Original Research Article

INFLUENCE OF ORGANIC AND INORGANIC SOIL AMENDMENTS ON SOIL pH AND MACRONUTRIENTS

ABSTRACT

Inorganic and organic soil amendments are used to imporve the strcuture, aggregate stability and soil health. The popularity of using the amendment is based on the current status of soil degradation that led to decline in fertility of soils, resulting to low yields. Therefore, the objective of current study was to evalute diffrent organic and inorganic soil amendments and their effects of 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^{TM}, Super-hydro-grow polymer + Metham sodium, Metham sodium, Metham sodium & Orange peel, Super-hydro-grow polymer, Brassica tissues, Chalim^{TM} + Super-hydro-grow polymer, Brassica tissue + Orange peel, Metham sodium + Super-hydro-grow polymer and Control (where amendments were omitted). 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. The results revealed significant differences ($P \le 0.05$) on the effects of amendments on the evaluated soil properties. There was an increase in the concentration and availability of soil physicochemical characteristics which is an indicator of improved soil structure. Brassicae tissue +super hydrogrow polymer (BT+SHG) amendment was the most superior 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 19.7pmm, and potassium 1.37 %. The treatments without amendments (control) exhibited the least impact on all the soil chemical properties. It was concluded that BT+SHG was most superior amendment and can be used in the soils to improve the chemical properties due to its potential to release and enhance availability of mineral nutrients.

Key words: chelate, nitrogen, phosphorus, organic carbon, potassium, soil pH

1. INTRODUCTION

Soil amendments are added to the soil to improve the structure and increase the organic contents 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 implicated in increasing the incidence of common scab disease of potato and most recommendations suggest avoiding the use of fresh animal manures on soils destined 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 health. Also, the organic matter is related different physicochemical characteristics in 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 [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, [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. In the current study, the objective was to evaluate the influence of organic and inorganic soil amendments on soil pH and macronutrients

2. MATERIAL 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. 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 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™, 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 3969g per 2.4m x3.75m 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 3969g per 2.4m x3.75m 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 3.75m at the rate of 200 ml/m^2 i.e. (1800ml in 9 L of water). This was the positive control. This was done in each of the 6 furrows where each furrow received 1800ml of the mixture (10.800 L), approximately 2000L/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 2.4m x3.75m plot (250 kg/ha). Pre-determined concentrations of all the amendment 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. Fifty grams 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 analsyis was done at the beginning and at the end of the study. Soil total posphorus was determined by calorimetric anlyzer 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 ($p \leq 0.05$) 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 figure 1. In season one 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 one, 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 two (Figure 1). Irrespective of all amendments, end of second 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].

