Yield Response of Tea to Integrated Soil Fertility Management in Timbilil Tea Estate in Kericho, Kenya

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Yield Response of Tea to Integrated Soil Fertility Management in Timbilil Tea Estate in Kericho, Kenya

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***Abstract*— *Poor crop productivity, high cost of inorganic fertilizers and low crop response to inorganic fertilizers are major problems that affect sustainability of crop production in Kenya. Application of inorganic fertilizers at rates much below the recommendation, which is mainly due to the limited economic capacity of smallholder farmers, has become the underlying cause of poor crop productivity along with the worsening soil acidity. Hence, the present study was carried out to find out the effect of integrated soil fertility management on the productivity of tea Timbilil tea estate. Kericho, Kenya. 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 analyzed for total organic matter, nitrogen content, bulk density, porosity, soil pH, porosity, particle density and soil moisture content. The data obtained were subjected to analysis of variance (ANOVA) using MSTAT-C programme package. SPSS version17.0 was used to analyse Pearson correlation and all the data presented in tables and figures. The tea yields determined showed a weak positive correlation between SOM and yields.The tea yields determined showed a weak positive correlation between SOM and yields. Results showed that fertilizer types significantly ($p \leq 0.05$) affected SOM with enriched sheep manure giving the highest values. Fertilizer rates had no significant ($p \leq 0.05$) difference on SOM. Fertilizer application at the highest rate of 240 kg N/ha had the lowest SOM content, which means high fertilizer application, causes more harm than good.From the results obtained it can be concluded that enriched manures tend to increase SOM content in soil which improve productivity and is recommended especially in the tea industry.*

***Keywords*— Productivity, Soil, Tea,Manure, Fertilizer.**

I. INTRODUCTION

Tea (*Camellia sinensis*) is one of the leading cash crops in Kenya. It is the second largest foreign exchange earner hence contributes significantly to the Kenyan economy. Fertilizer is the second largest tea production cost item after plucking with significant bearing on both yield and quality of tea (TBK, 2010). Thus, cost-effective investment in fertilizer is necessary for sustainable tea production. The growth and productivity of tea like many other crops, mainly depends on the nutrient availability in the soil as well as their utilization by the plant. Sustainable agriculture plays a significant role in sustainable development and particularly in curbing environmental degradation and climate change and population density. Soil is a major and important component in ensuring this and therefore, optimizing fertilization strategies is becoming an urgent need for sustainable crop productivity (Fan et al., 2011).

Fertilizers increase the growth rate and density of harvested shoots thereby increasing yields.However, the fertilizers applied to the soil either is lost, by being bound by soil or are washed out of the soil (Njogu et al., 2014). Additionally, imbalances in the soil occur in terms of nutrients, causing the soils to be moribund hence unsustainable for tea production (Ayiemba&Nyabundi, 2010).

Fertilizer recommendations for tea are primarily based on field trials that determine the crop response to various rates of fertilizer applications and must optimize crop yield and quality, maximize profitability and reduce the risk of environmental pollution (Belanger et al., 2000).

Just like most crops, tea depends on the nutrient availability in the soil for increasing yield. Inorganic fertilizer NPK (nitrogen, phosphorus and potassium) 25:5:5 are recommended generally for optimum yield and quality of tea. Modern agriculture depletes large amounts of nutrients from the land in form of yield, such that nutrient losses must be balanced by the addition of fertilizer, either inorganic or organic (Mafongoya et al., 1998). However, many tea growers prefer the use inorganic fertilizers because they are easily available. Inorganic fertilizers have easily available macro and micronutrients, which enhance growth; however, long-term use of inorganic fertilizer on the fields causes soil and environmental degradation (Phukan et al.,2008). The application of nitrogenous fertilizers in rates that exceed the optimal recommended may be uneconomical and may induce the acidification of the soil to levels that adversely affect tea quality and absorption of other nutrients (Anon, 2000). These negative impacts of chemical fertilizers coupled with escalating prices have led to growing interests in the use of organic fertilizers as a source of nutrients (Mahajan et al., 2008).

