Original Research Article

INFLUENCE OF FARMING PRACTICES ON THE CHEMICAL PROPERTIES OF SOIL IN SMALL SCALE TEA FARMS IN KIRINYAGA AND THARAKA-NITHI COUNTIES OF KENYA

1.1 Abstract

Soil chemical properties are important for growth of plants as they determine the nutrient availability for their uptake. Farming practices are treatments applied to farms in efforts to maximize crop productivity. Experiments were set up in Kangaita, Kirinyaga County, and Weru, Tharaka-Nithi County using randomized complete bock design to establish the influence of farming practices on the chemical properties of soil. This was aimed at understanding the role of the farming practices on the availability of soil nutrients and their effect on tea productivity. Each study site was divided into three zones depending on elevation and three farming practices identified within each zone namely neglected farms, manure applied farms and chemical fertilizer (NPK) applied farm. Soil samples were collected randomly from farms in each zone and analyzed for chemical properties. Soil acidity increased from neglected farms through manure applied farms to NPK fertilizer applied (standard) farms. The soils had generally low levels of potassium, magnesium and zinc due to rapid removal through harvesting of the young shoots and leaves.

Key words:

growth, farms, farming practices, productivity, soil chemical properties,

1.2 Introduction

Chemical properties of soil determine availability of nutrients for uptake by plants. The balance of both macro and micro nutrients in any soil play a vital role in plant growth. The interactions of the nutrients also affect the availability of each other either positively or negatively (Hamid, 2006; Thenmonzi, 2012; Sultan *et al.,* 2014). Various cultural practices including weeding, fertilizer application and even harvesting of farm produce affect the nutrient composition and balance in the soil which in turn affect the performance of crops in terms of productivity. Other factors like leaching and surface run off also play a role in soil physical and chemical composition.

Tea is cultivated using a number of cultural practices which are aimed at increasing the productivity of the tea plant. These cultural practices include weeding, pruning, fertilizer application and plucking/harvesting rounds (TBK, 2013). These practices greatly affect biodiversity in the soil (Wachira *et al.*, 2014). Soil biodiversity is the variety of life below the ground and it's an indicator of sustainable land use (Wachira *et al.,* 2014). Soil hosts a wide range of microbes (fungi and bacteria), macrobes (termites and earthworms) and mesofauna (acari, collembolan and nematodes) (Bardgett, 2005; Wachira *et al.,* 2014). Wachira *et al.,* (2014) noted that land use affects soil characteristics like organic carbon which was highest in least disturbed land. This was attributed to low biological activity in tea husbandry and the monocrop husbandry characteristic in tea growing. The amount of organic matter in the soil affects the health and performance of the plants. The organic matter acts to suppresses parasitic microorganisms such as nematodes thus improving the health of the tea plants (TBK, 2013; Sultan *et al.,* 2014).

Farmers use chemical fertilizers in the cultivation of tea, mainly Di Ammonium Phosphate (DAP) during nursery establishment and planting and Nitrogen Phosphorus Potassium (NPK) for top dressing (TBK, 2003). Excessive application of fertilizer can cause imbalance in nutrient uptake and fix some nutrients leading to poor performance of the tea plant (Hamid, 2006; Thenmonzi, 2012; Sultan *et al.,* 2014). In Kenya's small scale holder tea farming, the recommended NPK application rate is 50kgs per 700 bushes (TBK, 2013).

1.3 Materials and methods

The study was carried out in already established small-scale tea farms in Kirinyaga and Tharaka-Nithi counties of Kenya. The two counties were chosen to allow for comparison between various ecological zones. One tea factory catchment managed by KTDA was chosen per county. Each factory catchment was zoned into three based on elevation, that is, high, medium and low elevation as represented in agro-ecological zones LH0, LH1 and UM1 as described by Jaetzold *et al.,* (2010). Three types of agricultural/farming practices were considered across the ecological zones within the area of study. These were non-cultivated (neglected) farms, cultivated farms with regular application of NPK fertilizer and farms practicing organic farming with organic mulching and/or manure application. The survey was set up in a randomized complete block design. Five sub-samples were randomly obtained from each farm. Twenty-seven samples were collected from the three farming practices replicated three times. The samples were transported in a cool box to the laboratory for analysis.