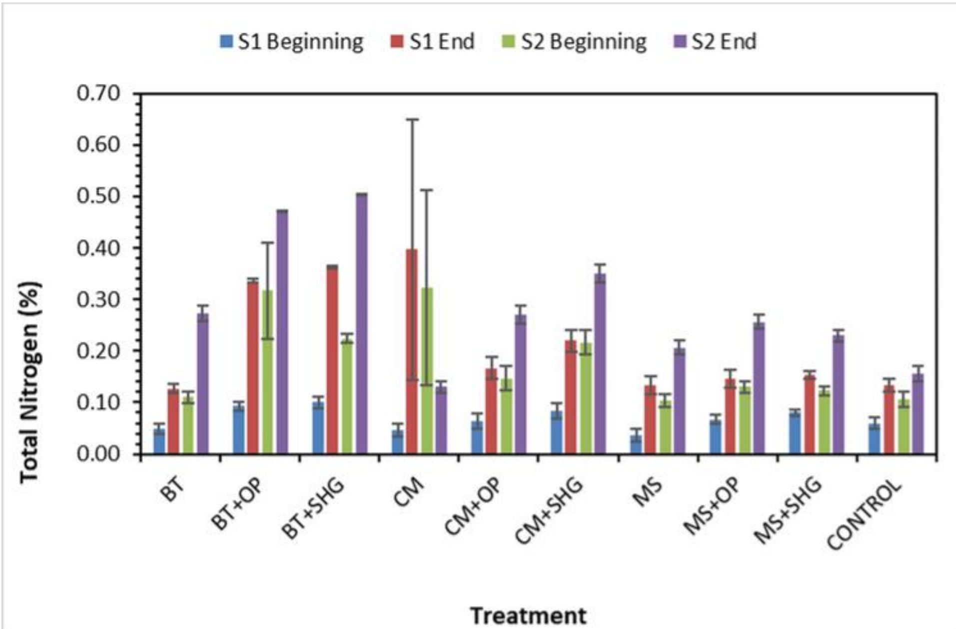

Figure 1: Influence of organic and inorganic soil amendments on total soil nitrogen BT-Brassicae Tissue, BT+OP -Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM- Chalim^{TM}, CM+OP- Chalim^{TM}+ Orange peel, CM+SHG- Chalim^{TM}+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP- Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer

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 use of plant-based soil amendments resulted in an increase in total nitrogen in the soil. Therefore, it is clear that application of both organic and inorganic 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 ($P≤0.05$) were revealed in the pH changes across the soil amendments used in season two 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 (Figure 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. (Figure 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.

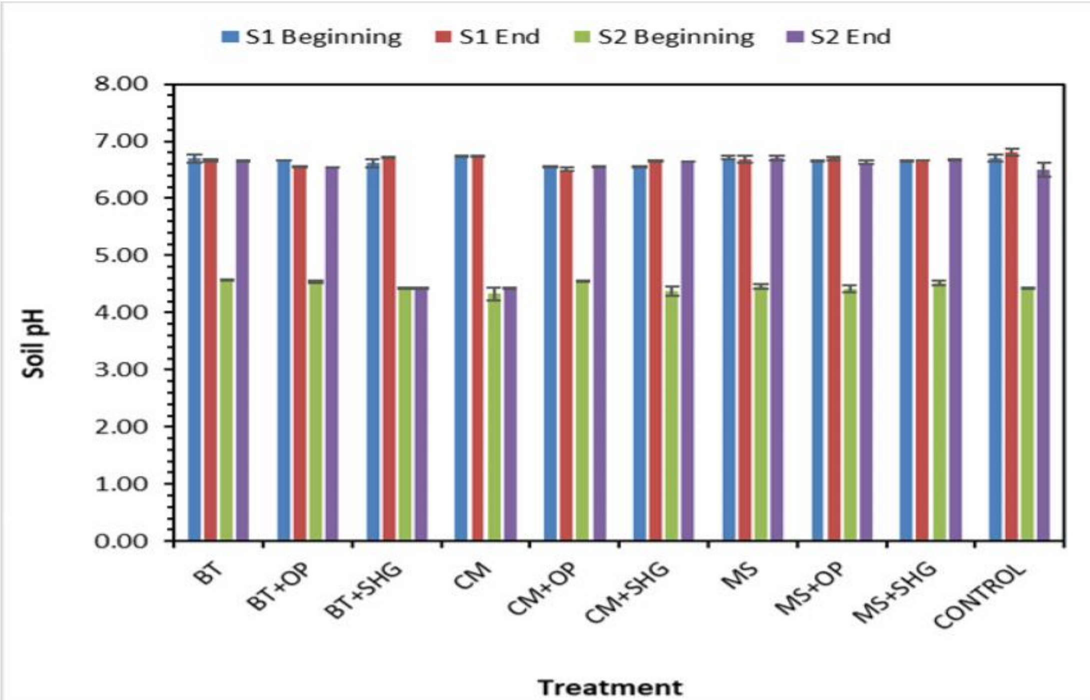

Figure 2: Influence of organic and inorganic soil amendments on soil pH: BT-Brassicae Tissue, BT+OP Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM- Chalim^{TM}, CM+OP- Chalim^{TM}+ Orange peel, CM+SHG- Chalim^{TM}+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP- Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer

The findings of this study conform with those 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 the application of amendment led to improvement of the soils condition by providing a more conducive environment for the microorganisms that facilitate 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 two as demonstrated in figure 3. During season one, 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% (Figure 3). In season two, 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].

