Effects of organic amendments and NPK on soil chemical properties in Kano Plains, Kisumu, Kenya

Abstract

Agricultural lands in many parts of the world are threatened by soil degradation as indicated by their declining soil organic matter, loss of fertility, and low productivity. Organic amendments have the potential to alter the soil's chemical characteristics as they can change the biotic and abiotic properties of the soil. The effect of six organic amendments applied each at 8.33 t/ha on the soil chemical characteristics, compared to NPK fertilizer applied at 250 kg/ha was investigated. The experiment was conducted at the Great Lakes University of Kisumu's agricultural farm at Kibos in Kenya. To determine the effect of the organic amendments on the soil's chemical characteristics, soil samples were collected once before the application of the organic amendments (initial) and thereafter at the end of every season. The results showed that the organic amendments affected the soil chemical properties. Compared to NPK fertilizer treatment, soil treated with organic amendments showed pH ranges (5.76 to 6.04) above that resulting from NPK application (5.59). All composts increased soil organic carbon (133, 298, 192 and 185%) for Boom Max, Ecoplanting, Evergrow, and Filter mud respectively compared to the initial levels. The total nitrogen was also increased to levels between 0.14 to 0.18 cmol/kg as compared to that of NPK treated plot (0.15cmol/kg), indicating close similarity. Available phosphorus increased by the application of Boom Max, Evergrow, Filter mud and Market waste slurry by 24, 44,39 and 1022% over the NPK effect, while exchangeable potassium increased by 9.5 and 24% by Evergrow and Market waste slurry over the effect of NPK. Exchangeable calcium increased by all the applied organics but only Evergrow and Market waste slurry exceeded that produced by NPK by 7.0 and 18.6% respectively. Likewise, all amendments increased soil exchangeable magnesium except dung slurry, but only market waste slurry exceeded that produced by NPK by 28%. All the amendments increased the cation exchange capacity compared to the original soil CEC but only Evergrow, Filter mud and Market waste slurry raised the soil's CEC beyond that affected by NPK by 5.5, 10 and 40% respectively.

Keywords: soil health, organic amendments, NPK, exchangeable.

Introduction

The Cowpea (*VignaunguiculataL.Walp*)

Cowpea (*VignaunguiculataL. walp*) is a tropical annual herbaceous legume that belongs to the family Papilionaceae (Fabaceae), order Leguminosae and genus Vigna (Maletsema*et al.*, 2020). Cowpea is utilized in eastern and southern Africa both as grain and leaf (Keller*et al.*, 2005). It is well adapted to drought-prone areas, has a short maturity period and a variety of uses which makes it an attractive alternative crop for farmers in arid and semi-arid regions where rainfall is low and unreliable (Hallsnslebenet *al.* 2009).

Cowpea grain contains 23% protein and 57% carbohydrate, while the leaves contain 27-34% protein (Belane and Dakora, 2009). The nutritional value of cowpea is a rich source of protein, a good source of vitamins A, B, and C,and also contains a high rate of minerals (Baloch, 1994), such as phosphorous, calcium and iron (Anonymous, 2007). The protein in cowpeas is rich in amino acids viz lycine and tryptophan as compared to cereal grains (Deepa Joshi *et Al.,* 2016).

Due to its high adaptability to different environments, low input costs and high protein content, it is highly suited for cultivation in countries with protein deficiency. Among legumes, cowpea is the most cultivated and most consumed especially in Asia and tropical Africa (Danis *et al.* 2013). In addition to their importance in human food, cowpeas are also useful for soil fertilization through symbiotic nitrogen fixation and is useful in providing nitrogen, especially in areas where poor soil fertility is a problem (Diouf Diaga, 2011; Sheahan, 2012). It therefore provides soil nitrogen to cereal crops, particularly maize, millet, and sorghum when grown in rotation or mixed in areas of poor soil. (Nkaa*et al.,* 2014).

Even though cowpea is commonly grown in Kenya due to the rise in demand, consumption and market value, many production challenges have led to reduced productivity and production. Cowpea yield remains one of the lowest despite this dramatic increase in cowpea production among the food legumes in sub-Saharan Africa; remaining at 450kg^{-}ha in 2006 -2008 which is only 50% of the estimated yields in all other developing regions. Its yields are very low due to several constraints including poor soil (inadequate N, P, K, Ca, Mg, S, and Organic Matter), use of low yielding variety of seeds as planting material, plant nutrients imbalances, low soil moisture content (Nkaa*et al.*, 2014; Ecocrop., 2009).

A positive response of cowpeas to both organic and inorganic fertilizers have been reported by several authors. It has also been established that cowpeas do not require a high rate of nitrogen fertilization because of their ability to fix their own (Nkaa*et al.*, 2014). Use of organic fertilizer is popular for reducing the environmental impacts of wastes while increasing organic matter and nitrogen in soils. Fertilizer is any material of natural or artificial origin (other than liming material) that is applied to soil or plant tissues to provide one or additional plant nutrients essential to the expansion of plants, maturity of time, size of plant parts and biochemical content of plants and seed capabilities (Subedi *et al.*, 2022).

To maintain consistency in high biomass productivity, soil nutrient management is essential, and fertilization is the only way to supply soil nutrients within a short period (Han, *et al.*, 2016). Adegbidi*et al.*, (2003) reported that fertilization costs accounted for 20-30% of the total production costs in biomass production. Soil fertility is the most important constraint limiting crop yield among resource-poor farmers in the developing world (Ansa *et al.*, 2019). Fertilizers play an important role in increasing crop production (Stewart *et al.*, 2012). It has also been proved that organic fertilizers improve crop qualities especially those of vegetables and fruits (Larson *et al.*, 2000; Xu *et al.*, 2000). The use of chemical fertilizers and organic manure or fertilizer has both positive and negative effects on plant growth and the soil. Chemical fertilizers are relatively expensive, have high nutrient content and are rapidly taken up by plants (Han*et al.*, 2016). However, the use of excess fertilizer can result in several problems, such as nutrient loss, surface and groundwater contamination, soil acidification and basification, reduction in useful microbial communities and increased sensitivity to harmful insects (Chen *et al.*, 2006). Organic manure has several shortcomings, including low nutrient content, slow decomposition and different nutrient compositions depending on its organic materials, compared to chemical fertilizers.

Organic farming is defined as a production system that avoids or largely excludes the use of synthetically compounded fertilizers (Panda, 2010), and depends mainly on organic recycling of biological and industrial waste nutrient energy. The system is based on the perception that tomorrow's ecology is more important than today's economy. It aims to utilize local resources present in abundance with enormous potential for application to maintain long-term fertility of the soil. According to Pei *et al*., (2021), organic fertilizer is an alternative to chemical fertilizer with no loss in crop yield and quality, and its use will avoid all forms of pollution, and reduce fossil fuel energy in agricultural practices while providing foodstuffs and maintaining rural environment and preserving non-agricultural ecological habitats.

Organic manures are known to produce optimal conditions in the soil for high yields and good quality crops. Organic fertilizer application can improve the physical and chemical properties of soil such as structure, water retention, nutrients and cation exchange capacity and promote biological soil properties (Tejada *et al.,* 2003; Chang *et al.,* 2010 and; Qiu *et al.,* 2021).

Organic fertilizers are an important source of nutrients that contribute to achieving a circular economy, reducing the environmental impacts of waste and increasing organic matter and nitrogen content in soils while reducing external inputs in agro-eco-systems. Xia *et al.* (2017) reported an overall increase in crop production of 4.4% when mature partially substituted synthetic fertilizers. According to Hati, (2007) organic fertilizers have positive effects in maintaining soil properties such as;apH increases in acid soil, increasing water holding capacity, hydraulic conductivity and infiltration rate, and reducing soil bulk density (Ndiaye et al., 2007).

Tropical soils are poor in organic matter and major plant nutrients. Soil organic matter is the key to soil fertility and productivity since it induces life into the inert mixture (Sand, silt, and clay) and promotes biological activities. It is also known that optimal growth of plants is not only caused by the total amount of nutrients in the soil but also influenced by physical-chemical-biological properties of the soil such as: soil texture, organic matter, cation exchange capacity, pH, electrical conductivity, and activity of the soil microbes (Bell and Dell, 2008). It is similarly known that excessive chemical fertilizer application adversely affect soil physical and chemical properties, resulting in soil hardiness and acidification, which eventually lead to decline in soil organic matter and fertility (Gu *et al.* 2015; LV *et al.* 2020). The purpose of this experiment was to find out the contribution of organic fertilizers as a tool for the regeneration of degraded soils,secure more income, and creation of more employment locally.

Material and methods

3.1 Study Area

This investigation was conducted during the 2022 and 2023 cropping seasons at the field farm of the Great Lakes University of Kisumu (GLUK) agricultural farm. The site is located in Kibos within Miwani West Sublocation of Miwani ward of Muhoroni Subcounty of Kisumu County Kenya.

The area falls within the Lake Victoria lowlands and flood plains called the Kano plains, a vast lowland flat area experiencing a subhumid climate. The plain is mainly an extending locustrine deposits characterized by montmorillonite clay with blackish colour. The surface soil texture is clay with poor drainage. The chemical properties of the soil before the experiment are presented in the Table 2.

The general aspects of the climatic conditions of the study area were done using climatological statistics of one full meteorological station, Kenya Sugar Research Institute in Kibos, Kisumu County. Climatic conditions of the study area are such that the mean maximum temperature ranges from about 27^0C to about 32^0C and a mean minimum temperature range from about 14^0C to 18^0C.The relative humidity (0900Hrs) East African Standard time ranges from 56% to 75%with the peak being May and July months of the year.

The average annual rainfall ranges from 1100mm to about 1600mm and the climate is described as semi-humid and fairly warm with an altitude of about 1150m above sea level.

