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Influence of Organic and Inorganic Soil Amendments on Soil pH and Macronutrients

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Authors' contributions

This work was carried out in collaboration among all authors. Author EKK did the sample collection, carried out experiment, analyzed data and prepared the first draft. Author ZMK provided the working experimental design for treatment and guided (supervised) the activity. Authors JMM and POO provided general guidance on the experiment and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The popularity of using the Inorganic and organic soil amendments is based on the current status of soil degradation that led to decline in fertility of soils, resulting to low yields. The objective of current study was to evalute different organic and inorganic soil amendments and their effects on soil pH and macronutrients. The study was laid out as randomized complete block design (RCBD) in split plot arrangement for two seasons. The treatments were Chalim™, Super-hydro-grow polymer + Metham sodium, Metham sodium, Metham sodium & Orange peel, Super-hydro-grow polymer, Brassica tissues, Chalim™ + Super-hydro-grow polymer, Brassica tissue + Orange peel, Metham sodium + Super-hydro-grow polymer and Control (no amendments). Soils were sampled from each experimental site, dried and taken to laboratories for determination of soil chemical properties both at initial and at the end of the experiment. The soil physicochemical attributes assessed included: Soil pH, nitrogen, carbon, phosphorus, potassium and calcium. There was an significant increase ($P \leq 0.05$) in the concentration and availability of soil physicochemical characteristics after treatment which is an indicator of improved soil structure. Brassicae tissue

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+super hydrogrow polymer (BT+SHG) amendment was the best as it resulted to highest concentration and availability of the mineral elements in the soil recording total nitrogen of 0.50 %, organic carbon 5.47 %, phosphorus 19.7 mg/kg, and potassium 1.37 %. The control exhibited the least impact on all the soil chemical properties. We recommend BT+SHG amendment to farmers to promote soil fertility which will consequently produce better yield.

Keywords: Chelate; nitrogen; phosphorus; organic carbon; potassium; soil pH; soil amendment; macronutrient.

1. INTRODUCTION

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 [1]. Adding a soil amendment, also known as soil conditioning; helps improve plant growth and health [2]. 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 [2]. Some organic amendments suppress certain soil-borne plant pathogens and/or the diseases they cause, and several have been effectively used for control of plant parasitic nematodes. Organic amendments, however, can also increase diseases for instance, animal manures have been reported to increase the incidence of common scab disease of potato and most recommendations suggest avoiding the use of fresh animal manures on soils prepared for potato production [3]. This implies the need to exercise caution when using organic amendments in soils since not all sources have beneficial attributes to the soil structure and fertility. Also, the organic matter affects different physicochemical characteristics of the soil [4]. Therefore, to avoid losses of the organic matter that is quite beneficial to agricultural productivity, organic amendments act as positive remedies to carbon content, nitrogen content and soil structure stability among others [3]. The inorganic soil amendments are used to supplement the organic matter that is already present in the soil [5]. 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 [5]. Polymers are widely used for many applications in agriculture: to combat viruses and other crop pathogens, and functionalized polymers are employed to increase the efficiency of pesticides and herbicides, allowing the application of lower doses and thus indirectly protecting the environment [6]. Some polymers acting as cementing material hold the primary soil particles together [7]. Super absorbent polymers help in reducing the consumption of irrigation water and the death rate of plants, improving fertilizer retention in the soil and increasing plant growth rate [7]. According to Shabaan et al. [8] 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. This middle zone of Kiambu county form part of the semi-arid areas and the soils are easily eroded. The soils are sandy or clay thus can only support drought resistant crops such as soya beans and sunflower as well as ranching. In the current study, the objective was to evaluate the influence of organic and inorganic soil amendments on soil pH and macronutrients. This current study will help to improve water holding capacity and soil nutrient reserves as while as soil pH.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was carried out in Kenyattta University situated in Kiambu County about 20 km from Nairobi city along Nairobi-Thika road. The county enjoys a warm climate with temperatures ranging between 12°C and 18.7°C. The rainfall aggregate for the county is 1000 mm each year. Its geographical coordinates are 1° 10' 0" South, 36° 50' 0" East. Low fertility soils are mainly found in the middle zone and the eastern part of the county which form part of the semi-arid areas. The soils in the midland zone are dissected and are easily eroded. The soils are sandy or clay and can support drought resistant crops such as soya beans and sunflower as well as ranching. The elevation of the main campus is 1720 meters above sea level (ASL) [9].