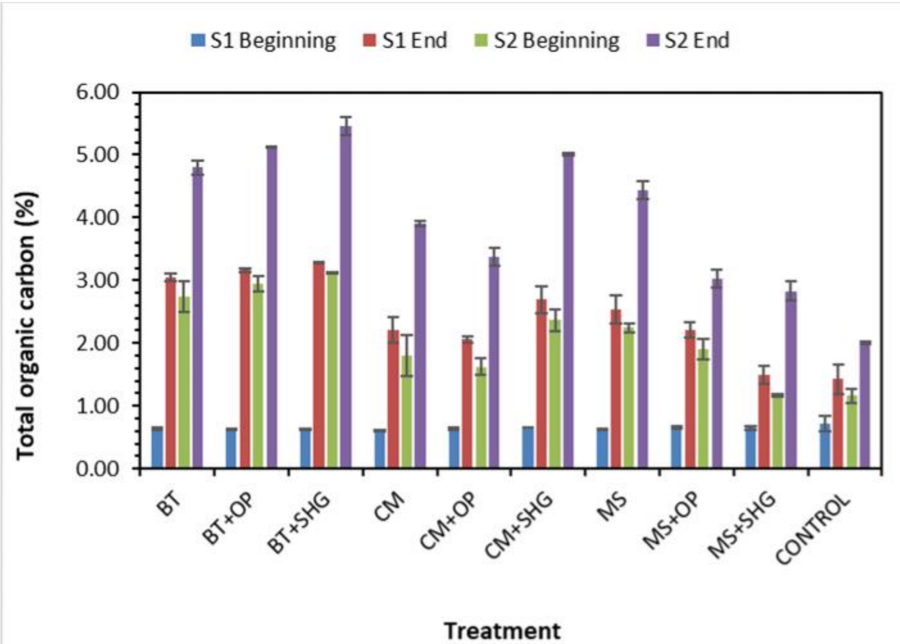

Figure 3: Effects of organic and inorganic soil amendments on soil total organic carbon: BT-Brassicae Tissue, BT+OP Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM- Chalim™, CM+OP- Chalim™+ Orange peel, CM+SHG- Chalim™+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP- Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer

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 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 ppm during the first season which was an increment form the initial of 9.7ppm as shown in figure 4. A similar trend was observed in season two where BT+SHG was still superior with phosphorus content increment (19.7 ppm). This was closely followed by the BT with 18.6 ppm and BT+OP recording 18.3 ppm. The control and the MS+OP had the least increment of organic carbon in the two season (Figure 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].

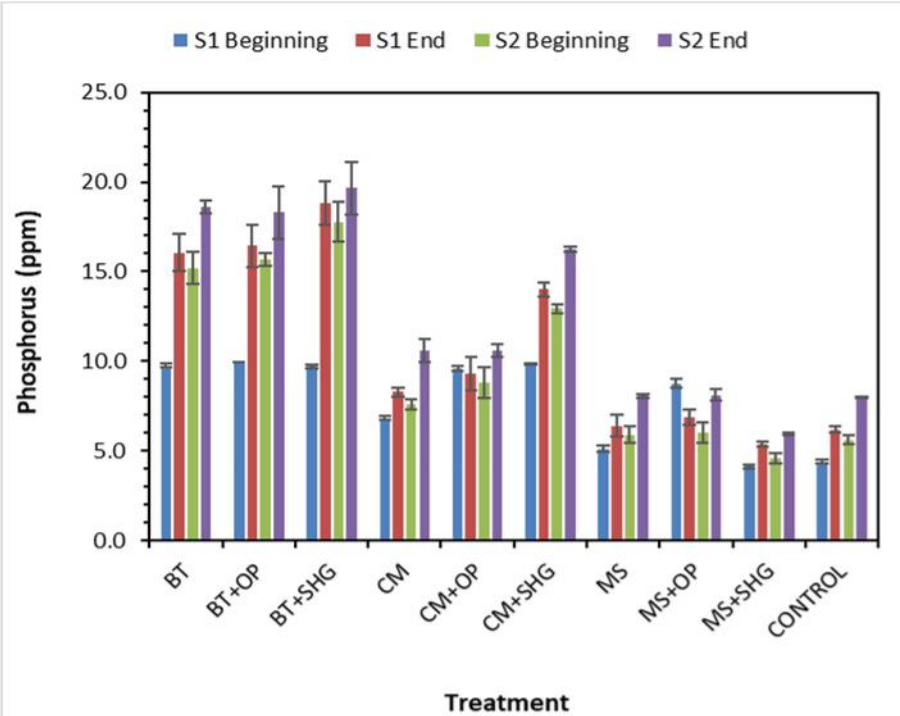

Figure 4: Effects of organic and inorganic soil amendments on soil phosphorous; BT- Brassicae Tissue, BT+OP Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM- Chalim^{TM}, CM+OP- Chalim^{TM}+ Orange peel, CM+SHG- Chalim^{TM}+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP- Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer

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, P being one of them. This agrees with the findings of this study that application of soil amendments led to an increment phosphorus in the soil. 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.