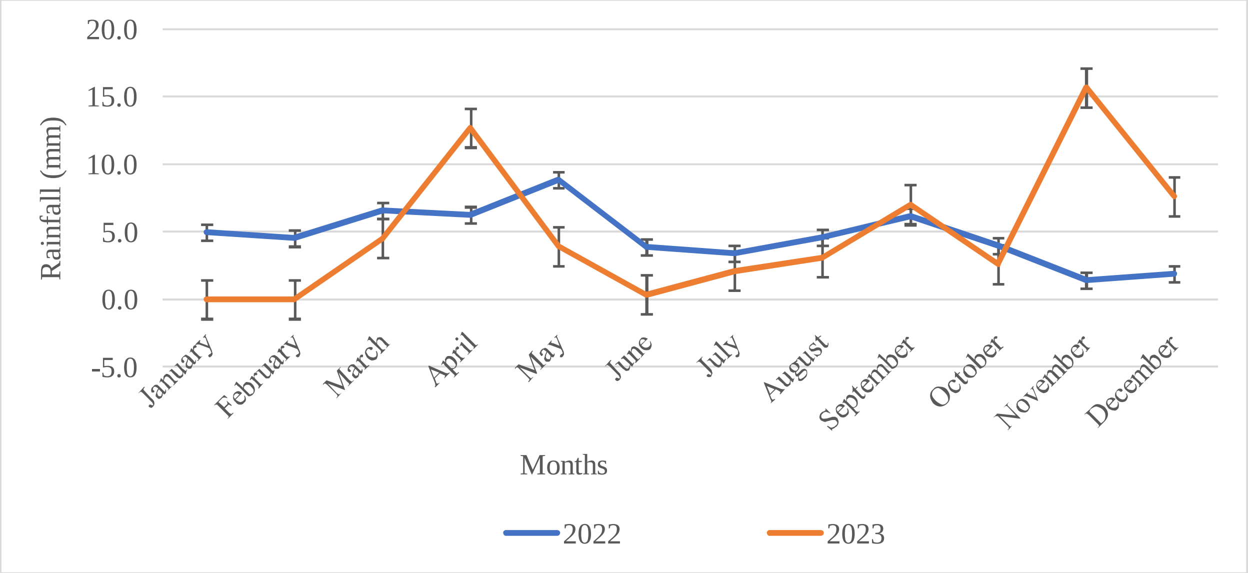

Figure 1. The average rainfall distribution in the study area during the study period

The experiment was set up in a randomized complete block design (RCBD) with three (3) replications. There were five treatments in the long rains and seven treatments in the short rains including control (T_1). The following were the treatments.

Table 1. Treatment Details

Long Rains 2022 Treatments	Short Rains 2022 treatments
T_1 = Eve @8.33t/ha per season	T_1= Ds @ 8.33 t/ha per Season
T_2 = Eco @8.33t/ha per season	T_6=MWS@8.33kg/ha per season
T_3 = Bx @8.33t/ha per season	
T_4 =Fm @ 8.33t/ha per season	
T_5 =NPK @ 250 kg/ha per season	

Where; Eve =Evergrow, Eco= Ecoplanting, NPK = Nitrogen, Phosphorus and Potassium, DS = Dung slurry, Fm = Filter Mud, Bx = Boomax, and MWS = Waste Slurry Market

Each organic fertilizer was soil applied in furrows and soil incorporated before planting. Planting was done on the same day as incorporation. Thelayout, therefore, represented soil amendments with different types of organic fertilizers.

Soil Chemical Analysis

Soil samples were collected at a depth of 0.20cm from each plot and its replicate prior to planting for physical and chemical properties analysis., pH, organic carbon and total nitrogen available. Phosphorus and exchangeable potassium, calcium, magnesium and aluminium were measured and C:N ratio calculated

Analysis of the chemical properties of the soils were done before and after the experimentation. Similarly, the nutrient status of each organic fertilizer for the experiment was determined through a soil laboratory analysis.

4.0 Results and Discussions

Evaluation of the chemical constituents of the organic fertilizers in use.

The present investigation was undertaken to examine how different organic amendments affect the chemical soil properties, the concentration of extractable soil micronutrients and their different chemical pools in black cotton soil to understand the build-up of the nutrients in soil upon application of different soil organic amendments /manure.

Properties of the different organic amendments and NPK used in the experiment.

Table 2. **Presents the chemical composition of the six organic amendments and NPK**

Parameter	**Fertilizers**							
	EcoP	**EverG**	**BM**	**FM**	**DS**	**MWS**	**NPK (Basal)**	**NPK (Top dress)**
pH (1:2.5)	7.94	7.95	9.29	6.30	6.87	7.21	9.10	9.80
Nitrogen (%)	2.45	1.87	0.86	0.20	0.02	0.01	15.4	11.20
Phosphorous (ppm)	580.0	1660.0	9.34	23.70	35.0	62.7	5.87	5.87
Potassium (cmol/kg)	12.72	9.10	16.74	0.70	8.69	11.67	5.22	4.24
Carbon (%)	42.89	27.73	15.80	0.70	16.6	20.8	0.00	0.00
Calcium (cmol/kg)	0.57	0.14	39.20	2.40	4.97	20.33	3.32	2.14

Magnesium (cmol/kg)	1.35	1.61	4.68	-	0.55	19.92	0.55	0.71
Ca:Mg ratio	0.70	0.15	13.98	-	0.41	0.05	6.04	3.01
Iron (ppm)	10.80	2.10	196	-	21.10	20.9	645.0	916.0
Sodium (cmol/kg)	0.84	6.09	2.10	-	792	72.3	331.0	2250.0
CEC (cmol/kg)	15.48	15.94	62.72	-	37.44	32.45	32.45	37.44
Aluminium (ppm)	35.60	10.30	416	1.3	<0.10	0.10	166.6	920.0
C: N ratio	17.51	14.83	18.37	3.5	830	2080.0	0.00	0.00

Key: BM= Boom Max, EcoP= Ecoplanting, EverG=Evergrow, DS=Dung slurry, FM=Filter mud, MWS=Market waste slurry

The initial chemical properties of the experimental soil

Table 3:Thechemical properties of experimental soil

PLOTS	pH	%N	P(ppm)	K (Cmol/Kg	%C	Ca (Cmol/Kg	Mg (Cmol/Kg	Al(ppm)	Na (Cmol/Kg	CEC (Cmol/Kg	Ca:Mg Ratio	Fe(ppm)
BM plot	5.9	0.2	18.0	0.7	1.1	1.4	1.0	1.9	0.89	19.57	5.29	227.5
EcoPplot	4.5	0.1	20.2	0.7	0.6	1.6	0.7	1.1	0.89	19.57	5.29	227.5
EverG plot	6.0	0.2	21.2	0.8	1.0	2.3	1.4	1.7	0.89	19.57	5.29	227.5
DS plot	6.24	0.17	12.1	0.4	2.7	11.07	3.9	742.7	1.06	16.43	4.8	232.17
FM plot	5.8	0.1	22.1	0.6	0.9	2	1.0	2.1	0.89	19.57	5.29	227.5
MWS plot	6.49	0.25	271.48	0.6	3.9	17.1	4.27	473	0.71	22.72	5.78	222.83

Key: BM= Boom Max, EcoP= Ecoplanting, EverG=Evergrow, DS=Dung slurry, FM=Filter mud, MWS=Market waste slurry

Table 2. presents the chemical composition of the six organic amendments and NPK used during the experimentation. The pH of the amendments and NPK fertilizers varied and could be grouped such that the Filter mud, Dung slurry and Market waste slurry pH were in the range of 6.1 to 7.3 or slightly acidic to neutral, while that of Ecoplanting and Evergrow were moderately alkaline (pH 7.4 to 8.4). The inorganic fertilizer (NPK,both top dress and basal) and Boom max had pH above of 8.5and were strongly alkaline according to the Oregon State University Extension Service Soil Test Interpretation Guide. The normal crop response would range from very good for slightly acidic to neutral pH, moderately good for moderately alkaline and moderately goodto poor for strongly alkaline pH levels.BeyondpH 9.0 are described as strongly alkaline and may not allow crops to grow since at that level, micronutrients become a limiting factor (Jensen 2020)

The Nitrogen of various amendments and NPK ranged from 15.4% for basal NPK, 11.20% for top dress NPK, 2.45% for Eco planting 1.87% for Evergrow, 0.86 for Boom max, 0.20% for Filter mud and 0.02% and 0.01% for Dung slurry and Market waste slurry respectively.

The optimal range of Nitrogen (N) biological property range for use in vegetable production is 0.5% to 6.0% (Cooper band 2002; DEP 2010; Marriot and Zagorsk 2015; Rynk 1992; University of Massachusetts 2016). The prescription rules out Dung slurry and Market waste slurry to have adequate levels of starter nitrogen such that using them as the only source of nitrogen would be a challenge since the release of mineral nitrogen may not provide enough available nitrogen to match the time the crops need it. This is further supported by the fact that incubation of compost in the soil and short-term field studies demonstrated that compost is usually equivalent to -10+10% of the compost’s total Nitrogen (Sulivan *et al,* 2018)

The total carbon concentration ranged from less than 1.0% to about 43% the highest concentration was recorded with Ecoplanting at 42.89%, followed by Evergrowat 27.73%, Boom max at 15.80%, Market waste slurry at 20.80%, Dung slurry at 16.60% and Filter mud at 0.70%. The variation in Nitrogen concentration among organics influenced the C: N ratio to range as from as low as 3.5:1 with Filter mud to as high as over 2000:1 with Market waste slurry. This was closely followed by that of Dung slurry at 830:1. C: N ratio is an important property of organic amendments and organic materials that are easily decomposed in the soils have low organic C: N ratio (or contain a high proportion of nitrogen) and are valuable as fertilizers (Salin and Virch 2023). Most composts are considered finished when the C: N ratios are in the range of 12:1 to 22:1 with the ideal C: N ratio for compost ingredients being around 30:1 (Compost Management A and L Canada 2022). More thanC:Nof 30:1, nitrogen will be in excess and therefore escape as ammonia gas and therefore not enough nitrogen for optimal growth of microbial population and least impact on the plant growth. Applying composts with C: N of greater than 40:1 will result in ‘tying up Nitrogen” since as micro-organisms breakdown carbonaceous material, they will require more nitrogen than what is found in the compost and will “rob” the surrounding soil (and the crop) off nitrogen to decompose the compost (Reid *et al.* 2022) and may result into nitrogen deficiency in the crop. A C: N ratio in the teens or low twenties usually means there is more Nitrogen in the compost than microorganisms need so it will become plant-available more easily (Reid *et al*. 2022).