2.2 Eperimental Design and Treatments

The experiment was carried out between July, 2017- September, 2017 and between November, 2017- January, 2018 and was replicated three times for the two seasons. The experiment was laid out in randomized complete block design (RCBD) in split plot arrangement in the field. A plot measuring 66 m by 28.5 m was marked, cleared, ploughed, harrowed and demarcated into 150 plots each measuring 2.4 m x3.75 m. 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™, Super-hydro-grow polymer and Metham sodium, Metham sodium, Metham sodium +Orange peel, Super-hydro-grow polymer, Control, Brassica tissue, Chalim™ + 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 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.

2.4 Data Collection and Analysis

Soil samples were collected using zig zag method [10], 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. Intial and final soil pH was determined by use of pH meter. Total nitrogen was determined by Kjeldahl method and Ca and K hollow cathode lamps from Agilent Technologies, Inc. were used in the procedure. The analysis was done at the beginning and at the end of the study. Soil total posphorus was determined by calorimetric analyzer method as described by Moonrungsee et al. [11]. 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. pH, total nitrogen) 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 Total Nitrogen

Significant differences ($p \le 0.05$) were observed on organic and inorganic amendments on the soil nitrogen at the beginning and particularly the end of the experiments in two seasons. At the beginning of the experiment soil total nitrogen was relatively low as shown in Fig. 1. In season 1 the initial soil nitrogen was between 0.05% and 0.10%. Upon addition of the soil amendments, there was an increase in the amount of nitrogen concentration in the soil at the end of the season. At the end of season 1, Chalim[TM] (CM) treatment led to the highest increase of N (recording 0.40 %). The Brassica Tissue (BT) and control had the least accumulation or increase of nitrogen at the end of season 1 with each having 0.13 %. At the end of season 2, Brassica Tissue + Super-hydro-grow polymer (BT+SHG) elicited the highest total nitrogen increase of 0.50 %. The CM treatment resulted in a decrease of N recorded and had the lowest concentration (0.13 %) in at the end of season 2 (Fig. 1). Irrespective of all amendments, end of 2[nd] season depicted higher N in the soil except for CM. The CM being an inorganic amendment could have decreased the amount of nitrogen concentration in the soils due to high levels inorganic N mineralization. Also, the inorganic methods may not be sustainable in maintaining the soils organic matter for prolonged period compared to organic methods [12].

The findings of this study agrees with those of Goyal et al. [13] who reported an increase in the total soil nitrogen after application of both the organic and inorganic amendments in the cropping field. Both organic and inorganic amendments contributes to an increased supply of key mineral nutrients like nitrogen hence making them available in the soils as reported by Loper et al. [14]. This study results also agree with findings of Wuest and Gollany [15] who reported that the use of plant-based soil amendments resulted in an increase in total nitrogen in the soil. Therefore, it is clear that application of organic improved the soil microbial activites through promoting ability of mineral nitrogen release hence improving the chemical composition.

3.2 Influence of Organic and Inorganic Amendments on Soil pH

Significant differences ($P \leq 0.05$) were revealed in the pH changes across the soil amendments used in season 2 but no differences observed during season 1. The initial soil pH range for season 1 was 6.55-6.70 which is slightly acidic and did not show great differences at the end of the season (Fig. 2). This could imply that the soil amendment used during this time had low pH levels hence did not contribute to significant changes of pH at the end of the experiment. For season 2 initial pH was between 4.37- 4.56 which increased upon the application amendment with the MS treatment recording the highest pH of 6.70 (Fig. 2). This shows that the organic and the inorganic soil amendments acted as pH lowering (neutralizing) substances from acidity to alkalinity. The huge pH changes of almost two units may imply that the soil in question had very low buffer capacity, making the amendments to be quite effective.

