Original Research Article

INFLUENCE OF ORGANIC AND INORGANIC SOIL AMENDMENTS ON SOIL MOISTURE CONTENT AND MICRONUTRIENTS

ABSTRACT

Aims: This study was carried out to evaluate the influence of organic and inorganic soil amendments on soil moisture content and micronutrients with an aim of soil water retention and nutrients improvement in semi and arid areas.

Methodology: The study was laid out as randomized complete block design (RCBD) in split plot arrangement for two seasons. The treatments were Chalim^{TM}, Super-hydro-grow polymer and Metham sodium, Metham sodium, Metham sodium + Orange peel, Super-hydro-grow polymer, Control, Brassica tissue, Chalim^{TM} + Super-hydro-grow polymer, Brassica tissue + Orange peel and Metham sodium + Super-hydro-grow polymer. Soils were sampled from each experimental site, dried and taken to laboratories for determination of Zinc, Iron, Manganese and copper both at initial and at the end of the experiment using a SpectrAA- 40 atomic absorption spectrometer, PSC-56 programmable sample changer. Moisture content was calculated by subtracting total dry soil plus Petri dish weight from total wet soil plus Petri dish weight. Calculated moisture content was recorded in all samples across the two seasons for analysis.

Results: There was a Significant difference ($p \le 0.05$) in the treatment effect on soil moisture content in all the treatment except for MS and CM+op in both season one and season two in the green house. A combination of both organic and inorganic soil amendments like BT+OP, BT+ SHG had the highest moisture content. There was significant difference ($p \le 0.05$) in the soil amendments effect on the amount of Micronutrients in all the treatments in the beginning and end of the experiement.

Conclusion: Through this study, it was realized significant difference ($p \le 0.05$) in the soil amendments effect on soil moisture content in all the treatment in both season in the field. BT +SHG soil amendment was superior in maintaining soil moisture content in both season 1 and 2 in the field. It is therefore recommended that Metham sodium should not be applied in very dry soil to avoid reduction of the moisture content. There was micronutrient increment in all the treatments.

Comment [MI1]: This might not be necessary in this statement.

Keywords: Amendments, Inorganic, Organic, Micronutrient, Moisture content.

1. INTRODUCTION

The increasing global population coupled with the challenges of environmental degradation and an increasingly variable climate has created a world-wide need for improved food security [1, 2]. Green Revolution on one hand increased crop production per unit area and on other hand it also has resulted in greater depletion of soil phytoavailable micronutrients as less attention has been paid to micronutrients fertilization [3]. Impact of micronutrient deficiency in crop production is well documented as loss of yield [4]. The essential nutrients for plants are divided into two groups, macronutrients (N, P, S, K, Ca, Mg, Cl) and micronutrients (B, Co, Cu, Fe, Mn, Mo, Ni, Zn) [5]. While macronutrients have huge effects on the yield of crops and are needed in large amounts, micronutrient deficiency can also considerably reduce the yield and nutritional quality of crop products, although they are not required in large amounts [6]. Micronutrients play a vital role in gene expression, biosynthesis of protein, nucleic acids, growth substances, metabolism of carbohydrates and lipids through their involvement in various plant enzymic systems and other physiologically active molecules [4].

The provision of nutrients to the plant in quantities that are optimal for their subsequent utilization is a primary aim of crop fertilizer programme since yields and quality are adversely affected by any deviation [7]. Soil amendments are added to the soil to increase the organic contents and improve the structure to enable the soil to have a high capacity of holding nutrients [8]. Adding a soil amendment, also known as soil conditioning; helps improve plant growth and health [9]. The type of amendment depends on the prevailing soil composition/condition, the climate, and the type of plant**.** Amendments provide energy and nutrients to soil, drastically changing the environment for the growth and survival of crops and microorganisms [9]. Due to scarcity of organic amendments, the inorganic materials have become increasingly popular in adjusting the soils physicochemical characteristics, enhancing growth and consequently promoting yields of crop [10]. In order to enhance the micronutrient status of these soils, there is need for assessment of their initial micronutrient status in order to integrate the appropriate soil fertility management that involves judicious use of combined organic and inorganic fertilizers. This is a feasible approach which has been employed in overcoming soil fertility constraints [11, 12]. Therefore, an integrated use of inorganic fertilizers with organic manures is a sustainable approach for efficient nutrient usage which enhances efficiency of the chemical fertilizers while reducing nutrient losses [13]. Therefore, micronutrient deficiency has become a limiting factor for crop productivity in many agricultural soils. In order to obtain the genetic potential yields of crops, correcting micronutrients deficiencies is necessary. In order to enhance the micronutrient status of these soils, there is need for assessment of their initial micronutrient status in order to integrate the appropriate soil fertility management that involves judicious use of combined organic and inorganic fertilizers. This is a feasible approach which has been employed in overcoming soil fertility constraints [11, 12]. However, availability and uptake of micronutrients are affected by the presence of the macro-nutrients present in these amendments due to either negative or positive interactions [14].