On the other hand, Integrated soil fertility management (ISFM) which involves the combined use of organic and inorganic fertilizer is good for improved tea yield and soil health (Tabu et al., 2015). Organic manure is available from farmers in form of sheep, cattle, chicken or compost. In some instances, big companies can produce their own compost. James Finlay's, for example, produces organic manure from composted instant tea waste, which is consistent in its chemical composition as noted by Wanyoko et al, 2003. Patterson (2015) states that nutrients in sheep manure provide adequate plant nutrients because of the sheep's feeding regime. It is high in both phosphorus and potassium, essential elements for optimal plant growth. These nutrients help plants to establish strong roots, defend against pests and grow into vibrant and productive plants. Because of its low odor, it is easy to handle and apply sheep manure (Patterson, 2015). Against this background, the present study sought to determine the effect of amended soils on tea yield. The results of this study are of great importance to several stakeholders especially tea growers both locally and around the globe. From the data obtained, the study was able to generate information on the most efficient types and rates of fertilizer necessary to optimize yield and most importantly one that does not cause soil degradation.

II. MATERIALS AND METHODS

Study Area

The research used an existing experiment, which started in 1985 at Tea Research Institute, Timbilil Estate in Kericho as shown in figure 3 below. 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 1954.4mm and the mean temperature was 17.1^{o}C.

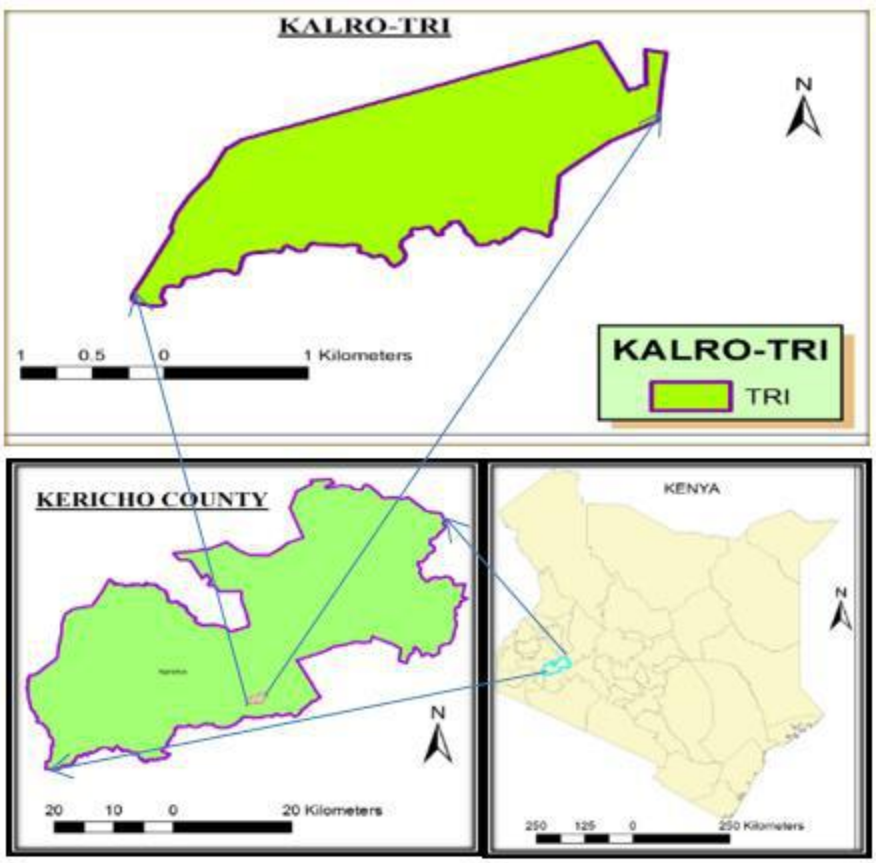

Fig.1: Study area

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The manures were initially applied at 20, 40, 60 and 80 kg N/ha/year till the year 1992 after which the rates were changed to 60, 120, 180 and 240 kg N/ha/year. The long-term average yields for the trial as from the year 1999 to the year of this study are as shown in the Figure 2.

