Plant Anal, 41: 29-51.

Singh HP, **Singh** TN, **2012.** Enhancement in zinc response of rice by magnesium in alkali soil. Indian J Plant Physiol, 10(2): 418-424.

Uddin MK, Islam MR, Rahman MM, Alam SMK, **2002.** Effect of zinc and boron supplied from chemical fertilizers and poultry manure to wetland rice(Cv. BRRI Dhan 30). J Biol Sci, 2(3): 165-167.

Venugopal R, **2005.** Performance of Rice varieties at different nitrogen levels in dry seeded irrigated condition. *M.Sc. (Ag)Thesis.* Acharya N. G. Ranga Agricultural University, Hyderabad, India.

Zayed BA, Salem AKM, El-Sharkawy HM, **2011.** Effect of different micronutrient treatments on rice growth and yield under saline soil condition. World J Agric Sci, 7(2): 179-184.

Zheng W, Mahmood H, Fisal N, Xuexian LI, **2020.** Magnesium fertilization improves crop yield in most production systems: A meta-analysis. Published online dio: 10.3389/fpls.2019.01727. PMCID: PMC6992656, PMID:32038691.

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