Two hundred grams of soil from the farms in each zone was analyzed for physical and chemical characteristics. The analysis was aimed at measuring the soil pH, exchangeable acidity, total nitrogen (N), total organic carbon (TOC), available nutrient elements (phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (mg) and manganese (Mn) and available trace elements (iron (Fe), zinc (Zn) and copper (Cu). Soil pH was determined in a 1:1 (w/v) soil – water suspension with a pH meter.

Exchangeable acidity was determined using titration method. The soil was oven dried at 40^0 C. Five grams of the oven dried soil sample (< 2mm) was placed into a 50ml container. This was followed by addition of 125ml of 1 M KCl to the container and the contents were stirred using a clean glass rod. The mixture was allowed to stand for 30 minutes. The mixture was filtered through a funnel and leached with 5 successive 12.5ml aliquots of 1 M KCl. Three drops of phenolphthalein indicator solution were added and then titrated with 0.1 M NaOH to the first permanent pink color of the end point. The burette was read and the volume (ml) of NaOH used was recorded. The titration readings were corrected for a blank of titration of 75 ml KCl solution.

Total nitrogen was determined using Kjeldahl method. Two grams of the soil sample (< 0.5mm) was oven dried at 40^0 C and digested with concentrated sulphuric acid containing potassium sulphate, selenium and copper sulphate hydrated at approximately 350^0C. Total nitrogen was determined by distillation followed by titration with diluted standardized 0.1 M NaOH.

Total organic carbon was determined using the calorimetric method. All the organic carbon in the oven dried soil sample (< 0.5mm) at 40^0C was oxidized by acidified dichromate at 150^0C for 30 minutes to ensure complete oxidation. Barium chloride was added to the cool digests. After mixing thoroughly, the digests were allowed to stand overnight. The carbon concentration was read on the spectrophotometer at 600nm.

Available nutrient elements (P, K, Na, Mg and Mn) were determined using the Mehlich Double Acid method. The oven dry soil samples at 40^0 C (< 2mm) were extracted in a 1:5 ratio (w/v) with a mixture of 0.1 M HCl and 0.025 M H_2SO_4. Na, Ca and K were determined using a flame photometer. P, Mg and Mn were determined spectrophotometrically.

Available trace elements (Fe, Zn and Cu) were determined by AAS (atomic absorption spectrophotometer). The oven dry (at 40^0 C) soil samples (<2mm) were extracted in a 1:10 ratio (w/v) with 0.1 M HCl. The elements were then determined with AAS (atomic absorption spectrophotometer).

Statistical analysis was done using Genstat edition 14.

1.4 Results

Soil chemical analysis conducted yielded results for soil pH, exchangeable acidity, total nitrogen, total organic carbon, phosphorus, potassium, calcium, magnesium, manganese, copper, iron, zinc and sodium. At Kangaita, the figures ranged as follows; pH 3.0-4.95, exchangeable acidity (me %) 0.3-0.5, total nitrogen (me %) 0.54-5.5, total organic carbon (%) 5.6-8.17, phosphorus (ppm) 50-180, potassium (me%) 0.2-2.79, (Table 1.1). At Weru, the figures ranged as follows; pH 4.0-5.2, exchangeable acidity (me%) 0.2-0.5, total nitrogen (me%) 0.14-0.4, total organic carbon (%) 1.3-3.95, phosphorus (ppm) 5-25, potassium (me%) 0.22-0.78 (Tables 1.1 and 1.2).