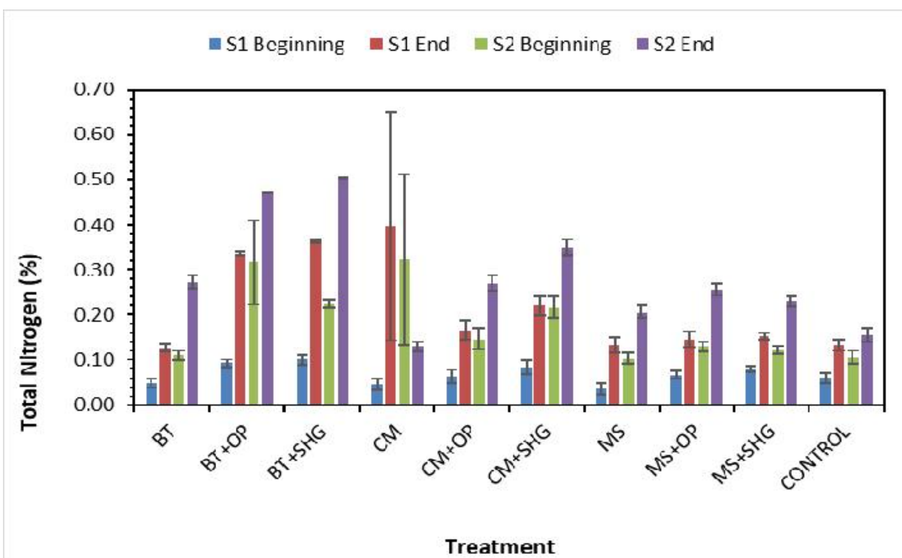

Fig. 1. Influence of organic and inorganic soil amendments on total soil nitrogen

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

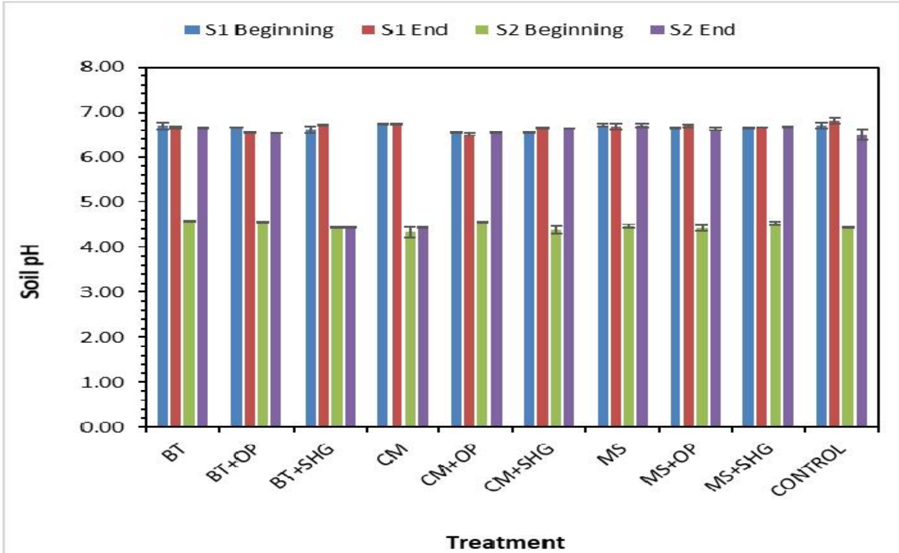

Fig. 2. Influence of organic and inorganic soil amendments on soil pH

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

The findings of this study conform with those of Álvarez et al. [16] who reported an increase in soil pH after application of the organic amendments. The increase of the soil pH to 6.70 considered conducive since the values remains close to neutrality which implies that most of the crops can thrive well in such near-neutral levels. Also it is an implication that, the application of amendment led to improvement of the soils condition by providing a more conducive environment for the microorganisms that facilitates modification of the soil structure. According to Abujabhah et al. [17] the soils pH sensitivity to organic matter is due to the buffering capacity, which could be the case for this study. The results of this study also confirm that application of organic and inorganic amendments can be used in reduction of the soil acidity hence improving the levels of fertility [18]. Another study carried out by Peltre et al. [19] confirmed that application of organic and inorganic amendments have significant contribution to the reduction soil pH and consequent increase in nutrient transfer.

3.3 Effects of Organic and Inorganic Soil Amendments on Total Organic Carbon

Total organic carbon was positively influenced by the soil amendments during season 1 and season 2 as demonstrated in Fig. 3. During season 1, the total organic carbon was relatively lower; with ranges between 0.62% and 0.72%. At the end of the season there was a three folds increase in organic carbon content in the soil. The BT+SHG was superior in increasing carbon in the soil (3.28%), while the control had the lowest, with the value of 1.43% (Fig. 3). In season 2, a similar trend was observed, with the control having the lowest increase of carbon content (2.01%) and BT+SHG having the highest accumulation of 5.47%. The accumulation of organic carbon content with application of both organic and inorganic amendments could be due to high organic content. Soil organic carbon, the major component of soil organic matter, is extremely important in all soil processes. Soil organic carbon is one of the most important constituents of the soil due to its capacity to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization [20].