The availability of water is the most important factor that limits development of agriculture in arid and semi-arid [15]. According to Shabaan *et al.* [16] the benefits derived from polymer application to soil include an increase in the water holding capacity and soil nutrient reserves and a reduction in soil compaction. The intrinsic water-holding capacity of organic amendments is greater than that of most mineral soils [17], so degraded soils with organic amendments can show an immediate increase in water-holding capacity [18]. Organic amendments may [19] or may not [20] increase available water. The question to be posed is how to build up and maintain soil fertility under the poverty faced by many farmers. The need for added external nutrients and maintain soil moisture is imperative as inorganic commercial fertilizers are expensive; their use is sometimes unprofitable especially because of blanket recommendations. This study was carried out to evaluate the influence of organic and inorganic soil amendments on soil moisture content and micronutrients.

2. MATERIALS AND METHODS

2.1 Study site

The study was conducted at KALRO Kabete. The station is located in Nairobi County. It is situated about 8km Northwest of Nairobi 360411E and 01015'S and at an attitude of 1737m above sea level in the upper semi-humid agro-ecological zone UM3 [21]. The rainfall is bimodal; the average received ranging from 600 to 2000 mm per year. The area is reliable and favorable for agricultural activities, with the April-July period receiving 60 % and October-November 40 % of precipitation. It has two crop growing periods with a total of 150-214 days. The mean annual temperature ranges from 18.0^{o}C to 21.9 ^{o}C. Soils at KARLO, Kabete, are dominated by humic Nitisols [22] with a clay texture and are known locally as Kikuyu red loam.