Table 1.1: Soil test results for Kangaita

Zone	Farming practice	Soil pH	EA me%	TN %	TOC %	P ppm	K me%	Ca me%	Mg me%	Mn me%	Cu ppm	Fe ppm	Zn ppm	Na me%
Upper	Standard	3.00a	0.50a	0.56a	5.86a	125.00d	0.40cd	3.00a	1.67c	0.82f	3.81b	122.00f	3.52c	0.22cd
Upper	Manure	4.05d	0.50a	0.65bc	6.81bc	140.00e	2.72f	10.67g	3.63e	0.43d	0.66a	56.63d	8.62d	1.22f
Upper	Neglected	4.07d	0.50a	0.60b	6.61b	80.00b	0.26b	3.67b	0.56a	0.41d	0.64a	38.00c	3.95c	0.14a
Medium	Standard	3.80c	0.50a	0.65bc	6.62b	150.00f	0.42d	5.00d	0.95b	0.44d	0.54a	24.40a	2.20b	0.20c
Medium	Manure	3.32b	0.50a	0.65bc	6.69b	145.00ef	0.30b	4.00c	1.95d	0.30c	1.12a	145.00h	9.98e	0.17b
Medium	Neglected	4.25e	0.50a	0.56a	5.73a	50.00a	0.20a	3.00a	0.93b	0.60e	1.02a	34.43b	3.48c	0.16ab
Lower	Standard	3.02a	0.50a	0.79e	8.14e	178.30g	0.28b	6.00e	0.95b	0.28c	0.40a	137.00g	1.11a	0.20c
Lower	Manure	4.01d	0.50a	0.69cd	7.06cd	95.00c	1.50e	9.30f	3.80f	0.20b	0.57a	40.70c	13.10f	1.04e
Lower	Neglected	4.08d	0.50a	0.70d	7.25d	85.00b	0.36c	5.00d	0.93b	0.11a	4.90b	68.70e	2.00b	0.24d
	LSD	0.15	-	0.04	0.33	5.36	0.05	0.31	0.02	0.02	2.10	3.00	0.67	0.02
	C.V%	2.40	-	3.80	2.90	2.70	4.10	3.30	0.90	3.90	79.90	2.30	7.30	3.50

Means followed by different letters within the same column are significantly different. EA – exchangeable acidity, TN – Total Nitrogen, TOC – Total Organic Carbon P – Phosphorus, K – Potassium, Ca – Calcium, Mg – Magnesium, Mn – Manganese, Cu – Copper, Fe – Iron, Zn – Zinc, Na – Sodium, me – milli equivalents, ppm – parts per million, Upper - LH0, Medium - LH1, Lower - UM1

Table 1.2: Soil test results for Weru

Zone	Farming practice	Soil pH	EA me%	TN %	TC %	P ppm	K me%	Ca me%	Mg me%	Mn me%	Cu ppm	Fe ppm	Zn ppm	Na me%
Upper	Standard	4.33b	0.40a	0.38e	4.05g	10.00b	0.40d	8.23fg	0.46ab	0.71f	1.71ab	49.20h	5.51h	0.21c
Upper	Manure	4.12a	0.50a	0.35d	3.46f	23.33d	0.51e	8.26g	0.81b	0.30c	1.82ab	53.27i	2.22f	0.40e
Upper	Neglected	4.12a	0.50a	0.38e	3.93g	20.00c	0.22a	5.40d	0.50ab	0.18a	1.00a	34.10d	1.08a	0.16ab
Medium	Standard	5.16e	0.20a	0.22b	2.26cd	6.67a	0.28c	6.20e	1.76c	0.46e	2.89b	44.67g	2.08e	0.18b
Medium	Manure	5.02d	0.30a	0.24c	2.46de	23.33d	0.75f	12.20h	1.50c	0.21b	15.67e	23.90c	1.70b	0.35d
Medium	Neglected	4.42bc	0.40a	0.25c	2.65e	10.00b	0.24ab	8.00f	0.50ab	0.41d	1.00a	35.13e	3.22g	0.18b
Lower	Standard	4.47c	0.40a	0.21c	2.01bc	10.00b	0.26bc	5.00c	0.17a	0.71f	9.18d	13.97b	1.75c	0.14a
Lower	Manure	4.10a	0.50a	0.14a	1.34a	5.00a	0.52e	8.26g	0.47ab	0.44e	23.46f	39.50f	2.07e	0.36d
Lower	Neglected	4.16a	0.50a	0.15a	1.81b	10.00b	0.24ab	4.16a	0.57ab	0.88g	4.80c	11.60a	2.00d	0.15a
	LSD	0.11	-	0.01	0.36	3.00	0.02	0.24	0.40	0.02	1.36	0.45	0.05	0.02
	C.V%	1.50	-	2.80	7.90	13.20	3.10	2.10	31.30	2.90	11.50	0.80	1.20	5.60

