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Effect of Enriched Sheep Manure Rates on Physico-Chemical Parameters of Tea Soil in Timbilil Tea Estate, Kericho, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. All the authors designed the study, performed the statistical analysis, wrote the protocol, managed the analyses of the study, read and approved the final manuscript.

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ABSTRACT

The regular harvesting of tea (two leaves and a bud) implies that nutrients are continuously mined from the soil. On the other hand, integrated soil fertility management (ISFM) which involves the combined use of organic and inorganic fertiliser is good for improved soil health. Therefore, the study was carried out to determine the effect of enriched sheep manure rates on physico-chemical parameters of tea soil. An ongoing field trial in Timbilil Tea Estate in Kericho started in 1985 to study the response of sheep manure, NPK 25:5:5 and a combination of both on tea plants were used. The trial was set up in a Randomized Complete Block Design (RCBD) with three replicates. Forty-two composite soil samples were collected randomly from each of the experimental plots. The data collection process included soil sampling during the short rain season in 2017 and annual tea yield sampling. The samples were analysed for the total organic matter, nitrogen content, bulk density, porosity, soil pH, porosity, particle density and soil moisture content. Results showed that fertiliser types significantly ($p<0.05$) affected SOM with enriched sheep manure giving the highest values. Fertiliser rates had no significant ($p>0.05$) difference on SOM. Fertiliser application at the

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highest rate of 240 kg N/ha had the lowest SOM content, which means high fertiliser application, causes more harm than good. Therefore, enriched manures increase SOM content in the soil which could improve productivity in the tea industry.

Keywords: Improvement; tea; animal manure; soil parameters.

1. INTRODUCTION

Tea (*Camellia sinensis*) is one of the main cash crops in Kenya. It is believed that the tea plant can remain in production for up to 100 years. However, regular harvesting of the crop (two leaves and a bud) suggests that nutrients are continuously mined from the soil. Previously, a study by Bore [1] explained that tea is a beverage crop cultivated for its fresh leaves (2 leaves + bud) in plantations as monocrop and requires high soil nutrients, particularly N, P, K, Ca and Mg. These nutrients are critical and their deficiency and or inadequate supply would eventually lead to poor tea seedling establishment and performance on the field. Therefore, tea production cannot be optimised without fertiliser application. A previous study conducted by [2] recorded that tea production is commercially by nutrient supply through inorganic fertilisers at rates between 150 – 300 kg N ha^{-1} for black tea (fermented tea) and up to 1000 kg N ha^{-1} for green tea (unfermented tea) [3]. These rates are high and require about 50 % of the total annual farm variable inputs [4]. In Kenya, a fertiliser rate of 100-200 kg N/ha in form of NPKS is recommended for optimal yield of tea. Many farmers use more than the recommended rates in a bid to realise high crop yield [4]. Presently there is a global short supply and high procurement cost of inorganic fertilisers and the poor resource farmers cannot afford this. Therefore, there is a need to look for alternative nutrient sources, that are cheap, readily available and affordable to the farmers. Heavy application of inorganic fertilisers leads to deterioration of soil cation exchange capacity (CEC), and clay contents of the soil, high concentration of Al and silicate in drainage water in addition to air pollution through nitrous gas emission, excessive leaching leads to underground water pollution [5]. Saikah et al. [6] explained that continuous use of the inorganic, however, threatens the sustainability of the system. On the other hand, integrated soil fertility management (ISFM) which involves the combined use of organic and inorganic fertiliser is good for improved tea yield and soil health [7]. The benefits of ISFM have been demonstrated especially in the annual crop systems, but the challenge is how much, in what proportions and when the different fertiliser types are to be used. Sheep manure, one of the alternative nutrient sources is limited in quality and quantity [8]. Most tropical soils are low in organic matter content, and they need proper organic matter management by way of organic fertiliser application for sustainable long term land use. Therefore, the present experiment was carried out to determine the effect of enriched sheep manure rates on physico-chemical parameters of tea soil in Timbilil Tea Estate, Kericho.

2. MATERIALS AND METHODS

2.1 Study Area

The research used an existing experiment, which started in 1985 at Tea Research Institute, Timbilil Estate in Kericho. The site is situated at an altitude of 2178 m above sea level, latitude 0^0 22'S and longitude 35^0 21' E. The total annual rainfall during the study period was 1954.4 mm and the mean temperature was 17.1°C. The entire experimental field covers an area of 3847.1 m^2 and a total of 70 mature tea bushes per plot (10 m × 7 m) bringing the number of effective bushes to 2940.