Evergrow had the highest concentration of Phosphorous (P) at 1660ppm followed by Ecoplanting at 1580ppm Market waste slurry at 62.70ppm Dung slurry at 35.00ppm, Filter mud at 23.70ppm, Boom max at 9.34ppm and NPK at 5.87ppm. The optimal phosphorus concentration of composts is the range of 2000 to 3000 ppm (equivalent to 0.2 to 0.3 % of the amendment) (Cooperland, 2002; DEP 2010; Marriot and Zaborski 2015; Rynk 1992; University of Massachusetts 2016), indicating inadequate phosphorus concentrations in all the amendments used in this experiment. All the amendments thus, will need extra phosphorus to support growth. Phosphorus as a major macronutrient is perhaps the most limited with respect to bioavailability due to its rapid precipitation and adsorption in soils (Vance*etal.*,2003), and its inadequacy in all the amendments should cause worry.

Potassium (K) concentration also ranged from 16.70cmol/kg in Boom max amendment, which was closely followed by that in Ecoplanting at 12.72cmol/kg and that of Market waste slurry at 11.67cmol/kg, Evergrow at 9.10cmol/kg, Dung slurry at 8.69cmol/kg and 5.22 and 4.24cmol/kg for basal and top-dress NPK respectively. The optimum range of potassium concentration is between 0.5 to 1.5 meq/100g equivalent to 0.5 to 1.5 cmol/kg (Compost Management – A&L Canada, 2022).

Levels less than 0.5cmol/kg (K) concentrations therefore need an element added to support growth, while levels over 1.5cmol/kg concentration may contribute to a soluble salt concentration that can resist root growth and cause plant injury. All the amendments used and NPK had more than adequate K concentration levels.

The highest concentration of Calcium (Ca) was realized in amendment Boom max at 39.20cmol/kg, which was followed by that of Market waste slurry at 20.33cmol/kg,Dung slurry at 4.97 cmol/ kg, NPK at 3.32, Ecoplanting at 0.57 cmol /kg and Evergrow at 0.14 cmol/kg. Ideal calcium concentration for composts is between 8.00 to 13.00 cmol/kg and therefore,the only amendment with adequate calcium concentrations (8.00cmol/kg to 13.00cmol/kg) was Boo max (Compost management – A&L Canada 2022) and the relationship between calcium and magnesium should be 5:1. The rest of the amendments and fertilizers had their concentrations of calcium below the ideal levels.

The full spectrum of Magnesium (Mg) as contained in the organic amendments and NPK was such that the Market waste slurry had the highest concentrations of Magnesium at 19.92cmol/kg. The concentrations in Boom max amendment followed distantly at 4.68cmol/kg, Evergrow at 1.61cmol/kg, Ecoplanting at 1.35cmol/kg, Filter mud at 1.00cmol/kg and the NPKs and the Dung slurry at less than 1.00cmol/kg each. The optimum Mg concentration is between 1.2 to 8.0 cmol/kg. Except for Filter mud and Dung slurry amendments, the rest of the organic amendments used had adequate Mg concentration levels (Compost management – A&L Canada 2022) and magnesium to Potassium levels (Mg: K levels) should be 7:1 for optimum availability of each nutrient (Compost management – A&L Canada 2022)

Sodium levels associated with various organic fertilizers were such that they did not contain levels injurious to plants. All the organic amendments contained levels less than 6000cmol/kg. Excess of 6000cmol/kg in the compost may injure plants (Salivan*et al*. 2018)

The Ca: Mg ratio values spread from the highest of 13.98:11 with Boom max to 0.05:1 with Market waste slurry which was the lowest. Others were 2.4:1 for Filter mud, 0.70:1 for Ecoplanting, 0.41:1 for Dung slurry, and 0.15: for Evergrow. Ca: Mg ratio of 6:1 is considered ideal in heavy clay soils and 3:1 is acceptable in sandy soils (Judy Earl, 2020). Where CEC is present in the correct ratio calcium is growth dominant and Ca: Mg ratio is >2:1 (Judy Earl, 2020). In this case, therefore, Ca: Mg ratio was only favourable with Boom max and Filter mud which had a ratio of >2:1, a ratio that favours microbial activity and plant nutrient uptake since calcium is an important carrier nutrient in both soil and plant tissues.

The amount of positive change that can be exchanged per mass of soil or the CEC of the organic amendment and NPK used in the experiment ranged from the highest at 62.72cmol/kg for Boom max to the lowest at 15.94cmol/kg for Ever grow. A CEC value above 10cmol/kg is preferred for plants (DPI 2000) and it can directly regulate plant biomass productivity. In this experiment, all the amendments had CEC levels of more than 10cmol/kg and therefore were at preferred levels Table 5.

Aluminium, iron and manganese are other cations that can occupy cation exchange sites. The levels of aluminium recorded for various treatments were highest with NPK top dress at 930.00ppm and the lowest at less than 0.01ppm for Market waste slurry. But aluminium (Al^{3+}) is not present in excessive quantities below a pH level of 5.0. Below pH 5.0 aluminium is precipitated out of the soil solution (NSW- Soil Management Guides). It is only below pH

5.0that it may become available as a cation and under pH 4.5 may become available at toxic levels displacing other cations from the clay or humus colloids.

Boom max had the highest concentrations of iron (Fe) among the organic amendments at 196.0 ppm. the rest of the organic amendments had iron concentrations of 21.0 ppm and below. Across all the amendments and NPK, NPK top dress had the highest iron concentrations at 916.0ppm followed by NPK basal at 645.0ppm. Like with aluminium, iron is a soil property related to phosphorous (P) that at acid pH values, phosphorous ions react with aluminium (Al) and iron (Fe) to form less soluble compounds (Jensen, 2020).

Effect Organic Amendments and NPK on Soil Chemical Properties.

Figures3 to 11, are graphical presentations of the effects of different organic amendments and inorganic fertilizer NPK on soil chemical properties.

The data on the effects of different soil organic amendments on some general chemical properties of soil after three seasons of application in the soil are presented in Table 4. The chemical properties of the soil were influenced by different sources of the soil nutrients (Organic and chemical).

Table 3. The effects of applied organic amendments on some soil chemical properties

	pH			N			C			P			Iron			Al		
	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3
BOOM	5.93	5.88	5.87	0.16	0.14	0.16	2.6	2.57	2.57	45.8	47.43	34.3	255	202.67	354	706.67	836.00	799
EcoP	6.15	5.87	5.76	0.16	0.14	0.15	2.4	2.39	2.39	20.9	14.03	15.5	256	193.67	390.3	761.67	885.67	983.67
EverG	6.33	5.82	5.84	0.18	0.15	0.16	3.0	2.92	2.92	18.7	32.93	39.9	213	193.33	495	471.33	846.67	1263.3
DS		5.88	5.88		0.14	0.14		2.30	2.30		12.62	8.58		183.33	329.3		984.67	963.67
FM	6.42	5.71	5.85	0.16	0.14	0.15	2.8	2.75	2.75	20.8	24.90	38.5	192	184.00	534	544.67	943.33	1476.7
MW S		6.22	6.04		0.19	0.18		3.41	3.41		20.77	311		206.00	598.7		813.33	1523.3
NPK	6.19	5.68	5.59	0.17	0.14	0.15	2.7	2.62	2.62	21.1	27.71	49.9	214	198.56	492.2	549.11	935.83	1331.5

	K			calcium			Mg			sodium			CEC			Ca: Mg		
	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3	Seas1	Seas2	Seas3
BOOM	0.54	0.85	0.54	11.5	7.52	2.31	3.9	3.34	2.87	1.23	0.28	1.15	17.1	12.00	19.58	5.01	3.75	8.69
EcoP	0.6	0.93	0.61	11.9	8.25	2.17	3.7	3.58	3.51	1.38	0.33	1.48	17.5	13.08	24.58	5.36	3.85	9.03
EverG	0.42	0.93	0.82	9.93	7.98	2.59	2.6	3.48	4.4	0.6	0.34	1.82	13.5	12.72	33.13	6.59	3.83	9.88
D. S		0.76	0.46		7.53	2.08		3.49	3.31		0.31	1.33		12.09	22.25		3.60	8.64
FM	0.43	0.85	0.71	9.7	8.23	2.34	2.4	3.45	4.38	0.79	0.34	2.09	13.3	12.87	34.54	6.75	3.97	10.42
MW S		1.01	1.24		10.35	2.75		3.68	5.89		0.30	2.34		15.34	43.37		4.63	9.56
NPK	0.39	0.85	0.74	9.8	8.16	2.42	3.0	3.62	4.59	0.75	0.32	1.99	14	12.94	31.40	5.47	3.76	8.88

Key: BM= Boom Max, EcoP= Ecoplanting, EverG=Evergrow, DS=Dung slurry, FM=Filter mud, MWS=Market waste slurry

Soil pH

Soil pH varied with the treatments as presented in Figure 2 below. The amendments and NPK fertilizer caused a general decrease in soil pHvalues except the results from Dung slurry that stayed constant between seasons one and one and three and seasons two and three respectively as follows:

