



# **Glomus intraradices and Funneliformis mosseae am Strains Influence on Soil Physical, Biological and Chemical Characteristics in Tea Plantations in Kenya**

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## **Authors' contributions**

*This work was carried out in collaboration between all the authors. All authors read and approved the final manuscript. Authors AC and JPGO designed the study and wrote the first draft of the manuscript. Authors NKK and author JPGO managed the analyses of the study. Authors AC and MM managed the literature searches. All authors read and approved the final manuscript*

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## **ABSTRACT**

Arbuscular mycorrhizal (AM) fungi occur over a wide range of agro climatic conditions and are geographically ubiquitous. Arbuscular mycorrhizal fungi are the medium of soil structure, they determine the flow of water, nutrients, and air, directs the pathways of root growth, and opens channels for the movement of soil animals. As the moderator of the microbial community, they also determine the metabolic processes of the soil. In other words, the mycorrhizal network is practically synonymous with ecosystem function. The tremendous advances in research on mycorrhizal physiology and ecology over the past 40 years have led to a greater understanding of the multiple roles of AMF in the ecosystem. The current study was informed due to the depletion of nutrients and poor soil microbiology in tea production whose production has declined in the recent years. The trial was conducted in the research and development greenhouse at the James Finlays Farm

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in Kericho County, Kenya. The experiment was laid out in a Randomized Complete Block Design (RCBD) with factorial arrangements of tea clones and mycorrhizae levels. The phosphorus treatments consisted of a standard rate of 107.66kg ha<sup>-1</sup>, two clones of the tea (S15/10 and SC 12/28) and two mycorrhizal strains (*Funneliformis mosseae* and *Glomus intraradices*) at two rates (50 kg ha<sup>-1</sup> and 70 kg ha<sup>-1</sup>) and an untreated control without mycorrhizae. The soil pH was positively influenced by reducing the acidity content significantly where mycorrhizae strains were introduced with the highest unit change (1.3) was recorded on clone SC 12/28 at the 50 kg Mycorrhizae ha<sup>-1</sup> rate. The same treatment also significantly increased the soil total phosphorus level (2.3 g/kg) compared to all other treatments with the least change observed on the control. Application of AMF strains *Glomus intraradices* and *Funneliformis mosseae* is recommended in tea production at the rate of 50 kg ha<sup>-1</sup> which improves and enhances the general positive characteristics of soil health.

**Keywords:** Arbuscular mycorrhizal (AM); soil; nutrients; microbial community.

## 1. INTRODUCTION

The leading foreign exchange earner crop in Kenya is tea which is contributing about 26% foreign exchange and 4% GDP [1,2]. The crops' plants are known to grow on acidic soils as is the case in the study area of Kericho in Kenya. The soils were found to be strongly leached with a low pH, high Al concentration, and marginal availability of nutrients. Low availability of P, owing to low native content and high P fixation capacity of acidic soils, is one of the main limiting factors for the productivity of tea plants [3].

Mycorrhizae tend to be the largest component in the ecosystem primarily because both the fungi and the associated roots are turned over rapidly. Many species of mycorrhizal fungus spores exist naturally in most soils [4]. Arbuscular mycorrhizal (AM) fungi are the most abundant type of fungi in the soil and are one of the most dominant and important organisms in the soil, comprising 5–50% of the total microbial biomass in soils. They play a key role in land reclamation, sustaining soil fertility and cycling of nutrients, which in turn increases plant vigour and productivity. Mycorrhizae differ in both structural characteristics and global distribution, which is strongly correlated with the respective functional role [5].

Productivity of agricultural land among small-holder peasant communities is diminishing due to various factors with the main ones being depleted soil fertility and destabilized nutrient acquisition by plants. Also, the soils are low in nutrient capital, moisture stress, occasioned by erosion, increased phosphorus fixation, high acidity with aluminium toxicity, and low soil biodiversity. These factors directly limit food production in annual cropping systems [6].

One of the potential solutions in land reclamation, sustaining soil fertility and cycling of nutrients, which in turn increases plant vigour and productivity is through application of mycorrhizae. Mycorrhizal fungi also play a significant role in the regulation of soil biological activity because of their abundance throughout the uppermost soil layer [7]. Soils typically contain several species of AMF, a combination of which is needed to function as an adequate plant soil interface [8,9] but there is limited information of how these combinations can improve soils within the tea growing estates and farms thus prompting this study.

## 2. MATERIALS AND METHODS

### 2.1 Sites Description

The study was conducted at the Applied Research Department of James Finlay which is located between Kericho and Bomet Counties of Rift Valley, Kenya. The location altitude is 2157 above sea level with average annual rainfall of about 2000mm. It lies on the Equator, at latitude 0° 24'21.09"S and longitude 35° 19'26.73"E.