2.2 Treatments

A high yielding clone TRFK 31/8 was used in the experiment. The treatments were included:

Inorganic fertiliser NPKS 25:5:5, sheep manure and Enriched sheep manure (sheep manure: NPK 25:5:5 at ratios of 4:1 and 8:1.

2.3 Research Design

The study was laid out in a Randomized Complete Block Design (RCBD) replicated three times. Each of the treatments was tested at rates 0, 60, 120, 180 and 240 kg N/ ha/year. The sheep manure was collected from farmers' fields, analysed for chemical composition [9] standardised based on the N content and then applied to the mature tea as follows:

Table 1. Treatment type and rate

Treatment	Rate (kg N/ha)
Control (no fertiliser)	0
Sheep Manure	60
	120
	180
	240
Enriched Sheep Manure At 4:1	60
	120
	180
	240
Enriched Sheep Manure At 8:1	60
	120
	180
	240
Inorganic fertiliser (NPK **25:5:5**)	180

2.4 Soil Sampling

Soil sampling was done once during the short rain season and this is because the seasons affect SOM content and this season represented all the seasons. Soil samples were obtained from predetermined sampling depths of 0-15, 15-30 and 30-45 cm using a post-hole auger. 3 samples from each treatment were collected and mixed together to get a composite sample. The soils samples were then put in well labelled bags and transported to the laboratory where a field-moist subsample was scooped and set aside for determination of pH. The remaining samples were then air dried to remove excess moisture then sieved in preparation for the analysis of the different elements.

2.5 Soil Chemical and Physical Analysis

Samples collected from the field were analysed for SOM using the hydrogen peroxide digestion method [10]. This method destroys the organic matter in the sample through oxidation. The hydrogen peroxide digestion method involved the addition of hydrogen peroxide to 10 g of each soil sample. Hydrogen peroxide was then continually added to the sample and mixed until sample frothing stopped. The mixture was heated to increase the speed and completeness of the peroxide digestion. The sample was oven dried at 105ºC, cooled and weighed. The percentage organic matter was determined gravimetrically and calculated as the difference between the initial and final sample weights divided by the initial sample weight times 100% to give % SOM.

Soil pH was determined using a glass electrode pH meter and standard buffer solutions of pH 4.0 and pH 7.0 on moist soil [9]. In this method, 25 g of the moist soil samples were weighed into a plastic containers and water added while stirring until it was nearly saturated. The mixture was the left to stand after which some more water was added to achieve a uniformly saturated soil-water paste. The mixture was left to stand for two hours then filtered and the filtrate collected in a test-tube. The conductivity of the filtrate was measured against that of the standards and the pH determined.

Soil nitrogen was determined by the micro-Kjeldahl procedure that involves digestion with concentrated sulphuric acid at 330°C and hydrogen peroxide as an oxidant and selenium as a catalyst. The process was then followed by distillation and titration [9].

Soil particle density (g/cm^3) and bulk density (g/cm^3) were determined as described by Klute [11]. Soil sampling of the soil was done using core rings of known volume and the weight of both the core and soil taken. It was oven dried for 48 hours at 105ºC to remove the moisture and then weighed again. The bulk density was the determined by dividing the mass of the dry sample over the volume of the core ring.

Soil porosity (%) was determined by weighing 5 g of soil and putting it in a graduated cylinder. A known amount of water was poured bit by bit into the graduated cylinder until it fills the cylinder. The remaining amount of water was then measured and subtracted from the initial amount. The porosity is then calculated by dividing the used water by the total volume multiplied by 100%.

Soil moisture content (%) was determined by using the gravimetric method the initial weight of the soil sample was taken. The sample was then oven dried for 48 hours at 105ºC and the dry weight determined. Percentage soil moisture was calculated by finding the difference in the weights and dividing it by the initial weight and multiplying by 100%.

2.6 Statistical Analysis

Data obtained was subjected to analysis of variance using MSTAT-C programme package. The means were separated using Duncan's Multiple Range Test ($p \geq 0.05$) and the analysed data presented in tables.