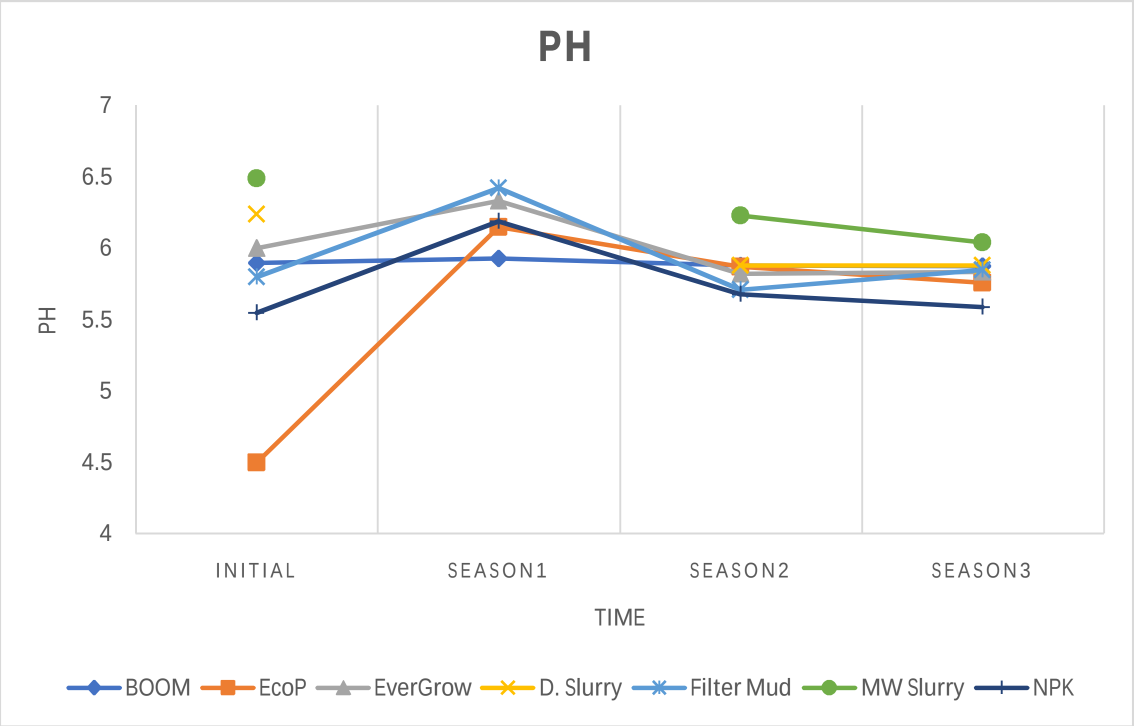

Figure 2. The influence of organic amendment and NPK applied on soil pH

Table 4. shows that while pH of soils treated with the various organic amendments decreased between season one and season three for various amendments, that of dung slurry stayed unchanged as follows;

- Boom Max from 5.93 to 5.87
- Ecoplanting from 6.15 to 5.76
- Evergrow from 6.33 to 5.84
- Dung slurry from 5.88 to 5.88
- Filter mud from 6.42 to 5.85
- Market waste slurry from 6.22 to 6.04
- NPK from 6.19 to 5.59

This could be explained by the fact that organic amendments being carbonaceous in nature are subjected to microbial decomposition and depending upon their chemical composition, produce a variety of water-soluble organic acids and many natural chelating complexing agents that alter the intensity of different chemical fractions of nutrients associated with soil solution, soil exchange, complex and other soil minerals (Huang and Cobran 2005).It was also evident that the organic amendments, generally decreased the soil pH values compared to their own original (initial or pre-plantingpH) and their final pH at the end of season three season as follows;

- Boom Max from 5.90 to 5.87
- Ecoplanting from 4.50 to 5.76
- Evergrow from 6.00 to 5.84
- Dung slurry from 6.24 to 5.88
- Filter mud from 5.80 to 5.85
- Market waste slurry from 6.49 to 6.04

Only the Dung slurry amendment treatment showed a slight increase in soil pH(only 0.05). Despite the reduced pH levels of soils treated with the various organic amendments, the pH of soil treated with NPK fertilizer stayed lower than all, confirming the acidifying nature and power of inorganic fertilizers compared to organic fertilizers. Except the slight increase of soil pH by the Dung slurry treatment, all other organic amendments reduced the pH of the soils of their plots.

This may be attributed to the production of acidic functional groups released during the oxidation processes of organic amendment (Liu and Zhang, 2012). The addition of organic waste to soil contributes to the enhancements of active humidified components such as humic acid (HA) and Fulvic acid (FA) which could have caused a decrease in general pH as compared to those of the amendments and the initial soil pH (Mahendra *et al.*, 2019). But compared to the original soil pH,only Filter mud increased the soil pH from 6.24 to 5. 88.. Contrary to this finding,Eteng, (2015) reported that organic amendments in general increased soil pH regardless of the type of manure.

Organic Carbon

The different organic amendments increased the soil's total organic carbon contents as compared to the pre-application total carbon level, except that of dung slurry and Market waste slurry, a result consistent with the analysis recorded for the amendment in the present study that they contain organic carbon and increased the soil carbon content, between the pre- application time and season three (Table 4 and Figure 3).

The effects of soil amendments were positive responses by all treatments except the response from Dung slurry and the Market waste slurry which were negative. Organic carbon was released into the soil as the organic amendment decomposed. An increase in soil organic carbon is also an indication that organic matter is the most valuable source of carbon in the soil and continuous application for three seasons resulted in a build-up (Sulivan *et al*, 2018).

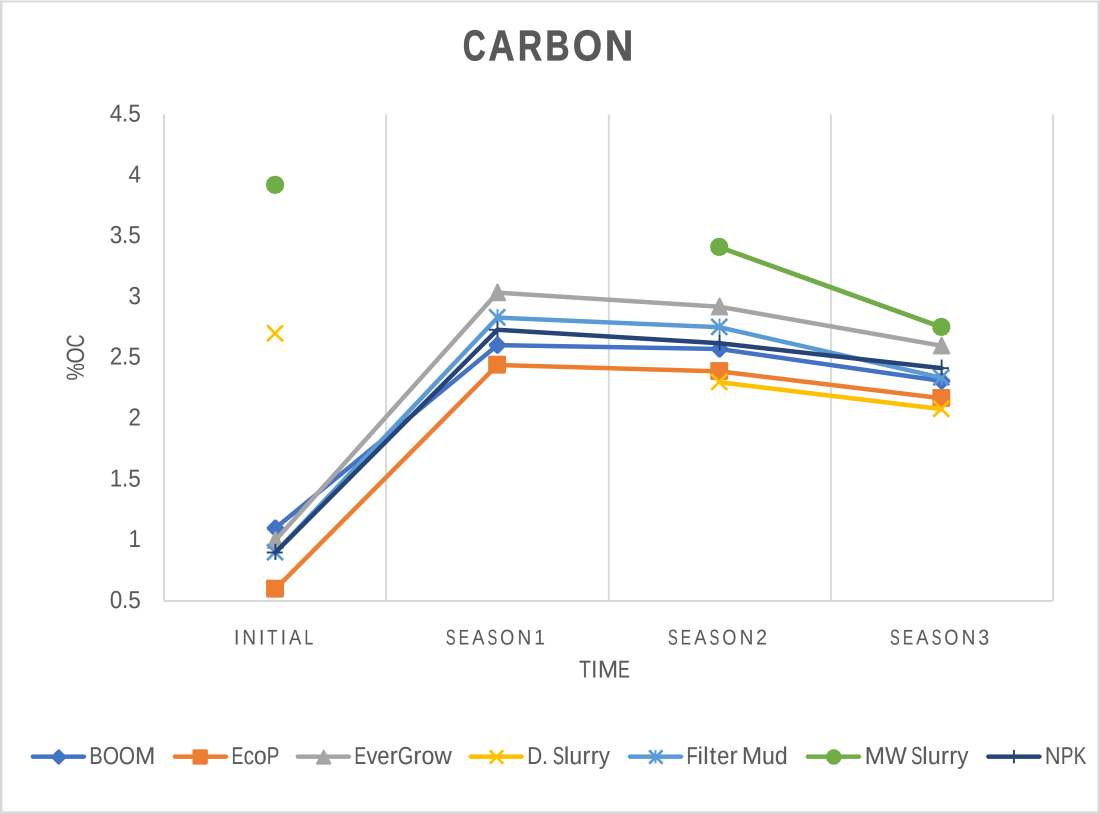

Figure 3. The influence of organic amendment and NPK applied on soil organic carbon

Zhang*etal.*,(2012) found biochar amendment to be rich in organic carbon concentrations, and of between 33%-35%, and is characterized by high mineral contents (Shenbagavalli and Mahimairaja, 2012). Several studies have proved that the addition of organic residues increases soil organic carbon level (Usman *et al,* 2004; Tang *et al.*, 2019). Ragheb *et al,* (2015) noticed the highest organic carbon in poultry manure-amended soils. Research has shown that nutrients in bio-slurry mostly vary with feed type (Jeptoo*et al.*,2013).Berihu (2021), on a field trial in Ethiopia, reported the inability of cow dung bio-slurry to alter the soil organic carbon content of the experimental plots. Kader *et al.*, (2019), while evaluating the manurial value of bio-slurry for tomato cultivation among several organic manures reported the lowest organic carbon from cow dung bio-slurry which was statistically inferior to soil organic carbon from cow dung feed type, since some of the carbon is removed duringfermentation.

Total Nitrogen

The response of soil total nitrogen to various organic amendments and NPK is presented in figure 4 and Table 4.

The application of all organic amendments brought varied outcomes. Application of Boom Max, Evergrow, Dung slurry and Market waste slurry reduced the total nitrogen content of the experimental plots. On the other hand, Ecoplanting and Filter mud increased the total nitrogen content of the experimental soil.

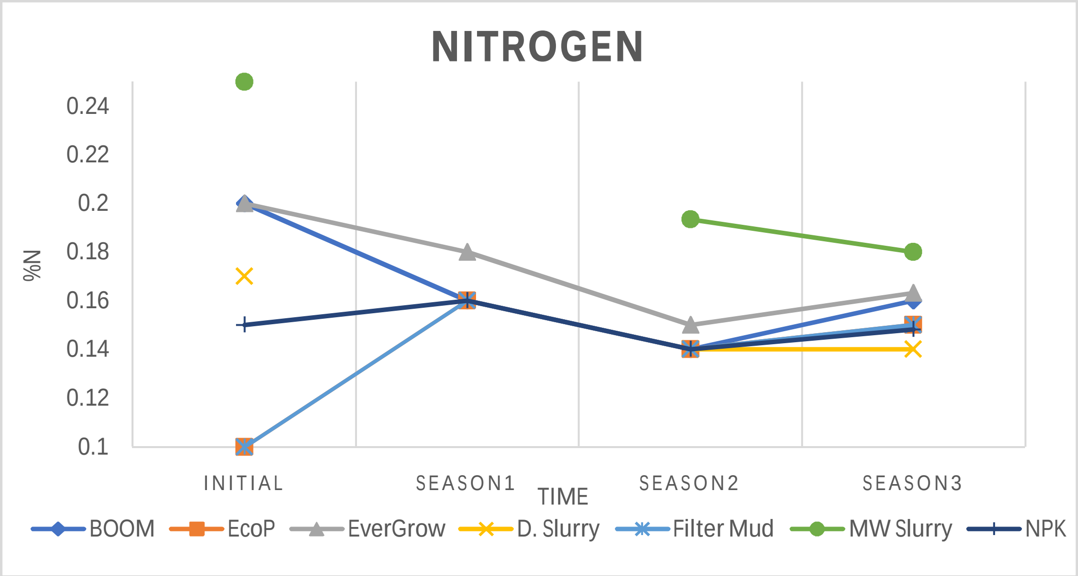

Figure 4. The influence of organic amendment and NPK applied on soil total nitrogen.

