The content of micronutrient in grass is important for quality improvement of livestock feeds. The objective of this study was to determine the response of Brachiaria grass to zinc-enriched fertilizer. The experiment was conducted in randomized complete block design (RCBD) with four replications. Zinc Sulphate was applied at four treatment levels comprising $T_1 = 0\%$ Zn ($\text{ZnSO}_4$ at 0 kg/ha), $T_2 = 50\%$ Zn ($\text{ZnSO}_4$ at 45.6 kg/ha), $T_3 = 100\%$ Zn ($\text{ZnSO}_4$ at 91.2 kg/ha) and $T_4 = 150\%$ Zn ($\text{ZnSO}_4$ at 136.8 kg/ha). Zinc fertilizer treatment had a significant effect on zinc concentration in Brachiaria grass at $p<0.001$. Significant differences were observed among all the four mean concentrations of zinc in grass except between 0% and 50% and between 100% and 150% Zn. The results showed that the fertilization of Brachiaria grass with zinc fertilizer application at 100% (91.2 kg/ha) level resulted in the optimal Zinc uptake and Zinc concentration in Brachiaria biomass. Considering the input cost of applying Zinc-fortified fertilizers, application of $\text{ZnSO}_4$ at the rate of 91.2 kg/ha (100% concentration) is recommended. Consequently, Zinc uptake in bio-fortified Brachiaria grass correlate with increasing levels of Zinc fertilizer application in the soil. The application of Zinc-fortified fertilizers in Brachiaria production will enhance fodder quality and yields to meet the increasing demand for animal feeds and increase food production for the growing population.

Key words: Bio-fortification, fortified fertilizers, grass performance, zinc uptake

INTRODUCTION

Agronomic bio-fortification of increasing the concentration of microelements in edible plant tissues relies on fertilizers applied and/or improved solubility and mobilization of already present microelements in the soil (Cakmak, 2008). When plants are grown on the soil where microelements are unavailable, the target application of soluble inorganic fertilizers is carried out over roots or leaves (Maqbool and Beshir, 2019). According to Cakmak (2008), Zinc (Zn) is usually applied to plants as $\text{ZnSO}_4$ or in the form of synthetic chelates. The concentration of Zn in plants, can be increased through application of Zn fertilizers in the soil. According to Broadley et al. (2007), applying Zn fertilizers through roots can increase the concentration of Zn in leaves, tubers, and fruits. The residual effects of Zn fertilizer on plants may also be visible several years after application.

Although various sources of Zn are available in the market, the inorganic compounds $\text{ZnSO}_4$ and $\text{ZnO}$ are the most commonly used Zn fertilizers and for cost reasons are unlikely to be replaced by other compounds (Shivay et al., 2008). Zinc sources can be applied alone into the soil. However, incorporating Zn in macronutrient formulations has become popular as it allows a more uniform distribution of Zn into the soil and eliminates the need of additional field operations. In Zn-enriched fertilizers, the availability of Zn can be affected by the chemical reactions of Zn and the phosphorus component of the macronutrient carrier which reduce the water solubility of Zn (Maqbool and Beshir, 2019). Therefore, the objective of this study was to determine the performance of Brachiaria grass under various zinc-fortified fertilizer application rates in the soil.
MATERIALS AND METHODS

Experimental site
The experiment was conducted at the Dairy Research Institute of the Kenya Agricultural and Livestock Research Organization (KALRO) in Naivasha sub-county, Nakuru County. It is located within the Kenya’s Rift-Valley on Longitude 0° 40’ S and Latitude 36° 26’ E at 1900 m above sea level. The region receives a bimodal rainfall pattern occurring mainly in late March to June and September to December for the long and short rains, respectively. Although the mean temperature is 17.9°C, daily values range from 6 to 26°C especially during the dry months, while the relative humidity ranges from 60 to 75%. The region’s climate and soil characteristics are described adequately by Jaetzold and Schmidt, (1983). The soils are volcanic in origin, slightly to moderately alkaline (pH 7.4), deep, dark grey to dark brown with humic topsoil, and are sodic. The soil fertility is low and deficient in trace elements and requires fertilization and mineral supplementation for optimum production of fodder. The farm was predominated by star grass (Cynodon plectostachyus) with scattered tall acacia trees (Acacia xanthophleia).