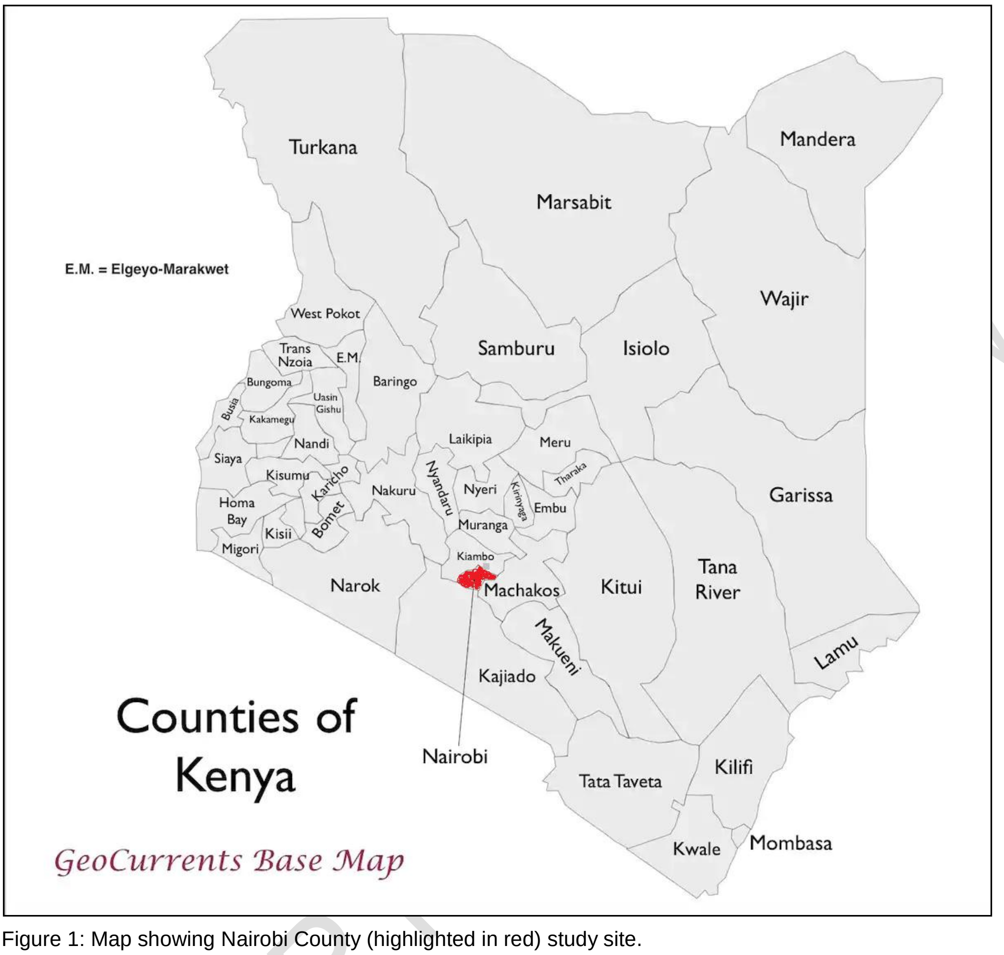

Figure 1: Map showing Nairobi County (highlighted in red) study site.

2.2 Experimental Design and Treatments

The experiment was carried out in July, 2017 and was replicated three times. The experiment was laid out in randomized complete block design (RCBD) in split plot arrangement in the field. A plot measuring 66m by 28.5m was marked, cleared, ploughed, harrowed and demarcated into 150 plots each measuring 2.4m x3.75m. Spacing of the host crops of interest: potato - (Tigoni variety), tomato (Caj variety) and capsicum (Califonia Wonder)) was carried out at 75 cm between the rows and 30 cm within the rows. The treatments were Chalim^{TM}, Super-hydro-grow polymer and Metham sodium, Metham sodium, Metham sodium + Orange peel, Super-hydro-grow polymer, Control, Brassica tissue, Chalim^{TM} + Super-hydro-grow polymer, Brassica tissue + Orange peel and Metham sodium + Super-hydro-grow polymer. All agronomic practices including, watering, fertilization, weeds, pests and disease control were well managed.

2.3 Preparation of Soil Amendments

Fresh leaves of cabbage plant residues were finely chopped and incorporated into the soil at a depth of 20 cm, at the rate of 3969 g per 2.4 m x3.75 m plot (4355.56 kg/ha), The inoculated soil was thoroughly mixed with the finely chopped cabbage plant residue, ensuring that all the residues were well incorporated in the soil. Freshly dried finely chopped peels of orange plant residues were incorporated into the soil at a depth of 20 cm, at the rate of 3969 g per 2.4 m x3.75 m plot (4355.56 kg/ha). The inoculated soil was thoroughly mixed with the finely chopped orange peels residues; ensuring that all the residues were well incorporated in the soil. Metham sodium, a chemical fumigant was applied in 12 plots of 2.4 m x 3.75 m at the rate of 200 ml/m^2 i.e. (1800 ml in 9 L of water). This was the positive control. This was done in each of the 6 furrows where each furrow received 1800 ml of the mixture (10.800 L), approximately 2000 L/ha. The sprayed furrows were thereafter covered with soil awaiting three weeks to the planting of the test crops. Chalim™ effect was assessed in the inoculated field after application at the rate of 227.81 g per 2.4 m x3.75 m plot (250 kg/ha). Super-hydro-grow polymer was applied in 12 plots of 2.4 m x 3.75 m at the rate of 200 ml/m^2 using knap-sack sprayer. Combination of Chalim™ + Super-hydro-grow polymer was applied at the rate of 227.81 g per 2.4 m x3.75 m plot (250 kg/ha) and 2.4 m x 3.75 m at the rate of 200 ml/m^2 respectively. Metham sodium + Super-hydro-grow polymer was applied in a 2.4 m x 3.75 m plot at the rate of 200 ml/m^2 and 3969 g per 2.4 m x3.75 m plot (4355.56 kg/ha). Metham sodium +Orange peel treatment was applied in a 2.4 m x 3.75 m at the rate of 200 ml/m^2 and Orange peel rate of 3969 g per 2.4 m x3.75 m plot (4355.56 kg/ha). Brassica tissue + Orange peel treatment were applied at a rate of 3969 g per 2.4 m x3.75 m plot (4355.56 kg/ha) and Orange peel at a rate of 3969 g per 2.4 m x3.75 m plot (4355.56 kg/ha) respectively. Pre-determined concentrations of all the amendments were applied per furrow and the crop of interest planted.