Compared to the total nitrogen contribution by the inorganic NPK fertilizer to the experimental soil, the total nitrogen levels of the various plots treated with different organic amendments ranged from 0.14 to 0.18 as compared to that caused by the NPK fertilizer. However, the bio-slurry amendments (Dung slurry and Market waste slurry) had their total nitrogen contents reduced from 0.17% to 0.10% and 0.25 to 0.20%, a reduction of 41.20% and 20% respectively. Bolten *et al.*, (2014) reported that 50% of the inorganic nitrogen in bio-slurry is converted to ammonium nitrogen (NH_4^+-N) a form that is directly available to plants for uptake but subject to losses due to volatilization and leaching and whose value also depends on the nutrient contents of the bio-slurry substrate. The ammonium volatilization after the application of bio-slurry to the soil could have been high, which may have reduced the value of the bio-slurry (dung slurry) as a nitrogen fertilizer. Coelho *et al.*, (2020) also mentioned nitrogen loss through ammonia volatilization as a shortcoming of biogas slurry together with reduced C:N ratios hindering its potential application as soil conditioner/ fertilizer in agriculture. Otherwise, there was a main effect of amendment type on the soil nitrogen level.These results indicate that all of the organic amendments (BoomMax,Ecoplanting, Evergrow, Dung slurry, Filter mud and Market waste slurry) supplied similar quantities of total nitrogen to the soil as did the inorganic fertilizer NPK and therefore can substitute for the inorganic nitrogen source. This is despite the different organic materials having different nitrogen release patternsdepending on the interaction between the material (stock) and the environmental conditions (Hue and Silver, 2000).

Phosphorous

Available phosphorous decreased in concentrations in the soils supplied with some of the amendments and at the end of season 3, were less in soil concentration than their concentrations in season 1 as follows;

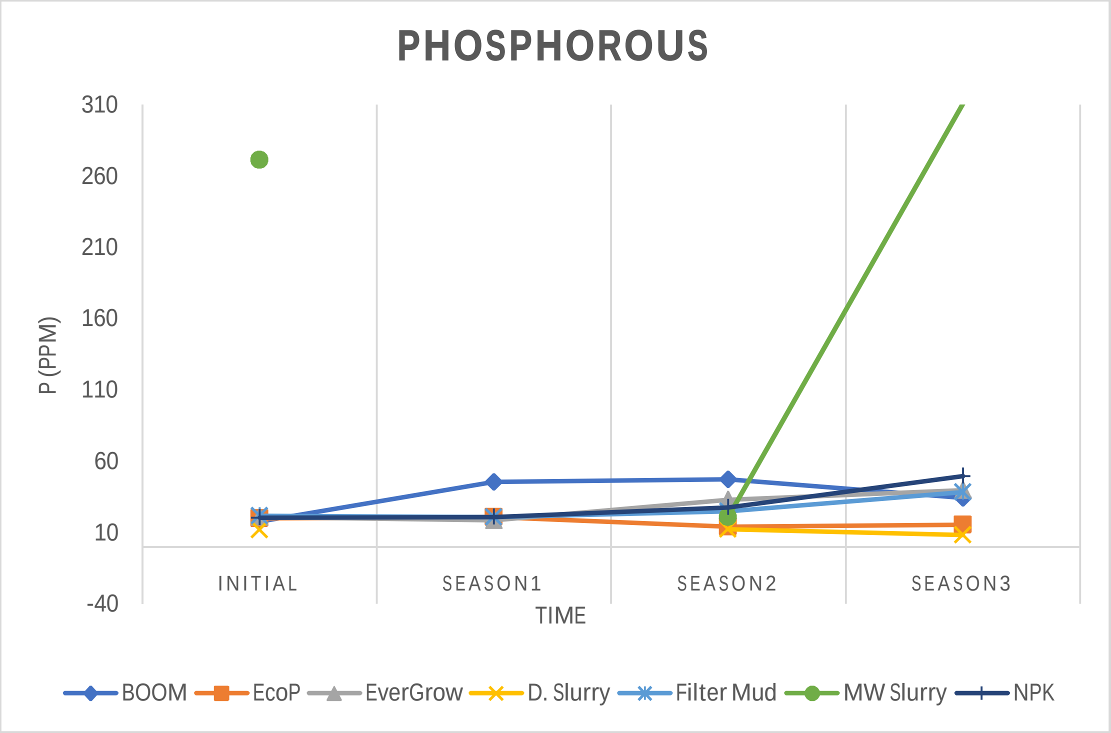

Figure 5. The influence of organic amendment and NPK applied on soil phosphorous

- Boom max from 45.80ppm to 34.30ppm
- Ecoplanting from 20.90ppm to 15.50ppm
- Dung slurry from 12-62ppm to 8.58ppm

Other amendments however had their concentrations increased in the soil that received them as follows;

- Evergrow from 18.70ppm to 39.90ppm
- Filter mud from 20.80pp to 38.50ppm
- Market waste slurry from 20.70ppm to 311.00ppm
- NPK from 21.10 ppm to 27.71ppm

Compared to the original soil concentrations of available phosphorus, the applied organic amendments brought the following changes in soil concentrations of available phosphorus:

- Boom Max from 18.0ppm to34.0ppm
- Ecoplanting from 20.2 to 16.0
- Dung slurry 12.1 to 8.6
- Evergrow 21.1 to 40.0
- Filter mud 22.1 to 39.0

- Market waste slurry 271.48 to 311.0
- NPK – to 50

Four of the amendments (Boom Max, Evergrow, Filter mud and Market waste slurry) increased the soil contents of available phosphorus at the end of season three while two of the amendments (Ecoplanting and Dung slurry), had decreased soil content of available phosphorus. The general trend of available phosphorus at the end of season three withcontinuousapplication of various organic amendments was Market waste slurry > NPK>Evergrow> Filter mud >Boom Max>Ecoplanting> Dung slurry.Except for the amendment Market waste slurry, noother amendment produced equal to or higher soil content of available phosphorus than the inorganic fertilizer NPK.This result is in agreement with the findings of Pennstate (2017) that the availability of phosphorus is influenced by soil pH and pH below 6.0 is associated with phosphorus deficiency and that the mineral is generally available to crops at soil pH of 6.0 to 7.0. This is contrary to the report by Hue and Silva (2000) and by Mohammed *et al*, (2007) who reported that the continued application of composts and manure increases soil phosphorous levels. Only the Market waste slurry had a pH of more than 6.0.Ch'ng*et al.*, (2014) reported that composts have been observed to release considerable amounts of organic acids into the soil thereby resulting in hydrolysis of organic phosphorous, hence improving phosphorous nutrition for the plant and microorganisms, contrary to the results of this study. According to Ahana *et al.*, (2020) the addition of different organic amendments as an agronomic practice changes soil properties through microbial decomposition and depending upon their chemical composition, changes soil properties and the intensities of different chemical pools of micronutrients to influence that availability of macro and micronutrients in the soil. This result is consistent with the analysis recorded for the amendment in the present study that all organic amendments did not have adequate available phosphorous in their composition to support growth because of the soil pH level (Table 4). The application of Boom Max, Ecoplanting, Evergrow, Dung slurry, and Filter mud, resulted in the availability of phosphorus in the soil but not good enough to compete with that produced as a result of the inorganic NPK except from the Market waste slurry. These findings suggest that organic amendments altered the chemical properties in a way that enhanced the availability of phosphorus in this study but because of the low soil pH (below 6.0), the levels of availability were lower than that from the inorganic fertilizer NPK.

Potassium

Exchangeable potassium in the soil as affected by various organic and chemical fertilizer NPK amendments used in the experiment are presented in Table 4 and Figure6. Exchangeable potassium in soil changed as follows between seasons one and seasons three;

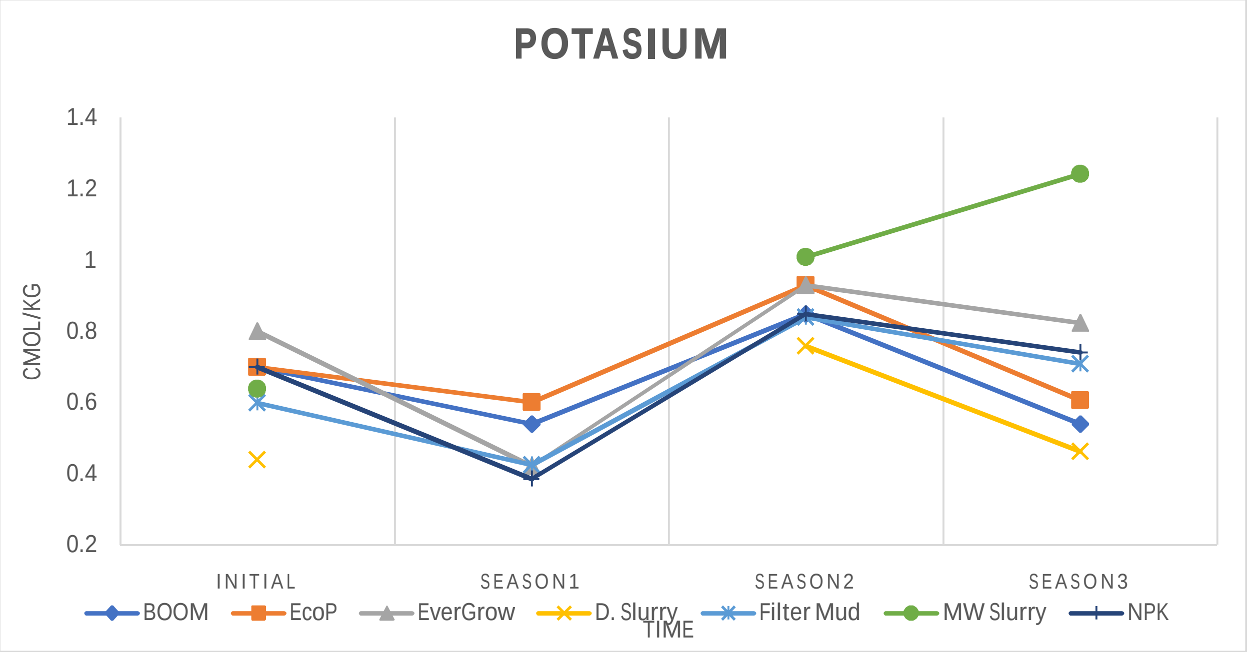

Figure 6. The influence of organic amendment and NPK applied on soil potassium

- Boom Max amended from 0.54cmol/kg to 0.54cmol/kg
- Ecoplanting amended from 0.60col/kg to 0.61cmol/kg
- Evergrow amended from 0.42cmol/kg to 0.81cmol/kg
- Dung slurry amended from 0.76cmol/kg to 0.46cmol/kg
- Filter mud amended from 0.43cmol/kg to 0.71cmol/kg
- Market waste slurry amended from 1.01cmol/kg to 1.24cmol/kg
- NPK fertilizer treatment from 0.85cmol/kg to 0.74cmol/kg