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 one, BT+SHG amendment was superior in increasing the amount of potassium in the soil with 0.80 me % at the beginning to 1.15 me % 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% figure 5. In season two, a similar trend was observed in season with BT+SHG being superior in potassium accumulation having a value of 1.37 me % being closely followed by MS+OP with 1.29 me %. 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.

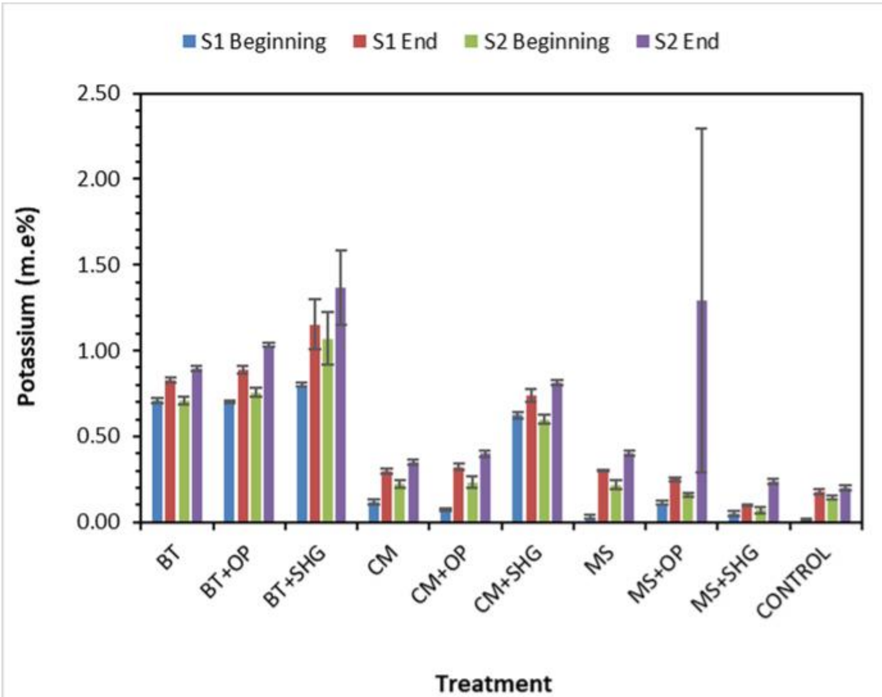

Figure 5: Effects of organic and inorganic soil amendments on soil potassium; BT- Brassicae Tissue, BT+OP Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM- Chalim™, CM+OP- Chalim™+ Orange peel, CM+SHG- Chalim™+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP- Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer

The 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 first season, it recorded a threefold increase from 4.3% at initial stages to 12.2 % at the end of the seasons, while in season two, it increased from 10.9 to 16.3 % (Figure 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 figure 6. This shows that the amendments had a positive influence hence the low levels in the plots without any treatments.