Experimental design
The experiment was made of Randomized Complete Block Design (RCBD) design made of four (ZnSO₄) treatments in 4 blocks. Each experiment plot was 250m².

Soil sampling and analysis
Soil samples were taken from the land where the Brachiaria grass was grown to determine the amount of zinc. Soil field sampling was done in a diagonal pattern at depths of 0-15 cm and 15-30 cm using Johnson Bucket soil auger (Thompson type) before the Brachiaria splits sourced from KALRO Ol-Jororok were planted. This was to determine the soil zinc composition at the beginning of the experiment. In addition, the samples of the grass planted were analyzed to ascertain the zinc content. These results were used to estimate the amounts of zinc fertilizer used in the soil application.

Land preparation and grass management
The experimental piece of land was ploughed using a disc plough to break the hard surface. Thereafter the experimental unit was harrowed twice to a fine tilth. Four tonnes of manure were evenly spread on the 0.4-hectare plot before harrowing for proper and even mixing with the soil giving a rate of 10 tonnes per hectare. The 16, 0000 Brachiaria splits were planted with a spacing of 50 cm x 50 cm in an experimental unit measuring 0.4 hectares. Due to lack of adequate rainfall, 80% of the splits dried up leading to replanting one month later. In order to ensure good stand establishment, the experimental area was irrigated using overhead irrigation system. Since the Brachiaria grass was not at the same level of growth, the grass was grown and harvested after three months. Thereafter, the zinc-fortified fertilizer treatment were applied in different blocks. In each block, one experimental unit was the control without ZnSO₄ application while the other three remaining experimental units were fertilized with ZnSO₄ of different application rates (T2 = 50% Zn (ZnSO₄ at 45.6 kg/ha); T3 = 100% Zn (ZnSO₄ at 91.2 kg/ha); T4 = 150% Zn (ZnSO₄ at 136.8 kg/ha).

Zinc fertilizer application rates
The fertilizer used for this study was zinc sulphate (ZnSO₄). A simple zinc sulphate fertilizer formulation was prepared with the aim of guiding the determination of the zinc treatment levels. The application of 20 kg of Zn per hectare (Nguku et al., 2016). Based on the ZnSO₄ fertilizer package labelling, the Zn level was 22% equivalent to 22 kg Zn/100 kg ZnSO₄. Therefore, recommendations of ZnSO₄/ hectare are 90.91 kg translating to a recommended rate of 36.4 kg ZnSO₄/ha. An area of 0.2 ha was used for soil application of ZnSO₄. (Table I).
TABLE I: ZINC SULPHATE (ZnSO₄) APPLICATION RATES

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Replicate</th>
<th>Experimental unit (plot)</th>
<th>ZnSO₄ rate (%)</th>
<th>ZnSO₄ rate (kg/plot)</th>
<th>ZnSO₄ rate (kg/ha)</th>
<th>Zn rate (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
<td>50</td>
<td>0.57</td>
<td>45.6</td>
<td>10.0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
<td>100</td>
<td>1.14</td>
<td>91.2</td>
<td>20.1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>4</td>
<td>150</td>
<td>1.71</td>
<td>136.8</td>
<td>30.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>3.42</td>
<td>273.6</td>
<td>60.2</td>
</tr>
</tbody>
</table>

Soil fertilizer application

For soil application, five kg of manure was used as the carrier material for ZnSO₄ per experimental unit (plot) including control plots. The application was done at 60 days after planting.

Laboratory testing for soil and grass biomass

The grass was analysed monthly to check for the rate and percentage uptake of ZnSO₄ from the soil. The soil samples obtained from the experimental units were analysed for zinc concentration using Atomic Absorption Spectrophotometry Method. A Perkin Elmer UV/VIS spectrometer Lambda 2 was used for zinc analysis. This was done at the Soil Laboratory, Faculty of Agriculture, University of Nairobi, CSI International Ltd and KALRO Naivasha. *Brachiaria* grass samples were obtained from each experimental unit and subjected to proximate analysis before and after applying the zinc sulphate fertilizer. The proximate analysis was done at KALRO Naivasha laboratories.