However, compared to the pre-trial (initial) soil concentrations of exchangeable potassium (Table 4), three amendment types (Boom Max, Ecoplanting, and Dung slurry)had decreased soil concentrations of the exchangeable potassium. On the other hand, three of the trial amendments (Evergrow, Filter Mud, and Market Waste Slurry) increased the soil concentrations of exchangeable potassium. The highest increase in exchangeable potassium was noticed in the case of Market waste slurry (0.64 cmol/kg) while the lowest increase was in the case of Evergrow amendment (0.01cmol/kg). In this study, differences in the concentration of exchangeable potassium in the soil were more related to amendment type. Among the different amendments, the application of Market waste slurry and Evergrow increased the concentration of exchangeable potassium beyond that caused by the inorganic fertilizer NPK (Table 4 and Figure 8). Other amendments(Dung slurry, Boom Max, Ecoplanting, and Filtermud) resulted in soil concentrations of exchangeable potassium less than that of the NPK fertilizer. Steiner *et al.*, (2007) reported that exchangeable potassium alongside phosphorous, calcium, and magnesium increased with chicken manure application in a tropical environment. Mahdy *et al.*, (2011) showed that the addition of organic amendments caused an increase in most potassium forms, and poultry manure-amended plots produced greater soil content of exchangeable potassium thanFilter cake (Filter mud) or potassium sulphate treated one. Dong *et al.*, (2005) reported contrasting information of lower potassium concentrations in soil with different organic matter treatments compared to mineral fertilizer treatment after three years of different organic matter treatments. Indowu*et al.*, (2017) reported a trial on the evaluation of pecan husks mulch that water-extractable potassium was higher in sandy soils than in finely textured soils after four weeks. Rafique *et al.*, (2012) also reported green manure residues to have led to higher and more immediate plant potassium uptake in coarse loamy soil compared to fine silty soils. Brito *et al.*, (2014) described the movement and after of solubilized potassium as depending on many factors which they distinguished as minerology (parent amendment), cation exchange capacity (CEC), soil organic matter, soil nutrient concentration and texture, water dynamics, environmental conditions, and soil management. Rawal *et al.*, (2022) reported significant differences in available potassium among soil textural classes and that the available potassium was low in silty clay loam and loam soil, whereas it was high in sandy loamy soil and where sandy loamy soil had a 75% higher initial availability of potassium than loam and silty clay loam.McCuley*etal.*,(2017) reported that macronutrients like potassium are more available at pHranges between 6.5 to 8.5 but this was not the case in this experiment since the pH of the trial plots had been decreased by the organic amendments to a level below 6.5.

From the foregoing, it is apparent that an effective source of potassium (the amendment) in one condition may be ineffective in another environment. Evergrow, Filter mud, and Market waste slurry as sources of extractable soil potassium increased soil available potassium as did the inorganic fertilizer source due to high potassium contents in them. The other three amendments as potassium sources were not able to express fully their potassium content potential probably because of an unfavourable environment, the black cotton soil, and the unfavourable soil pH.

Calcium

The data on the effects of different organic amendments on exchangeable calcium is presented in Figure 9 and Table (4).

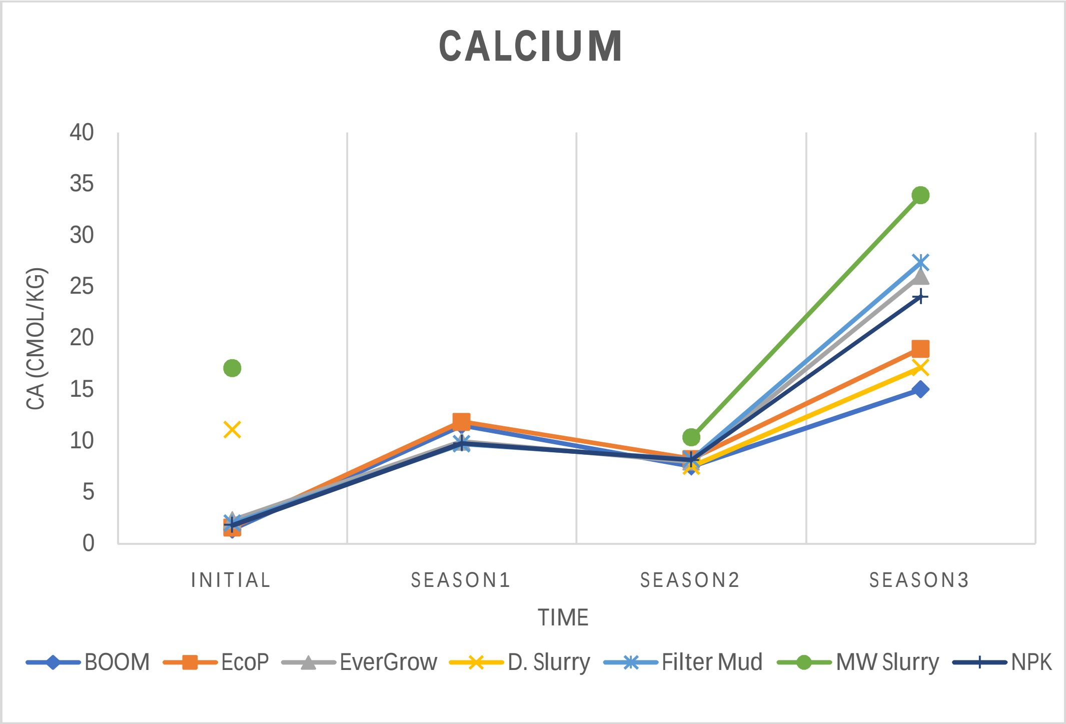

Figure 7. The influence of organic amendment and NPK applied on soil calcium

The behaviour among the organic amendments and NPK are as follows between seasons one and seasons three;

- Boom Max increased from 11.50cmol/kg to 23.10cmol/kg
- Ecoplanting increased from 11.90cmol/kg to 21.70cmol/kg
- Evergrow increased from 9.93cmo/kg to 26.00cmol/kg
- Dung slurry increased from 12.30cmol/kg to 20.80cmol/kg
- Filter mud increased from 9.70cmol/kg to 23.40cmol/kg
- Marke waste slurry increased from 10.35cmol/kg to 27.50cmol/kg
- Fertilizer (NPK) increased from 8.16cmol/kg to 24.20cmol/kg

However, from the pre-amendment application soil contents of exchangeable calcium, all fertilization treatments increased the soil contents of exchangeable calcium. The highest increase was recorded from Evergrow (27.70cmol/kg) while the least increase was recorded from Maret waste slurry (10.40 cmol/kg). Bulluck *et al.*, (2002) reported that calcium and magnesium concentrations in the soil increased twofold in soils with organic amendments over two years period. In contrast, no increase, or only slight increase in exchangeable calcium and magnesium concentrations occurred in soils with synthetic fertilizer over the same period.

Bulluck *et al.*, (2002) described calcium as one of those nutrients added to the soil normally as a liming source and is permitted to mount up in the soils. Ogbodo *et al.*, (2009) did also report that exchangeable potassium, calcium and magnesium levels were higher in plots treated with organic amendments compared to those of inorganic fertilizer, and the higher levels of exchangeable potassium, calcium, and magnesium observed may have been due to the higher organic matter levels in the plots. Organic amendments therefore increased, the soil buffering capacity with the improvement in pH associated with their high contents of calcium and magnesium which had liming effects in the soil (Ogbodo *et al.*,2009)

The application of all amendments (organic and inorganic) brought an increase in exchangeable calcium concentrations in soil owing to the release of soluble calcium ions upon their mineralization. The highest increase was noted in the case of Market waste slurry and Evergrow which resulted in higher levels of exchangeable calcium than the inorganic NPK fertilizer. The least increase was noted in Boom Max amendment. It may therefore be concluded that the test organic amendments were able to compete fairly with the inorganic NPK fertilizer in providing exchangeable calcium to the soil for plant growth and can therefore replace inorganic fertilizers in agricultural production.