Comment [MI2]: It might be interesting to see the composition of the amendments used.

2.4 Data collection and analysis

Soil samples were collected using zig zag method, where a sterile dry glass Petri dish was used per sample. 50 g of wet soil was added from respective plots to an already labelled dry glass Petri dish and total weight taken. The sample was oven dried at 122 °C for 24 hours. Moisture content was calculated by subtracting total dry soil plus Petri dish weight from total wet soil plus Petri dish weight. Calculated moisture content was recorded in all samples across the two seasons for analysis. The oven-dried soil samples were extracted in a 1:10 ratio (w/v) with 0.1 M HCl. A SpectrAA- 40 atomic absorption spectrometer, PSC-56 programmable sample changer, Epson LX-80printer, and copper, zinc, iron and Manganese hollow cathode lamps from Agilent Technologies, Inc. were used in the procedure. The collected data was subjected to a three-way ANOVA to determine if the main effects and interaction effect between three independent variables (i.e. Season, time and treatment) on a continuous dependent variables (i.e. moisture content, Micronutrients) were significant using Genstat Edition 15. Whenever F tests were significant, means were separated using Fisher's protected least significant difference test at 5 % level.

3. RESULTS AND DISCUSSION

3.1 Influence of organic and inorganic amendments on soil moisture content

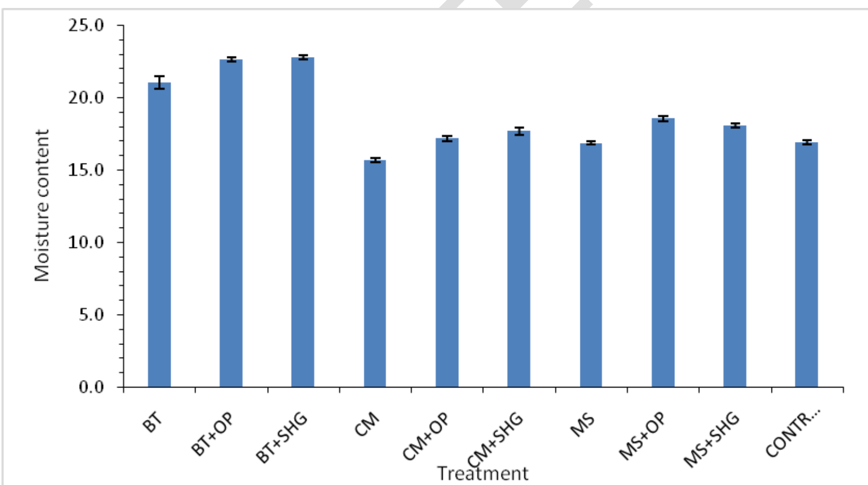

Figure 2. Effect of organic and inorganic amendments on moisture content (Season 1)