### 2.2 Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with factorial arrangements between the tea clones (SC 12/28 and S 15/10) and the mycorrhizal strains at three rates (0, 50 kg ha<sup>-1</sup> and 70 kg ha<sup>-1</sup>). The treatments were laid out in a factorial arrangement because of the two factors (tea clones and AMF strains) and replicated three times. The clones were selected because of their high yielding potential while two AM strains *Glomus intraradices* and *Glomus mosseae*

(currently renamed *Funnelliformis mosseae*) were selected because of their popularity in enhancing root establishment and nutrient uptake.

### 2.3 Data Collection on Soil Characteristics Change

The soil samples were analysed for the following chemical properties using the described procedures before transplanting and after the study of the transplants to determine soil properties change. The soil pH was determined electrometrically as described by Van Lierop W [10]. Total nitrogen was determined by the Macro Kjeldahl method [11]. Available phosphorus was determined by the Olsen method [12]. Potassium was measured using the flame photometer method [11] whereby a neutral salt solution replaced cations present on the soil exchange complex. Organic carbon was determined using the Walkley-Black procedures [13]. Lastly, the Ca, Mg, Mn, Cu, Fe, Zn, and Na were determined using the Diethylenetriamine Pentaacetic Acid (DTPA) method as described by Lindsay and Norvell [14].

### 2.4 Data Analyses

Data was collected, cleaned, and subjected to the Two-way analysis of variance (ANOVA) to determine treatment effects on dependent variables at  $P \leq 0.05$  probability level using GenStat statistical package Version 15.1. In case

where there were significant differences, separation of means was done using Fischer's Protected LSD test at 95% confidence level.

## 3. RESULTS AND DISCUSSION

### 3.1 Soil Chemical and Physical Changes

The net soil chemical and physical properties showed significant changes before and after application of Arbuscular mycorrhizae on the two clones of tea under different levels (Tables 1 and 2). The highest change was observed on the organic carbon, total nitrogen, zinc, and calcium in both clones when mycorrhizae was added at the rates of 50 and 70 kg ha<sup>-1</sup> while the lowest was on the control treatment. There was a significant reduction on the aluminium content in the soil due to application of mycorrhizae in both rates under the 2 tea clones. The change on the sulphur content was marginal on both levels of mycorrhizae application in both tea clones. The phosphorus content in the soil improved in both clones due to application of the mycorrhizae with a range of +1.9 and +2.5 mg/kg as shown in Tables 1 and 2.

The increase in the soil carbon was majorly because the AM fungi influences bacterial, fungal, and microarthropod communities by providing them with substrates in the forms of decomposing fine ephemeral hyphae and the deposition of hyphal biomolecules which directly

**Table 1. Influence of arbuscular mycorrhizae on soil chemical and physical net change on clone SC 12/28 under different rates**

Soil Property	Initial Soil Status	50 kg/ha	70 kg/ha	Control
pH (KCl)	4.1	+0.6	+0.5	+0.3
Sand	69.3	-2.3	-3.1	+0.2
Clay	21.9	-3.4	-4.1	+1.1
Loam	8.8	+4.2	+4.8	-0.3
Organic Carbon (g/kg)	6.8	+29.6	+27.7	+10.6
Total N (g/kg)	0.7	+2.5	+2.5	+0.1
Total Phosphorus (g/kg)	0.5	+0.7	+0.8	+0.2
Total Sulfur (g/kg)	0.3	+0.2	+0.2	+0.1
Potassium (exch.) (mmol+/kg)	1.7	+6.9	+7.4	+1.7
Calcium (exch.) (mmol+/kg)	17.4	+62.2	+50.6	+21.9
Magnesium (exch.) (mmol+/kg)	20.6	+9.1	+8.0	+3.8
Zinc (M3) (mg/kg)	0.1	+7.1	+12.4	+1.1
Copper (M3) (mg/kg)	ND	+1	+3.3	+1.4
Cation Exchange Capacity (mmol+/kg)	107.8	+61.9	+86.1	+23.3
Total Aluminium (g/kg)	150.9	-21.2	-17.1	+18.9
Total Potassium (g/kg)	3.9	+1.7	+1.6	+0.6
Total Silica (g/kg)	185.8	+21.8	+9.4	+12.5
Total Iron (g/kg)	117.1	-10.5	-7.9	+10.7

**Table 2. Influence of arbuscular mycorrhizae on soil chemical and physical net change on clone S15/10 under different rates**