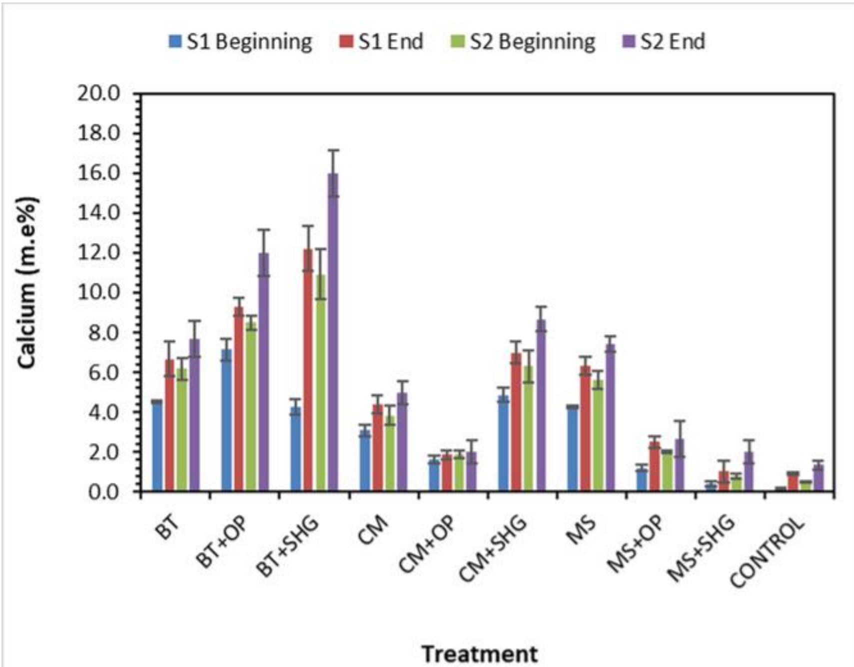

Figure 6: Effects of organic and inorganic soil amendments on soil calcium; BT- Brassicae Tissue, BT+OP Brassica tissue+Orange peel, BT+SHG- Brassicae Tissue+ Super-hydro-grow polymer, CM- Chalim™, CM+OP- Chalim™+ Orange peel, CM+SHG- Chalim™+ Super-hydro-grow polymer,MS- Metham sodium, Ms+OP- Metham sodium+ Orange peel, MS+SHG- Metham sodium+ Super-hydro-grow polymer

The 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.

4.0 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 superior 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 framers to use this kind of amendment to promote soil fertility and in consequently increase yields.

COMPETING INTERESTS

Authors have declared that no competing interests exist

REFERENCES

1. Saranraj P, Stella D. Vermicomposting and its importance in improvement of soil nutrients and agricultural crops. *Novus Natural Science Research*, 2012; *1*(1), 14-23.

2. Lazarovits G, Tenuta M, Conn KL. Organic amendments as a disease control strategy for soilborne diseases of high-value agricultural crops. *Australasian Plant Pathology*, 2001; *30*(2), 111-117.

3. Bailey KL, Lazarovits G. Suppressing soil-borne diseases with residue management and organic amendments. *Soil and tillage research*, 2003; *72*(2), 169-180.

4. Chenu C, Le Bissonnais Y, Arrouays D. Organic matter influence on clay wettability and soil aggregate stability. *Soil Science Society of America Journal*, 2000; *64*(4), 1479-1486.

5. Rehman MZU, Rizwan M, Ghafoor A, Naeem A, Ali S, Sabir M, Qayyum MF. Effect of inorganic amendments for in situ stabilization of cadmium in contaminated soils and its phyto-availability to wheat and rice under rotation. *Environmental Science and Pollution Research*, 2015; *22*(21), 16897-16906.

6. Manjunatha SB, Biradar DP, Aladakatti YR. Nanotechnology and its applications in agriculture: A review. *Journal of Farm Science*, 2016; 29(1), 1-13.

7. Kay BD. Soil structure and organic carbon: a review. In *Soil processes and the carbon cycle* (pp. 169-197). CRC Press; 2018.

8. Shaaban M, Van Zwieten L, Bashir S, Younas A, Núñez-Delgado A, Chhajro MA, Hu RA. Concise review of biochar application to agricultural soils to improve soil conditions and fight pollution. *Journal of environmental management*, 2018; *228*, 429-440.

9. Jaetzold R, Schmidt H, Hornetz B, Shisanya C. Central Kenya. Agroecological Zones and subzones. Ministry of Agriculture, Farm Management Hand book of Kenya Vol. II. Natural conditions and Farm Management information 2nd Edition Part B, Central Province: 2006; 434-438p

10. Bhatti AU, Fayyaz1 M, Bakksh A. Soil Sampling Strategies for Precision Soil Testing. Pak. J. Soil Sci., 1995; 10:1-4

11. Moonrungsee N, Pencharee S, Jakmunee J. Colorimetric analyzer based on mobile phone camera for determination of available phosphorus in soil. *Talanta*, 2015; *136*, 204-209

12. Diacono M, Montemurro F. Long-term effects of organic amendments on soil fertility. In *Sustainable Agriculture Volume* 2011*; 2* (pp. 761-786). Springer, Dordrecht.