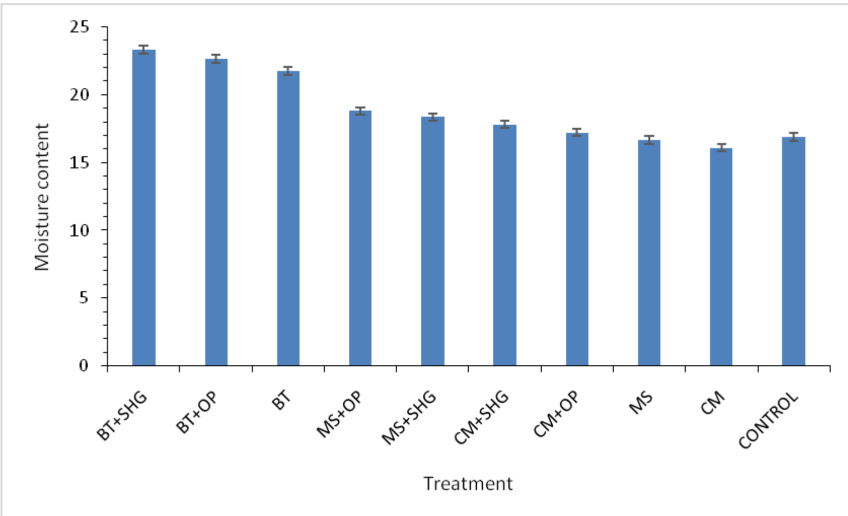

Figure 3. Effect of organic and inorganic amendments on moisture content (Season 2)

There was significant difference (p≤0.05) in the soil amendments effect on soil moisture content in all the treatment except for MS and CM in both season 1 and season 2 in the field. The two soil amendments that yielded the least amount of soil moisture content were inorganic in nature. The results concurs with findings of Kago *et al.* [23] that revealed that Metham sodium reduces moisture content in the soils amended with the treatment. It is therefore recommended that Metham sodium should not be applied in very dry soil to avoid reduction of the moisture content.

Comment [MI3]: This statement should be in the Conclusion not Resuls and Discussion.

A combination of both organic and inorganic soil amendments like BT+OP, BT+ SHG had the highest moisture content. In order to maintain water in the soil for longer period after an irrigation event, some additional materials such as organic matter, soil conditioners are added into the soil. Soil conditioners both natural and synthetic; contribute significantly to provide a reservoir of soil water to plant on demand in the upper layers of the soil where the root systems normally develop. Their use has been tested to increase the water holding capacity of sandy soils [24] and Nazarli *et al.* [25] and Dutra *et al.* [26] demonstrated the close relation between soil moisture and crop yield. BT +SHG soil amendments was superior in maintaining soil moisture content in both season 1 and 2 in the field. BT treatment is organic manures that not only improve the soil physical, chemical and biological properties [27] but also improves the moisture holding capacity of soil, thus resulting in enhanced crop productivity along with better quality of crop produce [28]. In order to increase crop water use efficiency (WUE) in arid and semi arid areas, new innovations for saving irrigation water need to be established. In connection with this, the rise of scientific management revolution of irrigation has been suggested as an option for reducing water use and at the same time increase the water use efficiency of crop production in arid and semi-arid regions [29]. Availability of water is the most important factor limiting development of agriculture in arid and semi-arid regions [15]. Simba [30] argues that water is the main input in horticulture which affects both quality and quantity of yield directly. In the control experiment the soil moisture content increased in season two due to the presence of agrosober gel even without any amendment. This is in agreement with a study done by Silberbush [24] that found a gel-forming hydrophilic polymer increases the water holding capacity of sandy soils. Gehring and Lewis [31] reported moisture stress of plants decreased by incorporation of a hydrogel into the medium. Wallace and Wallace [32] reported increased tomato, cotton, and lettuce emergence rates in various soils with different combinations of polyacylamide (PAM). Water held in the expanded hydrogel is intended as a soil reservoir for maximizing the efficiency of plant water uptake [33].

[1]

[1] *BT-Brassicae Tissue, BT+OP -Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM-Chalim^{TM}, CM+OP- Chalim^{TM}+ Orange peel, CM+SHG- Chalim^{TM}+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP-Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer*