3. RESULTS AND DISCUSSION

3.1 Effects of Soil Management Systems on Soil Physical Properties in Tea Bushes

Table 2 summarises the effects of different fertiliser types and rates on soil organic matter, bulk density, porosity, soil moisture content and particle density. From the Table, the means show that different fertiliser types showed a significant (p≤0.05) difference in relation to SOM. Enriched sheep manure at the ratio of 4:1 showed the highest SOM content followed by where NPK fertiliser was applied. SOM is a valued component of any sustainable production system. Many agricultural practices can influence the build-up or depletions of SOM. The same result has been confirmed by previous studies [12]. Similar results have been reported in many other studies [13]. They state that in both temperate and tropical regions addition of organic manures to the soil increases the soil organic matter content. To effectively increase SOM, therefore, the addition of organic treatments to the soil is crucial.

Further, the results also show that the application of ISFM is of great importance as this greatly improves the SOM content as opposed to application of organic and inorganic fertiliser alone. The control where no fertiliser was applied showed the lowest soil organic matter content. This was expected because fertiliser application is critical to any agricultural activity. Several other soil properties will, therefore, improve and consequently improve soil health and productivity and eventually improve soil degradation.

Table 2 further indicate that rates and the interaction between types and rates had no significant (p>0.05) difference on SOM. Generally, where no fertiliser was applied the lowest SOM content was observerved followed by at rate 240 kg N/ha. This means that no fertiliser application or application in too much quantities in the bid to increase yield does infact create more harm than good by degrading soil organic matter and consequently the soil quality. Similar results were observed by [14] where increase in N rates resulted in surface crusting, increased detachment by raindrops and decreased hydraulic conductivity.

The optimum soil conditions recommended for tea growth include a well-drained, deep and well-aerated soil with more than 2% organic matter [15]. In the present study,the values of organic matter are in the ranges of 5.0 to 8.0%. All the soil samples in the study area contains sufficient amount of organic matter. The slightly higher percentages can be attributed to the fact that during plucking the mature two leaves and a bud are picked because of the quality and the remaining leaves are left in situ.

Table 2. Effects of different fertiliser types and rates on physical properties of tea soil

Treatment	Rate (kg N/ha)	SOM	BD	P	SMC	PD
Control (No Fertiliser)	0	5.95	0.92	54.08	53.79	2.03
Sheep Manure	60	6.69	0.98	57.33	55.91	2.33
	120	5.58	0.93	57.09	59.01	2.18
	180	6.02	0.96	57.23	53.72	2.28
	240	6.05	0.93	56.05	58.77	2.17
Enriched Sheep Manure At 4:1	60	9.61	0.94	51.63	58.2	1.95
	120	9.58	0.91	54.88	56.66	2.06
	180	7.63	1	57.36	52.01	2.36
	240	7.03	0.95	55.2	58.42	2.14
Enriched Sheep Manure At 8:1	60	6.96	0.95	55.47	57.08	2.16
	120	7.6	0.96	55.8	50.02	2.2
	180	6.98	1.01	58.17	56.97	2.47
	240	6.99	0.89	57.76	55.57	2.14
Inorganic Fertiliser (NPK25:5:5)	180	7.62	0.92	49.95	49.32	1.86
P-Value		0.45	0.37	0.58	0.53	0.42

Sheep manure (SM); soil organic matter (SOM); bulk density (BD); porosity(P); soil moisture content (SMC); particle density (PD)

Soil is considered physically poor when it shows low rates of water infiltration, enhanced surface runoff, poor cohesion, low aeration and root density, and difficulty for mechanisation [16]. All the above-mentioned factors are affected in one way or another by the bulk density of the soil. Table 2 above further indicates that fertiliser rates significantly ($p<0.05$) affected bulk density with fertiliser application at the rate 180 Kg N/ha generally having the highest bulk density. Fertiliser types, that is whether the fertiliser applied was organic, inorganic or enriched had no significance ($p>0.05$) to bulk density. However, where the manure fertilisers were applied enriched and unenriched, the analysis showed slightly higher BD than where the NPK alone was applied. On the contrary, in their study on the changes in soil physical properties due to the organic waste application [17] observed a decrease in BD with application of organic sediments. In another long-term study done in semi-arid Mediterranean soil [3] found out that lower bulk densities were obtained where manure was applied and highest bulk densities were observed where mineral fertiliser was applied. BD is a dynamic soil property, altered by cultivation, compression by animals and machinery, weather and loss of organic matter.