As previously reported by Doan et al. [21], use of organic amendments increase the soil carbon content and also the soil structure, which strongly agrees with the findings of this study. The results of this study also agrees with the findings of Barthod et al. [22] who reported that use of organic amendment can lead to up to 45 $g.kg^{-1}$ of the original levels of soil carbon, consequently leading to soil structure stability. The findings of this current study also agree with those of Aban [23], who reported an increase in the total organic carbon upon application of organic and inorganic amendments.

3.4 Effects of Organic and Inorganic Soil Amendments on the Soil Phosphorous

Different soil amendments exhibited significant differences on the availability of phosphorus in the soil for the two seasons. The amendments contributed to an increase in soil phosphorus with BT+SHG having the highest amount of 18.8 mg/Kg during the 1st season which was an increment form the initial of 9.7 mg/Kg as shown in Fig. 4. A similar trend was observed in season 2 where BT+SHG was still the best with phosphorus content increment (19.7 mg/Kg). This was closely followed by the BT with 18.6 mg/Kg and BT+OP recording 18.3 mg/Kg. The control and the MS+OP had the least increment of organic carbon in the 2nd season (Fig. 4). The increase of the phosphorus concentration in the soil could be due to enhanced phosphatase activity by the organics amendments hence increasing mineralization of the available P to the soil [24].

Phosphorus is an essential mineral element for promoting growth and productivity of crops. According to Suthar [25] when soils are treated with organic and inorganic amendments there is a high recovery of nutrients, phosphorus being one of them. This agrees with the findings of this study that application of soil amendments led to an increment in soil phosphorus. This could be due to the fact that most of the soils have fixed forms of phosphorus hence making it difficult for plants to access it. Therefore, this could be an implication that amendments are effective in improving the soil structure and chemical properties. According to Albiach et al. [26], high activity of soil microorganisms promotes releases of the phosphorus in the soil which partially conforms with the findings of this study. Larney and Angers [27] reported that a combination of the organic and inorganic amendments promoted oxidation and degradation of the organic matter into the soil hence making the availability of phosphorus high which can be a good explanation of the results observed this current study.

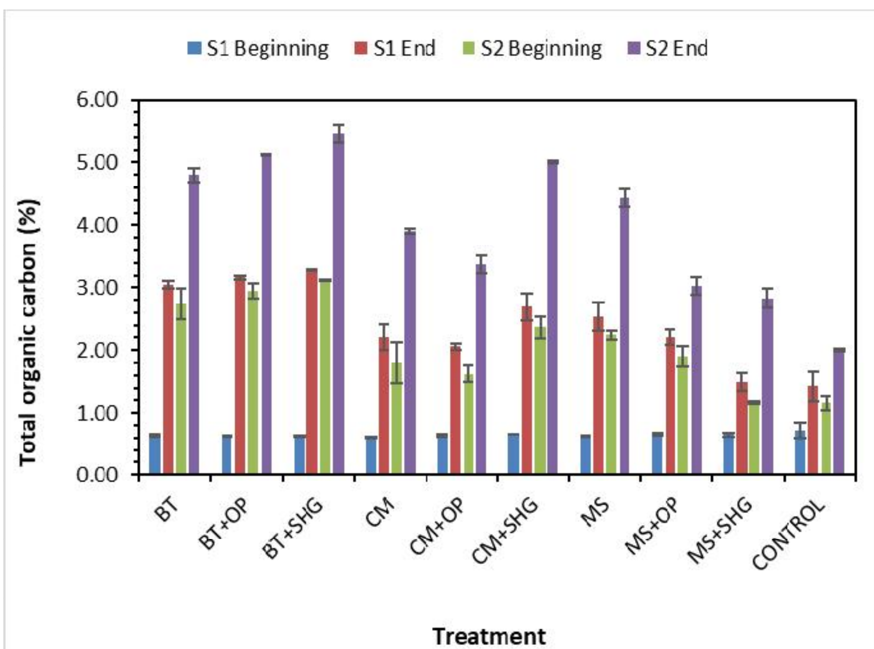

Fig. 3. Effects of organic and inorganic soil amendments on soil total organic carbon