3.2 Influence of organic and inorganic amendments on micronutrients

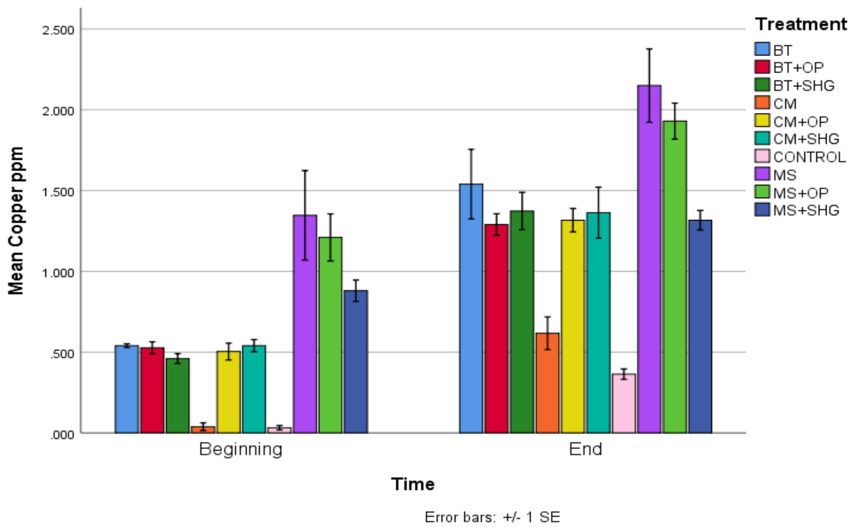

Figure 4. Effect of organic and inorganic amendments on amount of copper in the soil

There was significant difference ($p \leq 0.05$) in the soil amendments effect on the amount of copper in all the treatments in the beginning and end of the experiement. In our current study, MS and BT+OP soil amendments revealed to be superior in increment of copper. The least increament ofcopper was recorded in the control experiment followed by CM and MS+SHG. In general, the amount of Cu in the plots fertilized organically was higher than for soils fertilized with inorganic products. Katyal and Sharma [34] found that, DTPA-extractable Cu was significantly correlated with soil organic matter content, as it was in the present study. The higher levels of Cu in the plots fertilized organically may be due to the formation of organo–Cu complexes [35]. The organic matter in the amendments has Cu binding properties. As a result, soils amended with organic amendments may have larger Cu binding capacity than unamended soils [36]. The availability of micronutrients is particularly sensitive to changes in soil environment. The factors that affect the contents of such micronutrients are organic matter, soil pH, lime content, sand, silt, and clay contents revealed from different research experiments [37]. Singh *et al.* [38] showed that NPK fertilization significantly influenced the increase, and organic fertilization to reduce the mobility of Cu and Mn.

[2]

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[2] *BT-Brassicae Tissue, BT+OP -Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM-Chalim™, CM+OP- Chalim™+ Orange peel, CM+SHG- Chalim™+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP-Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer*

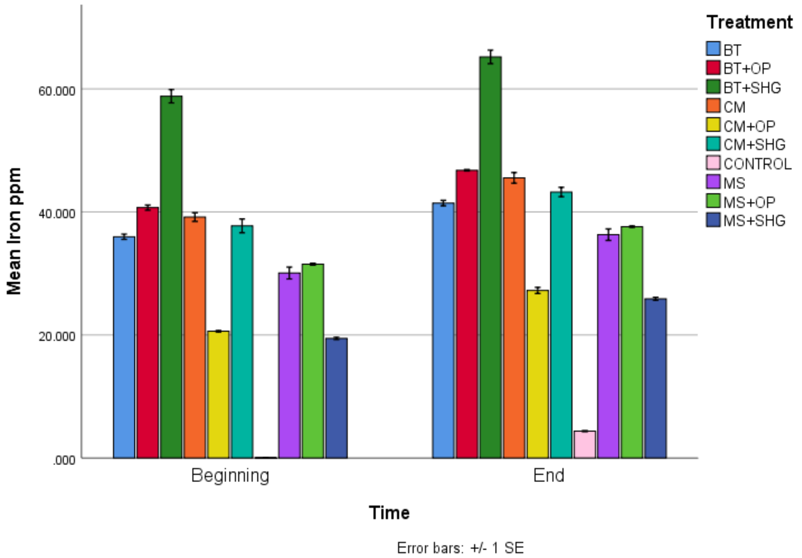

Figure 5. Effect of organic and inorganic amendments on amount of iron in the soil

There was significant difference (p≤0.05) in the soil amendments effect on the amount of iron in all the treatments in the beginning and end of the experiement. The study established a higher iron amount in CM compared to BT soil ammendment. This agrees with a study done by Kago *et al.* [23] that established plots treated with Chalim^{TM} treatments recorded higher amounts of iron compared to the other treatments with BT1908 that recorded lower values. Iron is an essential plant nutrient that is required in small quantity for growth and development of plant. It is harmful when present in large quantity in soils. Iron is taken up by plants at a much higher rate than is the case with other trace elements [39].