Data collection

Zinc concentration data was collected beginning four weeks after fertilizer application to a period of three months. The data was collected monthly from the 14th July to 26th October 2021. The data from proximate analysis was collected before and after fertilizer application. Biomass yield was measured on dry matter basis and expressed in tonnes/ha from mature *Brachiaria* grass.

Statistical analysis

The data was analyzed using the one-way analysis of variance statistical method using SPSS for windows, IBM SPSS Statistics 23.0 (2020). The linear model used for data analysis is given below.

\[ Y_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij} \]  

where; \( Y_{ij} \) = overall Zinc concentration of *Brachiaria* grass under the \( i^{th} \) treatment and in the \( j^{th} \) block, \( \mu \) = the overall mean effect, \( \alpha_i \) = the \( i^{th} \) treatment effect, \( \beta_j \) = the \( j^{th} \) block effect and \( \epsilon_{ij} \) = the random error.

The treatment means were compared using the Tukey’s honestly significance difference (HSD) test at 5% significance level. The magnitude of the observed mean value (q) was calculated using the formula shown below:

\[ q = \frac{Y_A - Y_B}{SE} \]  

where, \( Y_A \) is the larger of the two means being compared, \( Y_B \) is the smaller of the two means being compared, and \( SE \) is the standard error of the sum of the mean.

RESULTS AND DISCUSSION

Zinc concentration in *Brachiaria* grass

Table II shows the effect of soil zinc fertilizer on zinc concentration in *Brachiaria* grass. Tests of between-subjects effects were performed to determine how the dependent variable (zinc concentration in the grass) differed from the independent variable (soil zinc fertilizer treatment) at four levels thus T1, 0% (0 kg/ha); T2, 50% (45.6 kg/ha); T3, 100% (91.2 kg/ha) and T4, 150% (136.8 kg/ha). Results revealed that zinc fertilizer treatment had a significant effect on zinc concentration in *Brachiaria* grass (\( F(3, 1141.47) = 11.35; p < 0.001 \)). Performance of *Brachiaria* grass for biomass yield was measured quantitatively and qualitatively for zinc uptake from soil into *Brachiaria* grass. Consequently, the results of this study show the potential of *Brachiaria* grass as fodder for livestock and the most suitable application rate of Zn fertilizer.
A post hoc Tukey’s HSD test showed that the mean concentration of zinc in grass were significantly different between; T1 (control) and T3 (ZnSO₄ at 91.2 kg/ha), T1 and T4 (ZnSO₄ at 136.8 kg/ha), T2 (ZnSO₄ at 45.6 kg/ha) and T3, and T2 and T4 but not significantly different between T1 and T2 and between T3 and T4 as shown in Table II. This, implies that under the same conditions and cost-effective considerations, 100 percent Zn concentration (T3) level produced the optimal results compared to the other three treatments.

The nutrient composition of Brachiaria grass ranges as follows; energy 7.0 mj/kg, crude protein (9.1-15%) and crude fibre (21-41%) (Njarui et al., 2016). The crude protein obtained in Brachiaria after applying T2, T3 and T4 treatments were below the lower range of MG 4 from KALRO, whereas T1 which served as the control was within the lower range; suggesting a possible negative interaction between zinc and protein synthesis in the plant tissues.

### TABLE II - EFFECTS OF ZINC SULPHATE FERTILIZER APPLICATION RATES ON ZINC CONCENTRATION, CHEMICAL COMPOSITION, AND DRY MATTER YIELD OF BRACHIARIA GRASS.