Magnesium

The application of all amendment treatments either decreased or increased the concentrations of exchangeable magnesium between seasons one and three, as follows (Figure 8)

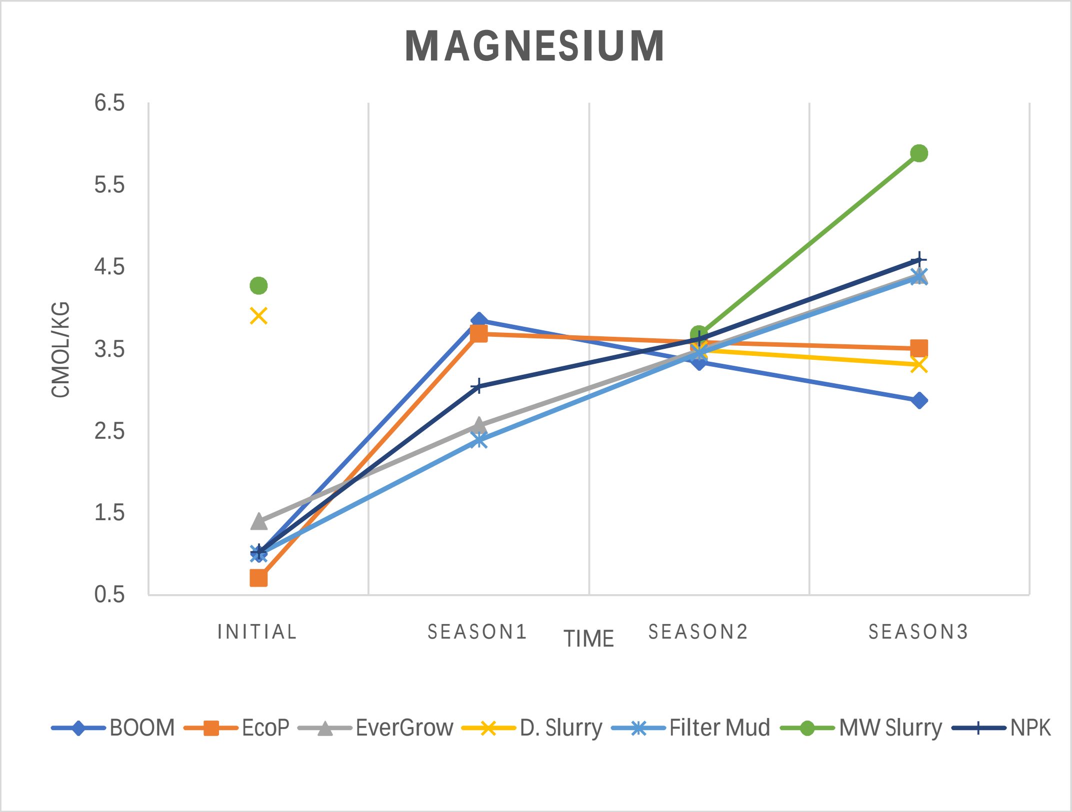

Figure 8. The influence of organic amendment and NPK applied on soil magnesium

- Boom Max amendment decreased from 3.90 cmol/kg to 3.34 cmol/kg
- Ecoplanting amendment decreased from 3.70 cmol/kg to 3.51 cmol/kg

- Dung slurry amendment decreased from 4.30 cmol/kg to 3.31 cmol/kg
- Evergrow amendment increased from 2.60 cmol/kg to 4.40 cmol/kg
- Filter mud amendment increased from 2.40 cmol/kg to 4.38 cmol/kg
- Market waste slurry amendment increased from 3.68 cmol/kg to 5.89 cmol/kg
- NPK amendment increased from 3.62 cmol/kg to 4.59 cmol/kg

However, compared to the original various soil concentrations of exchangeable magnesium (Table 2), all fertilization treatments except that of the Dung slurry, increased the soil concentrations of exchangeable magnesium. The largest increase was recorded from Filter mud (3.38cmol/kg) while the lowest increase was recorded from the Market waste slurry (1.62cmol/kg.Dung slurry was the only organic amendment with a negative increase (- 0.59 cmol/kg). Contrary to the findings of this study, Ogbodo *et al.*, (2009), found that concentrations of magnesium were greater in soils with incorporated organic amendments compared to inorganic fertilizers. Sharma, (2022) also reported concentrations of exchangeable magnesium in the soil to have increased and become greater with incorporated manures and cover crops. This is an indication that organic amendment is competent in maintaining micro-nutrients on a positive scale and favourably comparable to chemical-based systems. The nutrients that are normally applied in commercial fertilizers such as the liming sources (calcium and magnesium) are supplemented in organic amendments and permitted to increase in soil (Sharma, 2022). On the contrary, Dung slurry application resulted in a negative increase (decrease) in the content of exchangeable magnesium in the soil. Yu *et al.*, (2010) reported that the majority of slurries, particularly cow dung slurry have a low content of active ingredients, being greater than 99% water (w/v), its efficacy is rather weak and short-lived as compared with chemical counterparts, and the effective compensation of soil fertility cannot be fulfilled by the slurry alone. Zeng *et al.*, (2017) also reported the bio-gas slurry alone to be unable to fulfill the entire nutrient demand due to its bulkiness, high pH, and reduced rate of C/N transformation. It can therefore be concluded that apart from Dung slurry, the rest of the test organic amendments are capable of replacing inorganic NPK fertilizer in providing adequate exchangeable magnesium for plant growth and production with possible adjustment of the application rate.

Cation Exchange capacity (CEC)

The contribution of the organic amendments to the soil cation exchange capacity (CEC) increased as follows between season one and season three;

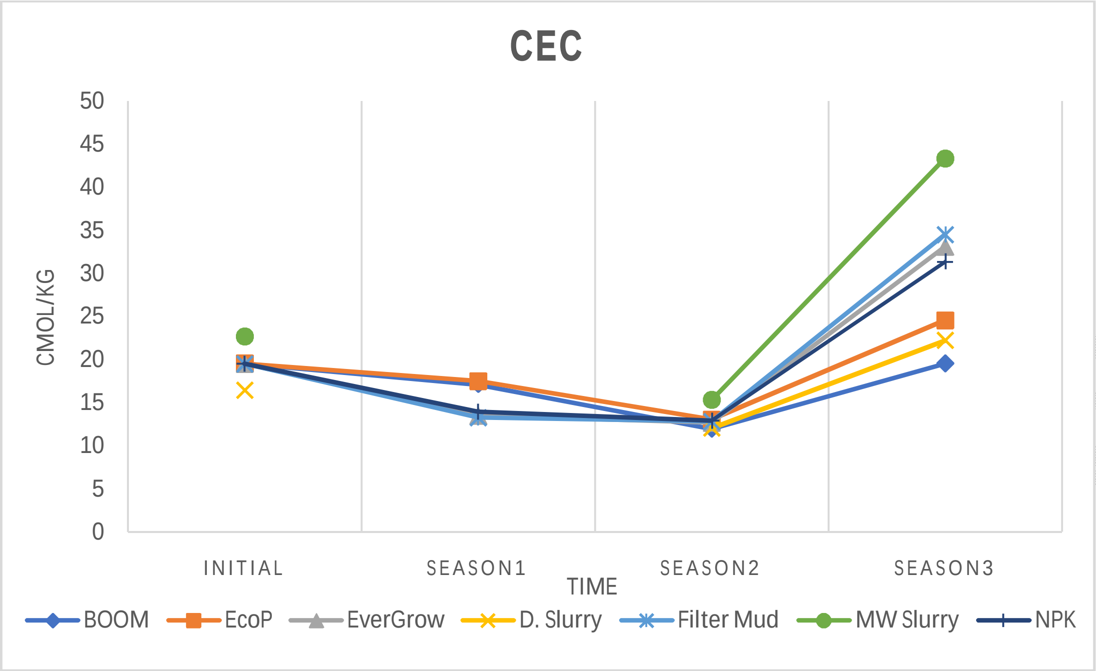

Figure 9. The influence of organic amendment and NPK applied on soil CEC

- Boom Max amendment from 17.10 cmol/kg to 19.58 cmol/kg
- Ecoplanting amendment from 17.50 cmol/kg to 24.58 cmol/kg
- Evergrow amendment from 13.50 cmol/kg to 33.13 cmol/kg
- Dung slurry amendment from 12.09cmol/kg to 22.25 cmol/kg
- Filter mud amendment from 13.30 cmol/kg to 34.54 cmol/kg
- Market waste slurry amendment from 15.84 cmol/kg to 43.87 cmol/kg
- NPK amendment from 14.00 cmol/kg to 31.40cmol/kg

CEC greater than 10cmol/kg is considered as experiencing no leaching of cations (PUCE 1914). In this study, all fertilization treatments increased the CEC of the soil. However, compared to the various original CECs of untreated soils (Table 3 and Figure 9) all fertilization treatments increased the CEC of the soil. The largest increase was registered from the Market waste slurry (21.15cmol/kg) while the least increase was recorded with Boom Max (0.01cmol/kg). One of the perceived benefits of the use of composts and manures over fertilizers is their ability to provide non-NPK nutrients (Aytenew and Bore, 2020). Bulluck *et al*, (2002) reported that organic amendments can provide advantages beyond the primary nutrients NPK like the nutrients that are normally applied in the liming sources (calcium and magnesium) are permitted to mount up in the soil. Kebede *et al.*, (2023) reported a significant increase in soil CEC as influenced by the food waste compost and leaf yard compost by both application and rate. Meana *et al.*, (2016) also assured that the high application of compost increases the CEC value of treated soils. Similarly, various findings indicated that compost amendment increases CEC due to input from stabilized organic matter rich in functional groups such as carboxylic and phenolic acid groups being released into the soil exchange sites as was reported by Duong *et al.*, (2013). In a study conducted by Li (2020), compost treatments increased CEC apart from organic carbon and nutrients, and adding organic matter has a CEC about four times greater than that of clay.

These results also indicated that the pre-fertilization CEC was high (19.57cmol/kg) on average. This could be explained by the fact that soils with high levels of swelling clay, as was the cases in this experiment have CEC of up to 30cmol/kg or more (Shermeen and Peter, 2016)supplying capacity which may be used singly or in integration supply needed nutrients in a farming situation.

Sodium

Soils with high levels of sodium (Na^+) may impact growth in several ways, including specific toxicity to sodium-sensitive plants, nutrient deficiencies or imbalances, high pH and dispersion of particles that cause poor physical conditions (Davis *et al.*, 2012). Thus, sodic soils tend to develop poor structure and drainage overtime because sodium ions on clay particles cause the soil particles to flocculate or disperse. A soil pH of above 8.4 typically indicates that sodium problem exists (Davis *et al.*, 2012), resulting in lock-up of phosphate, iron and other micronutrients.

The application of various soil amendments either decreased or increased the available levels of sodium in the soil as follows between seasons one and three as follows, (Figure 10).