Addition of organic soil amendments in this current study increased the amount of iron in the soil which disagrees with a study done by Oluwadare *et al.* [40] that found organic fertilizers significantly reduced Fe status below control but in the second year while increasing application rates of fertiplus and compost plus significantly reduced Fe status below the control. The decrease in soil Fe status in the second year was due to the increased soil pH from residual effect of the applied manures. Sahrawat [39], reported that the availability of Fe tend to decrease as pH increases. The responsible mechanism for this, might be the formation of low solubility compounds as also reported by Akporhonor and Agbaire [41]. Through both years, the resulting Fe status was still in the high rating (Fe > 10) as reported by Kparmwang *et al.* [42]. Deficiency of microelements in plants results firstly in decreasing plant resistance to harmful environmental factors, followed by declining yields and their quality [6].

[3]

[3] *BT-Brassicae Tissue, BT+OP -Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM-Chalim^{TM}, CM+OP- Chalim^{TM}+ Orange peel, CM+SHG- Chalim^{TM}+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP-Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer*

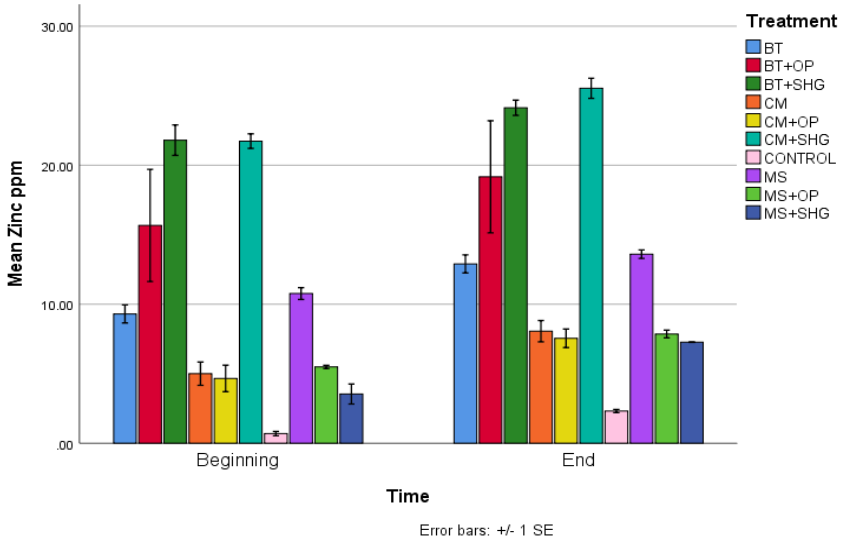

Figure 6. Effect of organic and inorganic amendments on amount of Zinc in the soil

There was significant difference (p≤0.05) in the soil amendments effect on the amount of Zinc in all the treatments in the beginning and end of the experiement. According to Kago *et al.* [23], the amount of zinc in the soil on plots treated with the various treatments was higher than the initial values although the treatments did not differ significantly (P>0.05) from each other.

The study established the amount of Zinc in BT+OP was higher than CM alone. This concurs with a study by Maqueda *et al.* (2011)) that Zn amount in the plots fertilized with organically was higher than in inorganic plots, and the differences were always significant. A study by Oluwadare *et al.* [40] in the first cropping season, effect of fertiplus on soil Zn status was not significant, while those of compost plus and NPK brought significant increase in Zn status. In the second year, application of each treatment increased Zn status significantly, with the highest increment of 0.75 mg/kg being gotten from 10 t/ha of fertiplus application. This agrees with findings of Kparmwang *et al*. [43]; Mustapha and Singh [44], who reported that organic matter serves as the main reservoir of plant available zinc in Nigeria savanna soils in view of the small amount of clay content. The second year increment in Zn status from the organo-minerals application was due to the residual effect of the organic fertilizers. Liming significantly decreased the content of available forms of Mn and Zn in soil. Singh *et al.* [38] showed that NPK fertilization significantly influenced the increase, and organic fertilization to reduce the mobility of Cu and Mn. In the case of zinc observed in this study, liming resulted in a decrease of its content, while FYM applications significantly increased the content of this element in soil in relation to the control object. Similar relationships were observed by Sienkiewicz *et al.* [45]. [4]