The effects of different fertiliser types and rates on the soil porosity. The Table indicates that there were no significant ($p>0.05$) differences among fertiliser types or rates and their interactions in terms of porosity. Intrawech et al. [18] measured saturated hydraulic conductivity, penetrometer resistance, bulk density, soil water content, water stable aggregation and compaction and found no significant difference between 10 years of annual applications (224 kg N\ha) of a range of ammonium fertilisers and control plots. Generally, SM had the highest porosity and NPK alone had the lowest. Porosity generally increased with increasing rates. This was contrary to Yeoh and Oades [19] showed that the water stable aggregates resulting from addition of phosphoric acid to soils led to higher porosities than untreated soils.

Soil moisture content was not significantly affected by fertiliser types or rates. In general, however, NPK had the lowest moisture and enriched manures had the highest. [4,17] showed that due to the general predominance of organic matter, sewage sludge or composted domiciliary wastes increase the water holding capacity, and consequently the soil moisture content. Particle density of soil is the mass of soil sample in a given volume of particles. It was found out that different fertiliser types and rates have no significant effect on soil particle density but sole SM and enriched SM showed the highest levels and sole NPK being the lowest.

Table 3 showed that fertiliser types significantly ($p\leq0.05$) affected the soil pH with sheep manure showing the highest pH and NPK alone showing the lowest. The increase in soil pH with organic manure was because during decomposition of organic materials, level of available cations was increased as described by [14]. Increased soil pH with addition of organic manure and vice versa with use of inorganic fertilisers and enriched manures has been noted in other studies by Shisanya [20]. Fertiliser rates did not significantly ($p>0.05$) affect the soil pH and neither did the interactions.

The pH requirement for the optimum growth of tea is in the range of 4.5-5.6 and from the study, plots treated with SM only had a slightly higher pH than the required range and this could eventually affect the tea yield.

Nitrogen (N) plays a key role in the growth of plants and it is the most deficient mineral element in the soil [21]. Table 3 shows the effect of different fertiliser rates and types on soil nitrogen. The results show that there was no significant ($p>0.05$) difference between fertiliser types, rates or all their interactions with soil N. This result can be attributed to environmental factors such as leaching and denitrification. Nitrogen in both its organic and inorganic forms is very mobile in soil and moves largely with the soil water. Similar results have been observed and reported in some studies such as Diepeningen et al. [22]. The researchers were comparing the effects of organic and conventional management on chemical and biological parameters in agricultural soil.

Further, the results show that where the NPK fertiliser alone was applied there were the lowest levels of soil N. This may be due to the fact that mineral fertilisers tend to be rapidly solubilised into forms assimilated by plants but at the same time may be lost from soil’s root zone by leaching and volatilisation, hence the lowest compared to the manure treatments [23].

Table 3. Effects of different fertiliser types and rates on tea soil chemical properties

Treatment	Rate (kg N/ha)	SN	PH
Control (No Fertiliser)	0	0.15a	5.90ab
Sheep Manure	60	0.09a	6.10 ab
	120	0.06a	6.27 ab
	180	0.08a	6.57a
	240	0.06a	6.23 ab
Enriched Sheep Manure At 4:1	60	0.05a	5.97 ab
	120	0.06a	5.57 abc
	180	0.06a	5.73 abc
	240	0.07a	4.73c
Enriched Sheep Manure At 8:1	60	0.06a	5.77 abc
	120	0.05a	5.60 abc
	180	0.07a	5.53bc
	240	0.07a	5.23bc
Inorganic Fertiliser (NPK)	180	0.04a	4.67c
P-Value		0.87	0.04**

*Sheep manure (SM); soil nitrogen (SN); ** denotes significance at p<0.05; Means followed by the same letter within a column are not significantly different (p≤0.05) according to Kruskal-Wallis test.*

4. CONCLUSION

Soil organic matter is significantly affected by different fertiliser types with enriched sheep manure having the highest SOM contents. Where no fertiliser was applied the SOM content was the lowest and application of NPK and sheep manure alone also resulted in lower SOM content. The current results suggest that in a bid to improve soil organic matter in ones farm, adding enriched manure as opposed to organic fertiliser alone is advisable. The application of fertilisers at different rates resulted in no significant difference in soil organic matter content. However, application at very high rates and applying no fertiliser completely resulted in lower soil organic matter content. This suggests that as much as it may not matter how much fertiliser you apply to change SOM content in your soil, it is also important to avoid applying too much or not applying at all.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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