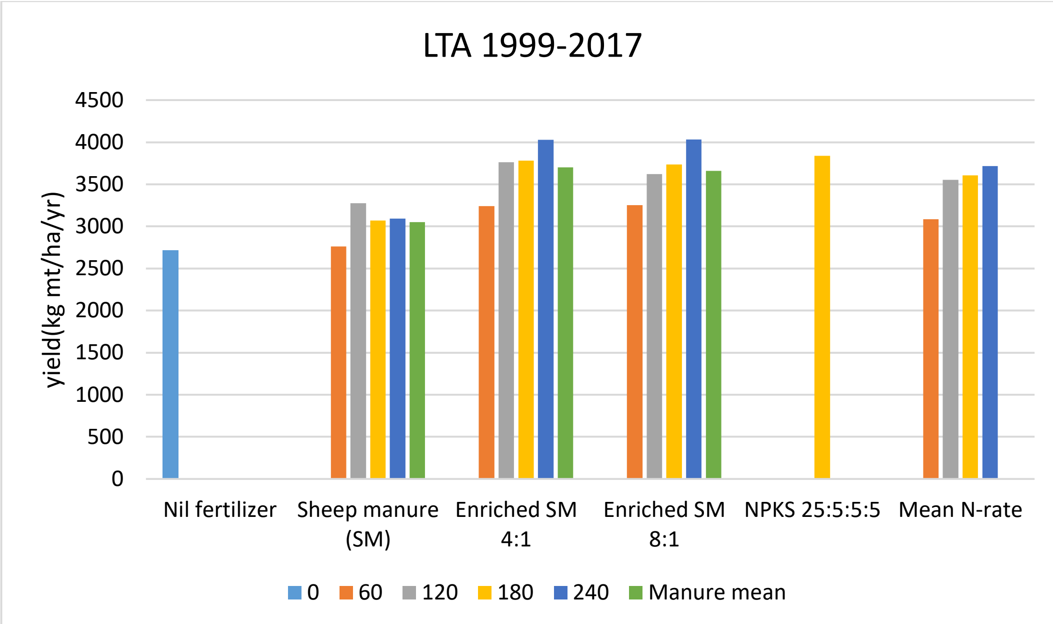

Fig.2: Long-term average yields of the experimental plot

Source: TRFK (2017)

Sample and Sampling Procedure

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.

Leaf Sampling

Fifty pieces of mature two leaves and a bud from each plot were plucked once in June and put in well-labelled bags. The samples were then taken to the laboratory where they were oven dried at 80ºc and milled for nitrogen status analysis.

Tea Yield Collection

Tea leaves were plucked at intervals of 7–10 days when the shoots had developed two mature leaves and a bud. The green leaf weight per plot was recorded for every plucking round for the entire study period. The green leaf yield was converted into kg made tea per hectare per year (KG MT ha^{-1} yr^{-1}) using the conversion factor of 0.225 (Pan et al., 2002). The monthly and consequently annual tea yields for the year under study period (2017) were recorded and input to a Microsoft Excel sheet.

Statistical Analysis and Presentation

Data obtained was subjected to analysis of variance using MSTAT-C programme package. The means were separted using Duncan's Multiple Range Test ($P \geq 0.05$) and the analysed data presented in tables and figures. Pearson correlation analysis was done using SPSS version 17.0 and data presented in tables.

III. RESULTS AND DISCUSSION

Yield is an important component in tea farming as the sole purpose of tea farming is to maximize yield for better economic benefits. Table 2 shows that there was a significant($p \leq 0.05$) difference in fertilizer types with NPK alone recording the highest yields and this can be attributed the fact that the N content is more available.