13. Goyal S, Chander K, Mundra MC, Kapoor KK. Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. *Biology and Fertility of Soils*, 1999; *29*(2), 196-200.

14. Loper S, Shober AL, Wiese C, Denny, GC, Stanley CD, Gilman EF. Organic soil amendment and tillage affect soil quality and plant performance in simulated residential landscapes. *HortScience*, 2010; *45*(10), 1522-1528.

15. Wuest SB, Gollany HT. Soil organic carbon and nitrogen after application of nine organic amendments. *Soil Science Society of America Journal*, 2013; *77*(1), 237-245.

16. Álvarez-Martín A, Hilton SL, Bending GD, Rodríguez-Cruz MS, Sánchez-Martín, M. J. Changes in activity and structure of the soil microbial community after application of azoxystrobin or pirimicarb and an organic amendment to an agricultural soil. *Applied soil ecology*, 2016; *106*, 47-57.

17. Abujabhah IS, Bound SA, Doyle R, Bowman JP. Effects of biochar and compost amendments on soil physico-chemical properties and the total community within a temperate agricultural soil. *Applied Soil Ecology*, 2016; *98*, 243-253.

18. Rahman F, Rahman MM, Rahman GM, Saleque MA, Hossain AS, Miah MG. Effect of organic and inorganic fertilizers and rice straw on carbon sequestration and soil fertility under a rice–rice cropping pattern. *Carbon Management*, 2016; *7*(1-2), 41-53.

19. Peltre C, Gregorich EG, Bruun S, Jensen LS, Magid J. Repeated application of organic waste affects soil organic matter composition: evidence from thermal analysis, FTIR-PAS, amino sugars and lignin biomarkers. *Soil Biology and Biochemistry*, 2017; *104*, 117-127.

20. Fontaine S, Mariotti A, Abbadie L. The priming effect of organic matter: a question of microbial competition?. *Soil Biology and Biochemistry*, 2003; *35*(6), 837-843.

21. Doan TT, Henry-des-Tureaux T, Rumpel C, Janeau JL, Jouquet P. Impact of compost, vermicompost and biochar on soil fertility, maize yield and soil erosion in Northern Vietnam: a three year mesocosm experiment. *Science of the Total Environment*, 2015; *514*, 147-154.

22. Barthod J, Rumpel C, Dignac MF. Composting with additives to improve organic amendments. A review. *Agronomy for sustainable development*, 2018; *38*(2), 17.

23. Aban JL. Soil Quality and Soil Organic Carbon Stocks (SOCS) of Soils Affected by Conventional and Organic-Fertilizer-Amended Farming Systems. 2015.

24. Richardson AE. Simpson RJ. Soil microorganisms mediating phosphorus availability update on microbial phosphorus. *Plant physiology*, 2011; *156*(3), 989-996.

25. Suthar S. Impact of vermicompost and composted farmyard manure on growth and yield of garlic (*Allium stivum* L.) field crop. *International Journal of Plant Production*, 2012; *3*(1), 27-38.

26. Albiach R, Canet R, Pomares F, Ingelmo F. Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bioresource technology*, 2000; *75*(1), 43-48.

27. Larney FJ, Angers D A. The role of organic amendments in soil reclamation: a review. *Canadian Journal of Soil Science*, 2012; *92*(1), 19-38

28. Goyal S, Chander K, Mundra MC, Kapoor KK. Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. *Biology and Fertility of Soils*, 1999; *29*(2), 196-200.

29. Steiner C, Teixeira WG, Lehmann J, Nehls T, de Macêdo JLV, Blum WE, Zech, W. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and soil*, 2007; *291*(1-2), 275-290.

30. Akrawi HSY. Effect of organic and inorganic fertilizer on availability of potassium in soil and yield of chickpea (Cicer arietinum L.). Iraqi Journal of Agricultural Sciences, 2018; 49(2).

31. García-Sánchez M, Šípková A, Száková J, Kaplan L, Ochecová P, Tlustoš P. Applications of organic and inorganic amendments induce changes in the mobility of mercury and macro-and micronutrients of soils. *The Scientific World Journal*; 2014.