Means followed by different letters within the same column are significantly different. EA – exchangeable acidity, TN – Total Nitrogen, TOC – Total Organic Carbon P – Phosphorus, K – Potassium, Ca – Calcium, Mg – Magnesium, Mn – Manganese, Cu – Copper, Fe – Iron, Zn – Zinc, Na – Sodium, me – milli equivalents, ppm – parts per million, Upper - LH0, Medium - LH1, Lower - UM1

There was a significant difference ($P<0.05$) in the three farming practices for soil pH, exchangeable acidity, total organic carbon, phosphorus, potassium, calcium, magnesium, manganese, copper zinc and sodium (Table 1.3 and Table 1.4). There was no significant difference for total nitrogen, and iron in the two sites.

Table 1.3: Effect of farming practices on Soil pH, exchangeable acidity, total organic carbon and micronutrients at Kangaita

Treatment	pH	EA me%	T N %	TOC %	P ppm	K me%	Ca me%	Mg me%	Mn me%	Cu ppm	Fe ppm	Zn ppm	Na me%
Manure	3.95b	0.40a	0.66a	6.80b	126.70b	1.51b	7.99b	3.13b	0.31a	5.77b	80.80a	10.57b	0.81b
Standard	3.11a	0.50b	1.17a	6.15a	151.10b	0.37a	4.67a	1.19a	0.52b	2.25a	94.50a	2.28a	0.21a
Neglected	4.44c	0.38a	0.67a	7.24c	71.70a	0.28a	3.89a	0.81a	0.38ab	2.19a	47.00a	3.15a	0.18a
LSD	0.24	0.04	0.953	0.24	26.14	0.61	1.93	0.56	0.14	1.89	51.55	1.73	0.28
C.V%	6.20	9.00	114.30	3.60	22.50	84.50	35.00	33.00	34.70	55.60	69.60	32.50	70.10

Means followed by different letters within the same column are significantly different. EA – exchangeable acidity, TN – Total Nitrogen, TOC – Total Organic Carbon P – Phosphorus, K – Potassium, Ca – Calcium, Mg – Magnesium, Mn – Manganese, Cu – Copper, Fe – Iron, Zn – Zinc, Na – Sodium, me – milli equivalents, ppm – parts per million

Table 1.4: Effect of farming practices on Soil pH, exchangeable acidity, total organic carbon and micronutrients at Weru

Treatment	pH	EA me%	TN %	TOC %	P ppm	K me%	Ca me%	Mg me%	Mn me%	Cu ppm	Fe ppm	Zn ppm	Na me%
Manure	4.41b	0.43b	0.24a	2.567b	17.22b	0.60b	8.36b	0.93a	0.32a	13.65b	38.90a	7.00b	0.37b
Standard	4.23a	0.46b	0.27a	2.22a	8.89a	0.32a	6.48a	0.80a	0.63b	4.60a	35.90a	3.11a	0.18a
Neglected	4.66c	0.34a	0.26a	2.87c	13.33ab	0.24a	5.86a	0.52a	0.50b	2.27a	26.90a	3.43a	0.17a
LSD	0.18	0.05	0.03	0.19	5.79	0.09	1.65	0.44	0.16	4.40	11.17	1.14	0.02
C.V%	4.00	11.80	9.30	7.60	44.10	22.70	24.00	58.40	34.30	64.4	33.00	25.30	8.80
P Value	<.001	<.001	0.07	0.015	0.025	<.001	0.015	0.168	0.004	<.001	0.091	<.001	<.001