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[4] *BT-Brassicae Tissue, BT+OP -Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM-Chalim^{TM}, CM+OP- Chalim^{TM}+ Orange peel, CM+SHG- Chalim^{TM}+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP-Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer*

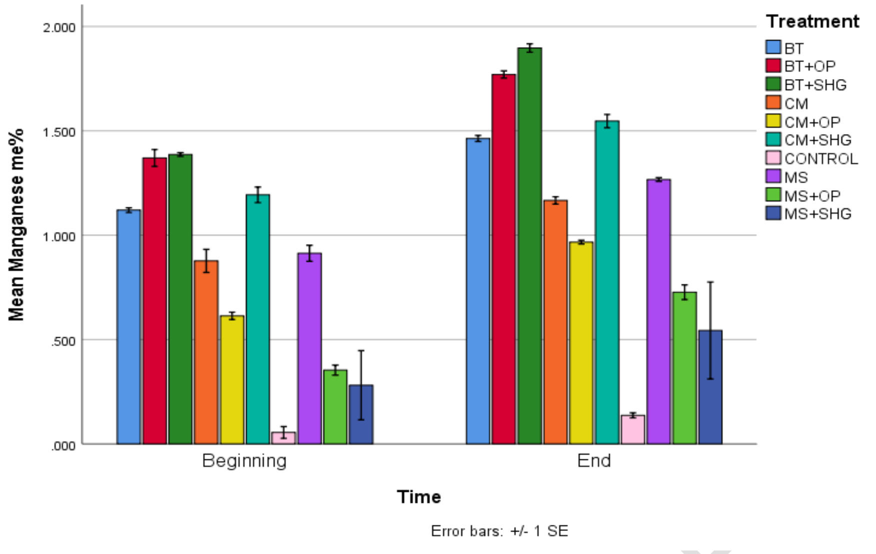

Figure 7. Effect of organic and inorganic amendments on amount of Manganese in the soil

There was significant difference (p≤0.05) in the soil amendments effect on the amount of Manganese in all the treatments in the beginning and end of the experiement. This disagrrees with a study done by Oluwadare *et al.* [40] found that there were no significant differences between the mean total micronutrient contents of the plots before the start of the experiment and after 5 years of organic or inorganic fertilization.

Oluwadare *et al.* [40] revealed that none of the treatments produced significant effect on soil Mn in the first year, except 10 t/ha fertiplus application which significantly reduced Mn status below the control. Just like the observed trend for Fe in the second year , soil Mn was also significantly decreased by the residual effects of both organic fertilizers. The increase in the soil micronutrient status in the second year was as a result of residual effect of fertiplus and compost plus.

[5]

COMPETING INTERESTS

The authors have no competing interests to declare

4. CONCLUSION

Through this study, it was realized significant difference (p≤0.05) in the soil amendments effect on soil moisture content in all the treatment except for MS and CM in both season 1 and season 2 in the field. BT +SHG soil amendment was superior in maintaining soil moisture content in both season 1 and 2 in the field. A combination of both organic and inorganic soil amendments like BT+OP, BT+ SHG had the highest moisture content. Metham sodium reduces moisture content in the soils amended with the treatment. It is therefore recommended that Metham sodium should not be applied in very dry soil to avoid reduction of the moisture content. The study established that polymers have the ability to absorb, hold and release water whenever required by the plants

[5] *BT-Brassicae Tissue, BT+OP -Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM-Chalim™, CM+OP- Chalim™+ Orange peel, CM+SHG- Chalim™+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP-Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer*

thus we recommend farmers to use it in arid and semi arid area to retain water in soils. In our current study, MS and BT+OP soil amendments revealed to be superior in increment of copper. The least increament ofcopper was recorded in the control experiment followed by CM and MS+SHG. There was significant difference (p≤0.05) in the soil amendments effect on Micronutrients in all the treatments in the beginning and end of the experiement.

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