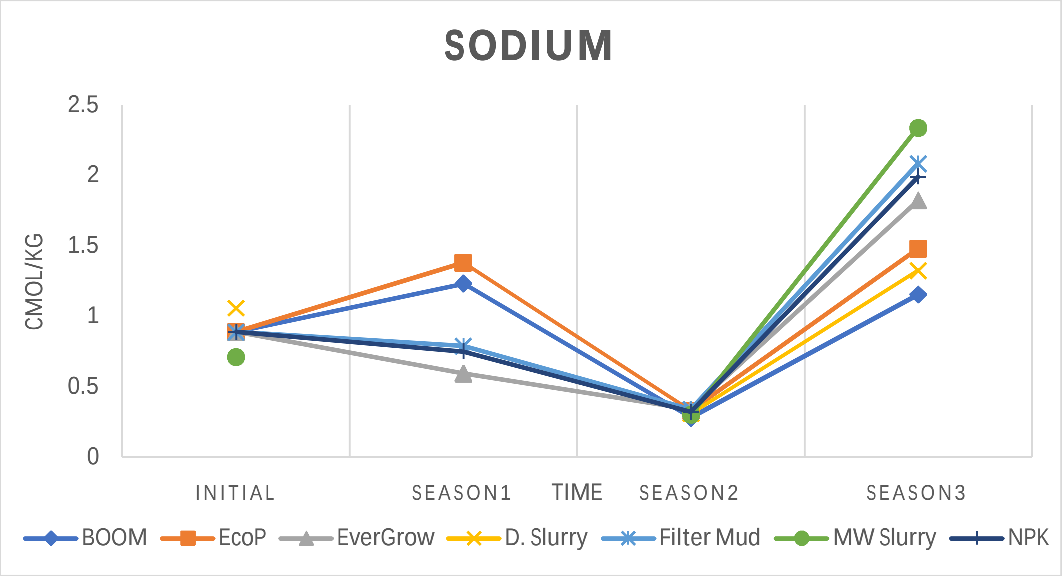

Figure 10. The influence of organic amendment and NPK applied on soil sodium.

- Boom max amendment decreased from 1.23 cmol/kg to 1.15 cmol/kg
- Dung slurry amendment decreased from 1.61 cmol/kg to 1.33 cmol/kg
- Ecoplanting amendment increased from 1.38 cmol/kg to 1.48 cmol/kg
- Evergrow amendment increased from 0.60 cmol/kg to 1.82 cmol/kg
- Filter mud amendment increased from 0.79cmol/kg to 2.08 cmol/kg

- Market waste slurry amendment increased from 0.32 cmol/kg to 2.34cmol/kg
- NPK increased from 0.32cmol/kg to 1.99 cmol/kg

However, when exchangeable sodium is present in quantities greater than 15% of CEC, then it would make the clay particles unstable in rainwater, making the soil dispersive with poor water entry and drainage and set too hard on drying (Qadir *et al.*, 2007). Table 5 shows the 15% equivalent of CEC generated by each organic amendment as compared to the available sodium levels at the end of season three. All the fertilization treatments resulted in available sodium concentrations in quantities that were safe for the clay particles and therefore safe from causing sodicity.

Table 4. The sodium concentration in the various organic amendments relative to their CECs

Amendment type	Corresponding CEC (cmol/kg)	15% of the CEC value (cmol/kg)	Available sodium levels (cmol/kg)
Boom Max	19.58	2.94	1.15
Ecoplanting	24.58	3.69	1.48
Evergrow	33.13	4.97	1.82
Dung slurry	22.55	3.38	1.33
Filter mud	34.54	5.18	2.08
Market waste slurry	43.37	6.51	2.34
NPK	34.40	4.71	1.99

Table 5. 15% values of the CEC of the amendments compared to available sodium concentrations of soils for each amendment at the end of season three.

Ca: Mg ratio

The calcium to magnesium ratio (Ca: Mg) was increased by all fertilizer treatments as follows between seasons one and three (Figure 11).

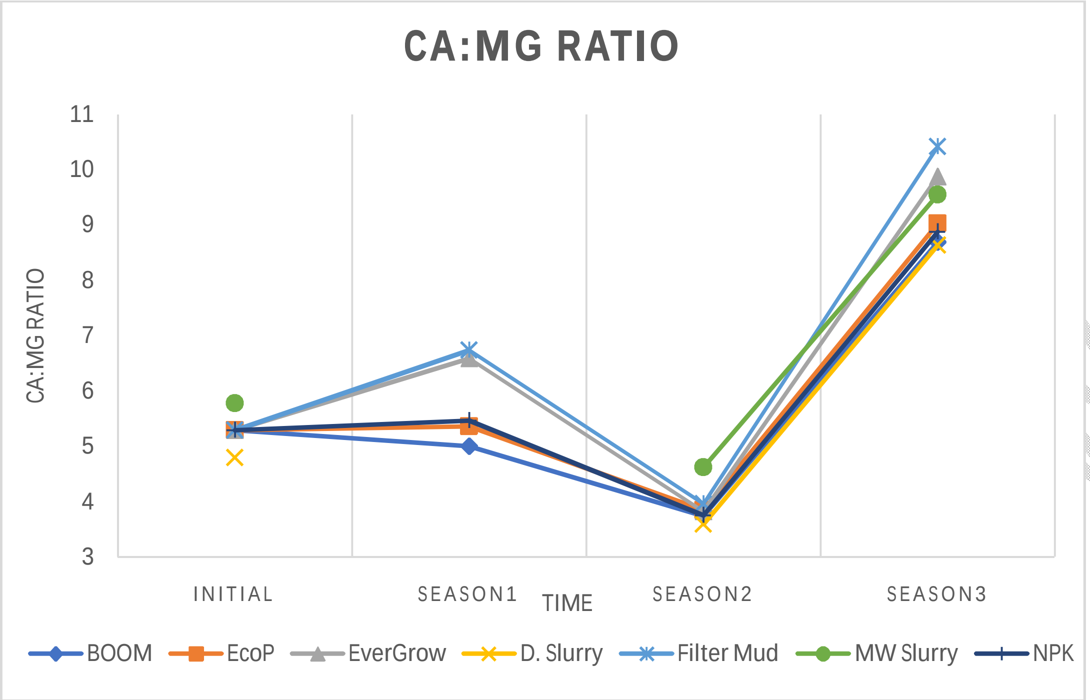

Figure 11. The influence of organic amendment and NPK applied on soil Ca: Mg ratio

- Boom max amendment increased from 5.01:1 to 8.69:1
- Ecoplantingamendment increased from 5.36:1 to 9.03:1
- Evergrowamendment increased from 6.59: to 9.88:1
- Dung slurryamendment increased from 4.75:1 to 8.64:1
- Filter mudamendment increased from 6.75:1 to 10.42:1
- Market waste slurryamendment increased from 4.63:1 to 9.56:1
- NPKamendment increased from 3.76:1 to 8.88:1

All soils contain Calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) attracted to the negative exchange sites on clays and organic matter (cation exchange complex of the soil (ISUE, 2024).

The results of this experiment indicated that at the end of season three, filter mud amendment produced the highest ratio of 10.42:1 and dung slurry the lowest ratio of 8.64:1. Soil Ca:Mg ratio naturally is above 1:1 (ISUE 2024). The theory is that “an ideal soil” will have a balanced ratio of calcium, magnesium, and potassium, i.e., fertilization should be based on the soil’s need rather than the crop’s need (ISUE 2024), and the suggested ideal ratio according to the theory is between 2.5 to 6.0, which has never proven to be of significance.

According to Koptike and Menzies (2007), there is very little research evidence to support any effect, either positive or negative of soil Ca:Mg ratio on crop production on yields. He advises that Ca: Mg ratio should not concern farmers if soil calcium and magnesium levels are adequate and soil pH acceptable and Ca:Mg ratio between 2:1 and 8:1 has been shown to not influence crop yields. Field and greenhouse experiments (ISUE 2024), indicated that crop productivity is not influenced by Ca: Mg ratio ranging from less than 1:1 to more than 25:1 outside what is normally measured in soils. More attention therefore should be shifted to the actual levels of plant-available magnesium and calcium as more important to crop performance than the ca: mg ratio. On the other hand, Sait *et al.*, (2015a), qualified Ca: Mg ratio to be important for gaseous exchange in soils for better photosynthesis and activity of aerobic microorganisms in the soil. The recommendation is 3:1 for sandy soils, 7;1 for clay soils (Phillips 2021). Further, plants also play a role in calcium and magnesium uptake and exclude excesses of calcium and magnesium at the root surface. The range therefore achieved by the various organic amendments and NPK (between 8.64:1 to 10.42:1) is therefore safe for any crop production, should they provide adequate available calcium and magnesium concentrations.

Conclusions and Recommendation

From this study, several conclusions can be drawn.Organic amendments differ in their properties and their macronutrient contents. Treatment of soils with organic amendments may alter soil properties and differently change the quantities of the various chemical fractions of macronutrients in the soil. Based on the laboratory soil analysis of the trial plots, the application of organic amendment Filter mud increased the soil contents of all the tested soil qualities and macronutrients (pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, calcium, and magnesium, and soil cation exchange capacity). It was closely followed by organic amendment Evergrow with six increases and Boom Max, Evergrow and Market waste slurry each with five increases in quantities of soil quality properties and nutrient levels. Dung slurry had the least contribution. All the compost based amendments increased the soil organic carbon indicating their potential as valuable sources of organic matter and sources of soil carbon and whose continuous application would result in soil carbon build-up. All the tested organic amendments (except Dung slurry) increased the soil content of the liming ions (calcium and magnesium) and thus a saving on possible lime application rate alongside their availability as fertilizers and contributors to the soil CEC, which was increased by the application of all the amendments. Two organic amendments (Ecoplanting and Filter mud) were the only amendments that increased the soil content of total nitrogen and soil pH indicating that when the others are in use,different sources of nitrogen must be considered.

These results also show that Filter mud as a compost was capable of increasing the soil content of all the soil quality parameters tested and yet was in immature form .It is our feeling that the amendment be given an opportunity in its mature form in the current environment and in others. In addition, the application of the amendments confined the soil pH to a range between 5.76 and 6.04, a range within which the availability of macronutrients (nitrogen, potassium,calcium, magnesium are(more available at pH range of 6.5 to 8.5 ; while phosphorus is most available within pH range of 6.0 to 7.0) is not favourable and which could have been due to the soil type. It would therefore be worth repeating in a different soil type to confirm these results.

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References.

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