Treatments	SOM	SN	pH	Yield
No fertilizer	5.95	0.15	5.90^{ab}	2505.67^{ef}
SM at 60 kg N/ha	6.69	0.09	6.10^{ab}	2420.67^{f}
SM at 120 kg N/ha	5.58	0.06	6.27^{ab}	2997.67^{de}

SM at 180 kg N/ha	6.02	0.08	6.57[a]	2872.00[def]
sheep manure at 240 kg N/ha	6.05	0.06	6.23 [ab]	2613.67[ef]
enriched SM at 4:1 at 60kg N/ha	9.61	0.05	5.97 [ab]	2925.33[def]
enriched SM at 4:1 at 120kg N/ha	9.58	0.06	5.57[abc]	3797.00[abc]
enriched SM at 4:1 at 180 kg N/ha	7.63	0.06	5.73[abc]	3809.67[abc]
enriched SMat 4:1 at 240 kg N/ha	7.03	0.07	4.73[c]	3852.00[abc]
enriched SM at 8:1 at 60kg N/ha	6.96	0.06	5.77[abc]	2703.67[ef]
enriched SM at 8:1 at 120 kg N/ha	7.60	0.05	5.60[abc]	3647.67[bc]
enriched SM at 8:1 at 180 kg N/ha	6.98	0.07	5.53[bc]	3332.00[cd]
enriched SM at 8:1 at 240 kg N/ha	6.99	0.07	5.23[bc]	3907.67[ab]
NPK at 180 kgN/ha	7.62	0.04	4.67[c]	4070.00[a]
P-value	0.45	0.87	0.04	0.00

Sheep manure (SM); soil organic matter (SOM); SN; soil nitrogen

The enriched fertilizers also recorded high yields and it could be because of the improved nutrient release. Similar finding has been reported using a mixture of NPK 2:2:0 and cattle manure (Shisanya et al., 2009). This further emphasizes the need for ISFM however these results varied from Kekana et al. (2014) who found the highest yield in enriched fertilizer followed by NPK alone.Adediran et al. (2003) specifically investigated the effect of different organic amendments on crop yield. They used poultry litter with organic wastes, maize residues, leaf litter, urban waste, weed biomass, and soybean residue and applied these to amaranthus and tomato crops. They found that for optimal crop yield different amendments were required for different crops: while urban waste was best and soybean residue worst for amaranthus production, maize and soybean residues proved to be best for tomato production.

Table 2 further indicates that there were significant ($p \leq 0.05$) differences in fertilizer rates and tea yields where fertilizer application at the recommended rate of 180 Kg N/ha had the highest means. The results showed that adding very little or too much fertilizer results in low yield production.Increasing the N fertilizer rate resulted in increase in crop yield. Similar findings were reported in other experiments on different N rate in Kenya (TRFK, 2002). The highest N rate of 240Kg N/ha however showed a decrease in yield which emphases the fact that too much fertilizer application is in fact detrimental.

Correlation between SOM and soil physical and chemical parameters and tea yields

Increases in SOM are seen as desirable in agriculture as higher levels are viewed as being directly related to improved plant nutrition, greater aggregate stability, reduced bulk density, improved water holding capacity, enhanced porosity and earlier warming in spring (Lal, 2002).

According to Pearson's correlation as shown in Table 3 the results indicate that there was a negative relationship between SOM and soil nitrogen, bulk density, porosity, particle density and soil pH, p= ≤0.01. Where there were increased SOM there were reduced bulk density and porosity hence influencing water retention properties of soil. This reason further explains the positive relationship between SOM and soil moisture content, r=.008, p= ≤0.01. This is where there was an increase SOM there was also an increase in soil moisture content. It is well established that addition of SOM can not only reduce bulk density and increase water holding capacity, but also effectively increase soil aggregate stability Angers and Carter (1996).