Means followed by different letters within the same column are significantly different. EA – exchangeable acidity, TN – Total Nitrogen, TOC – Total Organic Carbon P – Phosphorus, K – Potassium, Ca – Calcium, Mg – Magnesium, Mn – Manganese, Cu – Copper, Fe – Iron, Zn – Zinc, Na – Sodium, me – milli equivalents, ppm – parts per million

1.5 Discussion

The farming practices had a significant effect on the soil pH. The soil acidity was highest in inorganic fertilizer applied farms (Standard) followed by manure applied farms and lowest in neglected farms. Tea grows well in acidic soils of pH between 4.5 and 5.6 (Njogu *et al.*, 2013). However, as this study revealed and as noted by Sultan *et al.*, (2014), the continuous use of nitrogenous fertilizer increases the soil acidity. The farmers tend to use the recommended fertilizers non-judiciously with the hope of increasing yield but this instead leads to increase in soil acidity, pollution of water masses and poses a challenge to the sustainability of the tea production (Tabu *et al.*, 2015). The acidified soils tend to adversely affect the soil microorganisms (Thenmonzi *et al.*, 2012). The applied manure plays an important role in reducing soil acidity which is increased by continuous application of nitrogenous fertilizers (Sultan *et al.*, 2014).

There was a significant difference among the three farming practices in soil pH, exchangeable acidity, total organic carbon, phosphorus, potassium, calcium, magnesium, manganese, copper zinc and sodium. There was no significant difference for total nitrogen, and iron in the two sites. This can be attributed to the interaction of both macro and micro nutrients in the soil (IPCC, 1990;) and application of the fertilizers affecting soil pH (Sultan *et al*., 2014).

Soil pH was also affected by the farming practice due to the type and intensity of fertilizer application. High rates of inorganic nitrogenous fertilizers led to increased soil acidity (Sultan *et al*., 2014) while application of manure led to decrease in soil acidity.

Nelson (2006) noted that deficiency of zinc in the soil can be induced by a buildup of phosphorus resulting from excessive application of phosphate fertilizers. Kitundu *et al.*, (2006) noted that high levels of iron in the soil led to copper deficiency and that even though iron was found to be sufficient in the soil, it was poorly reflected in the leaves due to high levels of zinc in the leaves. Nath, (2013b) noted that high soil pH results to retention of micronutrients in the soil. Nath, (2013b) also noted that the concentration of Mn, Cu, Fe and Zn increases with the increase in organic content in the soil. Jessy (2010) noted that where potassium is not matched with nitrogen, there is depletion of starch reserves in the roots, degeneration of feeder roots characterized by die back and buildup of nitrates in the soil. Phosphorus is affected by soil acidity. Hamid (2006) reported that phosphorus availability to plants is highest when there is moderate pH of about 5.5 – 7 and becomes exceedingly unavailable at pH above 7 and below 5.5. Hamid (2006) further noted that in very acidic soils, phosphorus combines with hydroxides of iron and aluminum to form compounds that are unavailable to plants.

The availability of nitrogen in the soil is affected by other nutrients and it also affects the availability of other nutrients in the soil. IPCC, (1990) reported that increase in nitrogen leads to decrease in mature leaf P, K, Ca and Mg due to the acidification of the soil by the ammonia in the fertilizer. A decrease in mature leaf potassium can be attributed by leaching triggered by ammonium nitrate in NPK fertilizer (IPCC, 1990).

1.6 Conclusion

Various agricultural practices have a significant effect on the availability and nutrient balance in the soil. There are generally low levels of potassium, magnesium and zinc in soils under tea due to rapid removal through harvesting of the young shoots and leaves

1.7 References

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