BT-Brassicae Tissue, BT+OP -Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM- ChalimTM, CM+OP- ChalimTM+ Orange peel, CM+SHG- ChalimTM+ Super-hydro-grow polymer,MS-Metham sodium, Ms+OP- Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer

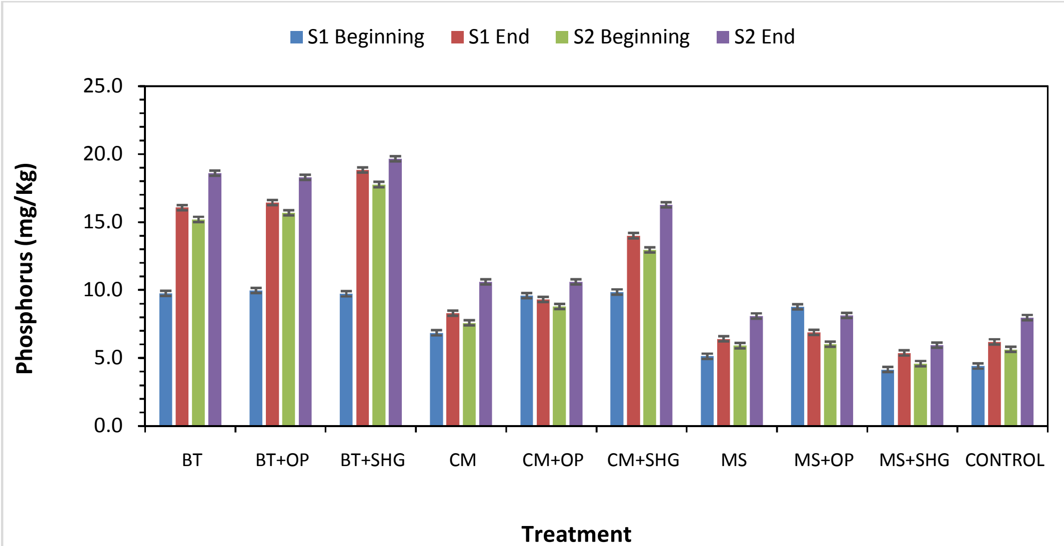

Fig. 4. Effects of organic and inorganic soil amendments on soil phosphorous

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

3.5 Potassium as Affected by Soil Organic and Inorganic Amendments

The study revealed significant variabilities in initial and final potassium levels upon application of soil amendments. In season 1, BT+SHG amendment was the best in increasing the amount of potassium in the soil with 0.80 m.e % at the beginning to 1.15 m.e % at the end of the experiment. On the other hand, the control had the least increment of potassium levels with initial being 0.02 % and the final being 0.18 % Fig. 5. In season two, a similar trend was observed in season with BT+SHG being the best in potassium accumulation having a value of 1.37 me % being closely followed by MS+OP with 1.29 m.e %. The control recorded the lowest increment in potassium concentration of 0.20 % which is quite low in promoting soil composition. In general, the soil had low K values.

The results of the current experiment agree with those of Goyal et al. [28] who reported an increase in soil potassium concentration upon application of combined organic and inorganic amendments. The activities of the microorganism are in the organic amendments account for increased availability of the K in the soil due to enzymatic activities. The study also agrees with that of Steiner [29] which reported higher levels of K in the soil solutions than when applied alone. Thus, a higher availability of potassium is enhanced by beneficial effects of manure that led to reduction potassium fixations. In another study carried out by Akrawi [30], it showed that there was a significant increase in available soil phosphorus upon addition of both organic and inorganic amendments.

3.6 Effects of Organic and Inorganic Amendments on the Exchangeable Soil Calcium

Calcium levels in the soil also varied significantly in the two seasons in response to organic and amendments treatments. BT+SHG was the best in increasing calcium concentration in soil in both season 1 and season 2. In the 1st season, it recorded a threefold increase from 4.3 % at initial stages to 12.2 % at the end of the seasons, while in season 2, it increased from 10.9 to 16.3 % (Fig. 6). As evidenced in other parameters, the control had the least calcium concentration with relatively very low values of 0.2 % and 1.4 % in season 1 and season 2 respectively as shown in Fig. 6. This shows that the amendments had a positive influence hence the low levels in the plots without any treatments.