<table>
<thead>
<tr>
<th>Treatment levels</th>
<th>Zinc concentration (ppm)</th>
<th>Chemical composition</th>
<th>Biomass yield (tonnes/ha.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry matter (DM %)</td>
<td>Ash (%)</td>
<td>Ether extract (%)</td>
</tr>
<tr>
<td>T1</td>
<td>30 ± 0.00ᵇ</td>
<td>90.37</td>
<td>16.34</td>
</tr>
<tr>
<td>T2</td>
<td>38.53 ± 6.89ᵇ</td>
<td>96.30</td>
<td>16.72</td>
</tr>
<tr>
<td>T3</td>
<td>62.68 ± 20.49ᵃ</td>
<td>96.40</td>
<td>16.98</td>
</tr>
<tr>
<td>T4</td>
<td>63.10 ± 19.08ᵃ</td>
<td>95.80</td>
<td>16.60</td>
</tr>
</tbody>
</table>

Means in a row and bearing different letters are significantly different at p< 0.05

**Effect of zinc application levels on Brachiaria grass zinc uptake**

In this study, the performance of Brachiaria grass was measured qualitatively as the amount of zinc uptake from the soil into the Brachiaria grass. Study results showed that zinc fertilizer treatment has a significant effect on zinc concentration in Brachiaria biomass (p<0.001) (Table II). Zinc concentration in Brachiaria grass, was highest when the zinc sulphate fertilizer was applied at the rate of 136.8 kg/ha. and lowest at zero percent rate of application 0 kg/ha. Zinc fertilizer application at the rate of 91.2 kg/ha recorded modest concentration of (62.682 ± 20.486 ppm). Morais et al. (2021) reported a greater zinc accumulation in the shoot of maize plants in response to a single use of Zn fertilization. Previous experimental results suggested that applying zinc fertilizers to the soil under zinc deficient conditions, is an effective strategy to increase crop yields (Maqbool and Beshir, 2019). In contrast Martins et al. (2014) reported a reduction in tissue zinc concentrations resulting from increased application of P-fertilizer to induce zinc (Zn) deficiency symptoms in plants. The crop recovery of Zn applied in fertilizers to the soil is generally low. The effectiveness of Zn fertilizers has been related to the water solubility of Zn in the fertilizer. However, the fate of fertilizer Zn depends on the fertilizer composition and the interaction of Zn with the soil and the fertilizer application method. A better understanding of these interactions may lead to the selection of appropriate fertilizer management practices.

**Biomass yield of Brachiaria grass**

The performance of Brachiaria grass measured quantitatively as yield in tonnes per hectares as presented in Table II. (Treatment T3) posted the highest grass yield of 10.1 t/ ha as wilted/dried under shade, equivalent to 505 kg as DM, respectively. The results of T3 agree with results reported on Brachiaria grass as yielding about 18 to 20 tonnes/acre as green fodder or 10 to 11 tonnes/acre when dried. Treatment T1, which served as control, reported the lowest grass yield of 6.6 tonnes per hectare as wilted/dried under shade which is equivalent to 330 kg as DM, respectively. Treatments T1, T2 and T4 reported
yields below the average recommended range in tonnes per hectare by KALRO (Njarui et al., 2016). This is also supported by Nguku et al. (2016) in a study that showed that of the many types of Brachiaria grasses cultivated. The findings also agree with Shivay and Prasad (2012), who demonstrated that the application of zinc-coated urea (ZnSO₄) or the use of Zn (ZnSO₄·7H₂O) in soils that were deficient in zinc significantly improved the yield of wheat and rice grains. In addition, soil application of Zn-chelates or ZnSO₄ in grains resulted in adequate uptake of zinc through the phloem, correspondingly this can improve the accretion of zinc in leaves, tubers, and fruit (Broadley et al., 2007). Progress has been made in improving zinc concentration in a number of crops in the grass family comprising wheat, through Zinc fertilizer application (Cakmak, 2008, 2009). This approach not only increased Zinc concentration but resulted in increased yields (Wakeel et al., 2018). According to Njarui et al. (2016).

**CONCLUSION**

Increase of Zinc application in soil significantly increase Zinc concentration in Brachiaria grass, thus presenting the potential for vertical translocation of zinc into forage biomass. The study revealed the that soil application of ZnSO₄ at the rate of 91.2 kg/ha yielded an optimal concentration of zinc in Brachiaria. The application of Zinc fertilizer in Brachiaria production will potentially enhance fodder quality and yields to lessen the growing demand for livestock feeds hence increase food production.

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**REFERENCES**


Wakeel, A., Farooq, M., Bashir, K. and Ozturk, L.