Soil Property	Initial Soil Status	50 kg/ha	70 kg/ha	Control
pH (KCl)	4.1	+1.3	+1	+0.7
Clay (%)	75.2	-2.5	-2.7	+0.1
Sand	10.6	-3.6	-3.8	+1.3
Silt	14.2	+4.7	+5.1	-0.5
Organic Carbon (g/kg)	6.8	+25.8	+23.5	+8.1
Total N (g/kg)	0.7	+2.3	+1.9	+0.3
Total Phosphorus (g/kg)	0.5	+2.3	+1.5	+0.1
Total Sulfur (g/kg)	0.3	+0.1	+0.1	-0.5
Potassium (exch.) (mmol+/kg)	1.7	+11.8	+9.5	+3.4
Calcium (exch.) (mmol+/kg)	17.4	+115.8	+71.6	+18.2
Magnesium (exch.) (mmol+/kg)	20.6	+8.8	+7.1	+3.1
Zinc (M3) (mg/kg)	0.1	+13.4	+8.8	+2.7
Copper (M3) (mg/kg)	ND	+2.1	+1.3	+1.4
Cation Exchange Capacity (mmol+/kg)	107.8	+138	+74.3	+15.6
Total Aluminium (g/kg)	150.9	-4.2	-14.9	+16.2
Total Potassium (g/kg)	3.9	+1.1	+0.9	+0.5
Total Silica(g/kg)	185.8	+13.4	+10.4	+10.2
Total Iron (g/kg)	117.1	-14.3	-12	+13.7

acts on the colloids influencing the soil structure [15]. Mycorrhizal fungi exudes (photosynthetically-derived) carbon into the mycorrhizosphere which attract soil organisms, these microorganisms in turn uses the exudates to transform organic matter and soil minerals into plant-available nutrients which also stabilize soil aggregates [16]. The arbuscular mycorrhizal fungi applied also worked as the medium of soil structure which is important in determining the flow of water, nutrients, and air, directs the pathways of root growth, and opens channels for the movement of soil microorganisms. It acts as a moderator of the microbial community and other metabolic processes of the soil. In other words, the mycorrhizal network is practically synonymous with ecosystem function [17].

The change in the soil pH towards neutral was probably because the mycorrhizal fungi enhanced plant growth, stimulate specific microbial activity, and induce the synthesis of oxidative enzymes that enhance degradation of pH [18]. Moreover, AMF may also have contributed on improving the phytoremediation performance of contaminated soils (Smith and Read). Mycorrhizae lower the rhizosphere acidity due to selective uptake of  $\text{NH}_4^+$  (ammonium-ions) and release of  $\text{H}^+$  ions. Increased soil pH increases the solubility of phosphorus precipitates. The hyphal uptake of  $\text{NH}_4^+$  also increased the flow of nitrogen to the plant as  $\text{NH}_4^+$  was adsorbed to the soil's inner surfaces

and must have been taken up by diffusion. Thus, AMF are to be considered as an important microbial component in the rhizosphere whose benefits on plants are related to improved nutrient status and water absorption, and increased tolerance and survival under environmental adverse conditions including acidity and salinity as observed in this study [19]. In a study by Cherotich et al. [20] on 20 different tea clones, they found that most of the mycorrhizal isolates were able to germinate at pH 3.8, whereby they lowered the rhizosphere pH due to selective uptake of  $\text{NH}_4^+$  (ammonium-ions) and release of  $\text{H}^+$  ions. It was also noted that, decreased soil pH increases the solubility of phosphorus precipitates. The hyphal uptake of  $\text{NH}_4^+$  also increases the flow of nitrogen to the plant as  $\text{NH}_4^+$  is adsorbed to the soil's inner surfaces and must be taken up by diffusion [20].

In summary, mycorrhiza form communication pathways between plants and soil, influencing plant nutrient cycling, and restoring and maintaining soil fertility, thus influencing the microbial communities of the rhizosphere, and extending the influence of plants to the soil. Therefore, they increase the diversity of the carbon sources available to the microorganisms in the rhizosphere, which is partly due to their nutritional mode, the excretion of catabolic enzymes to the surrounding medium, and to the direct access by the AMF to the plant carbon [21].

#### 4. CONCLUSION

Application of mycorrhizae significantly and positively influenced the soil physical, biological and chemical composition of soils within the study area. Application AMF strains *Glomus intraradices* and *Funneliformis mosseae* is recommended in improving the general soil fertility and condition at the rate of 50-70 kg ha<sup>-1</sup> and thereby offering a sustainable production system in tea production.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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