The increase in the calcium concentration in the soil upon addition of amendments could be as a result of availability of the exchangeable calcium in the amendments. Calcium is bonding agent in the aggregation of soil particles, wherein it helps to bind organic and inorganic substances. It is important in the development of a good soil structure, therefore, an increase implies high quality of soil. Also calcium acts as a nutrient filler, to maintain balance among nutrients and occupy space which otherwise would be taken up by acid elements. This study agrees with that of García-Sánchez et al. [31] who reported an increase in calcium levels when soils were treated with inorganic and organic treatments.

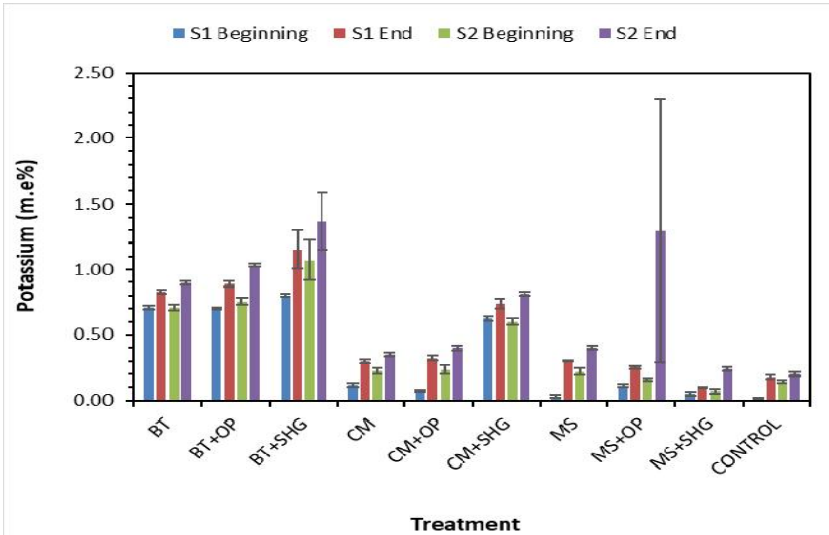

Fig. 5. Effects of organic and inorganic soil amendments on soil potassium

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

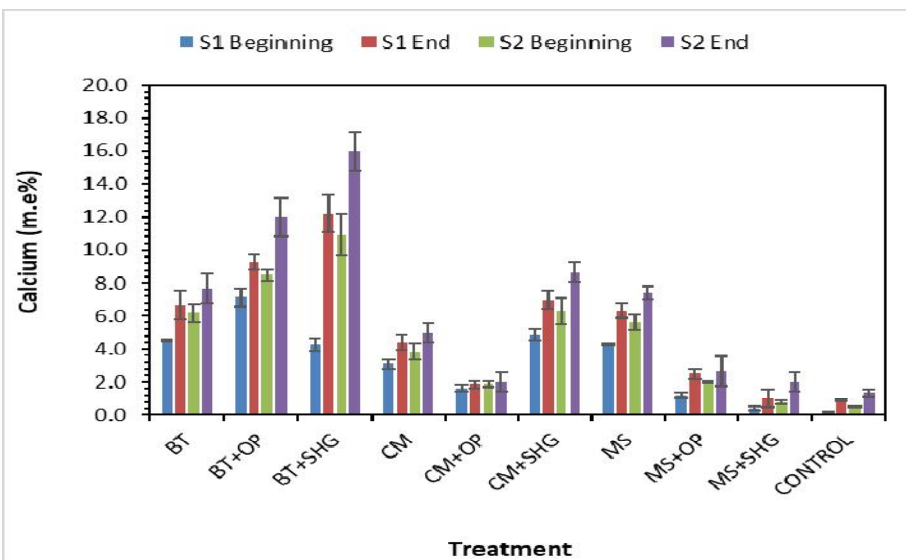

Fig. 6. Effects of organic and inorganic soil amendments on soil calcium

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

4. CONCLUSION

Organic and inorganic soil amendment resulted in positive influence of the soil chemical characteristics including total nitrogen, soil pH, total organic carbon, phosphorus, potassium and calcium. BT+SHG amendment was the best in increasing the concentration of the soil chemical properties. This implied that the combination of both the organic and inorganic amendment in one treatment has the highest potential of improving soil structure. Therefore, we recommend farmers to use this kind of amendment to promote soil fertility which will consequently produce better yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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