Additionally, where there were increased SOM there were reduced soil pH indicating that high SOM could cause high acidity in soil.Oades et al. (1989) noted that too much addition of organic residues could result in acidification due to increased nitrification of N and addition of lime would be required to maintain a steady-state pH.The effect of different organic materials on soil pH was investigated by Wong et al. (2000). They incubated an Oxisol and an Ultisol with pruning's of young tree shoots and observed an increase in pH and decreased exchangeable Al content during the first 14 days.

In other studies, Pocknee and Sumner (1997) incubated an acid topsoil with different types of plant materials to study the effect of type of SOM and rate of amendment on soil pH. All treatments increased pHwithin a matter of days or weeks, however, the magnitude of change and the duration of the effect varied with SOM type and rate of application as greater application always resulted in greater pH shifts.

From the study carried out a negative correlation was observed between SOM and soil N as shown in Table 3 The opposite effect was observed in studies done by Baldock and Nelson (1999) where they noted thatwith the exception of fertilizers, SOM provides the largest pool of macro-

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nutrients with greater than 95% of N and S and 20 to 75% of P found in SOM.

SOM is an important source of nutrients for plants in general and tea in particular. Nitrogen, phosphorus and sulphur are the essential macronutrients needed by the tea bush. Most of the nutrients in SOM are derived from the mineralization of SOM and become available for plant uptake during decomposition and for this reason, the particulate organic matter fraction is often considered the most important proportion of SOM in providing nutrients to plants (Wolf and Snyder, 2003). Losses of nutrients might however, occur due to leaching or conversion to gaseous forms or as a result of immobilization. The negative correlation found here may be attributed to that.

The effect of inorganic fertilizer as well as FYM, compost and green manure on the soil fertility status in general was tested by Tolanur and Badanur (2003). Their data confirmed the results from other studies by Agbenin and Goladi, 1997 that NPK alone was not able to arrest the decline of C and N, and only a combination of NPK together with organic amendments increased and sustained soil productivity. Further, the results showed that there was a weak positive relationship between soil organic matter and soil moisture content. As SOM increased soil moisture also increased and this can be explained because SOM improves the water holding capacity in the soil.

The Table 3 shows that there is a weak positive relationship between tea yields and SOM, r=+.177. Variation in tea yields can be explained by organic matter content up to 17.7%. This implies that even though organically rich soils enhance tea yields, the magnitude of influence is not statistically significant at $p \leq 0.05$. Approximately 82% variation in tea yield can possibly be explained by other factors such as rainfall, air temperature, seasons, soil type, soil temperature among others.

Table.3: Pearson Correlation table between SOM, yield and different soil properties

	Yield	SOM	SN	BD	P	SNC	PD	LN	pH
Yield	1.000								
SOM	0.177	1.000							
SN	-0.171	-0.183	1.000						
BD	-0.142	-0.087	0.120	1.000					
P	0.096	-0.251	0.179	0.307	1.000				
SMC	-0.143	0.009	-0.164	0.046	-0.016	1.000			
PD	0.030	-0.220	0.168	0.701	0.879	0.020	1.000		
LN	0.088	0.045	0.137	-0.084	0.143	-0.186	0.056	1.000	
pH	-0.546	-0.242	0.046	0.008	-0.037	0.128	-0.049	0.070	1.000

soil organic matter (%) (SOM); soil nitrogen (SN); bulk density(g/cm^3) (BD); porosity(P); soil moisture content (%) (SMC); particle density(g/cm^3) (PD), leaf nitrogen (%) (LN)

IV. CONCLUSION

The relationship between SOM and soil functions that define soil quality and health is, however, not always linear. The relation may vary with the method used to measure stability and other soil and environmental properties that influence structural behaviour.There was a positive correlation between tea yields and SOM, however it was a weak relation. The results suggest that increasing SOM increases tea yields. However, to observe actual significant yield increase other factors such enough rainfall, optimum temperatures among others should also be included. Therefore, in order to maintain or enhance tea yields increasing SOM content alone is not recommended. Ensuring other factors such as other good agricultural practices and weather factors are at the required levels is also of importance when in a bid to increase tea yields.

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