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EFFECT OF TILLAGE TOOLS (HAND HOE AND FORK) ON BANANA ROOTING SYSTEM OF THE EAST AFRICAN HIGHLANDS BANANA

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ABSTRACT: In East Africa, highland bananas (AAA-EA, *Musa* spp.) are a primary staple crop for smallholders (<2 ha) who traditionally practice labor-intensive non-mechanized farming, often with common beans (*Phaseolus vulgaris*) as an understorey intercrop. At the onset of the wet season, farmers till their banana fields to allow the bean intercropping. This study aimed at testing whether tillage with a forked hoe would causes less damage to the banana root system than the traditional hand hoe. Measurements were taken in Walungu / Sud-Kivu in the Eastern DR Congo. A field trial with highland bananas was planted in April 2008 to explore the impact of mulching and tillage on banana performance. It consisted of a randomized complete block design with four treatments and four replicates. On September 2010, each T0 plot (i.e., tilled with blade hoe and mulch removed at onset of wet season) was divided into two sub-plots. The first sub-plot was tilled with conventional hoe (blade) whereas a forked hoe was used in the second sub-plot. Banana root fresh weight and length of cord roots were assessed at 0-10 cm and 10-20 cm soil depths using the core sampling method. No significant difference was found between the two tillage tools, either in terms of root fresh weight or root length. For both blade hoe and forked hoe, tillage decreased significantly the root fresh weight and root length within the 0-10 cm soil layer, but showed little impact at greater depth. We conclude that any type of tillage practiced with a hoe by the farmers in the study area strongly affects the banana root system in the topsoil.

KEYWORDS: tillage tools, root system, banana, East African highlands.

1 INTRODUCTION

In Sud-Kivu (DR Congo), Rwanda and Burundi, bananas (Musa spp.) are frequently intercropped with annual crops, of which common bush beans (*Phaseolus vulgaris* L.) are the most common. At the onset of growing season of annual crops, the banana fields are tilled manually using a hand hoe (blade) or a forked hoe to prepare the seedbed. Farmers believe that tillage favors the bean performance, but it may also seriously damage the superficial banana root system ([1]; [2]). Compared with no-till plots, [3] reported a reduction by approximately 74 to 95% of the fresh weight and length of banana cord roots in the upper 10 cm soil layer in plots tilled with a hand hoe. To avoid banana roots being damaged by tilling with a hoe and to favor both the bean and banana growth, no-till or minimum tillage systems may be adequate alternatives. In case of minimum tillage, the choice of lesser harmful tillage tools is needed. Farmers indicated that the forked hoe may be such a tool. The study aimed at determining the comparative effects of forked hoe and blade hoe tillage on banana root system damage.

2 MATERIALS AND METHODS

The study was conducted in Walungu (2.440°S, 28.411°E, and 1,638 m above sea level) / Sud-Kivu in DR Congo. Soils in Walungu are rather infertile dystric, humic nitisols or humic Ferralsols [4], developed on eruptive formations from the Pliocene or Pleistocene and characterized by a heavy clay texture, low soil pH, low base saturations and high organic carbon contents [5]. Soil samples, taken 24 months after establishment of the plantation, were analyzed for standard physico-chemical

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properties (Table 1). The rainfall in Sud-Kivu is bimodal, the study area receives on average 1500–1800 mm per year, and the growing period extends to over 325 days per year [6].

The experiment was setup on April 2008 to evaluate the effect of four crop management systems on the agronomic performance of the bananas intercropped with beans system, and on the soil properties. The traditional banana management system (tillage with export of banana residues, T0) was compared with three alternative treatments not discussed here. The experimental layout was a randomized complete block design with four treatments and four replications. Planting materials were vigorous "sword" suckers of banana cultivar "Ndundu" (AAA-EA). Planting hole size was 50 x 50 x 50 cm, and plant spacing was 2 m x 2 m (2,500 plants/ha). Bush bean was sown in all treatments at spacing of 40 cm x 20 cm, with two seeds per hole (approximately 250,000 plants/ha). No fertilizers or organic manure background and pesticide were applied.

In this study, measurements were done only on T0 plots. Initially, control plots (T0) were plowed using a hand hoe (blade) before the planting of beans (September and February). Crop residues (leaves and stem of banana, and haulms of beans) were removed from the plot twice a year to facilitate tillage. Each T0 plot was divided into two sub-plots. The first sub-plot was tilled using the hand hoe whereas a forked hoe was used in the second sub-plot. The banana root system was characterized using a metal cylinder ("core sampling") which has the advantage of being simple, takes less time and gives a good estimate (>80%) of the banana root system [7]. The metal cylinder had a diameter of 30 cm and a height of 50 cm. Roots trapping was performed using the method described by [7]. Immediately after tillage, banana roots cut during tillage were carefully collected and removed from the plot in order to avoid interference with subsequent observations. The soil was then leveled gently with a rake. In each sub-plot, four mats were selected randomly for measurements. Eight measuring angles (0, 45, 90, 135, 180, 225, 270, 315 degree) were defined around each mat selected for observations. The angle 0° was defined in the direction of the emergence of the daughter sucker of the mat selected. Other angles were defined clockwise. From a mat to another, a different angle was chosen randomly. The edge of the metal cylinder was placed at 15 cm from the mat and driven into the ground. The first step was to drive the cylinder up to 10 cm depth and the second measurement was done from 10 to 20 cm depth at the same measuring point as the first one. For each soil depth (0-10 and 10-20 cm), the trapped roots were washed to discard soil particles and drained in the shade to remove excess wash water. Dead roots were removed before measurement.

Root characteristics assessed included root fresh weight and cord root length. Root fresh weight was measured using a precision balance (0.01 g). Length (cm) of roots was determined using a ruler. Fresh weight and length of the cord roots data were subjected to comparison of means tests (Student's test / Wilcoxon) using the SAS 9.2 Enterprise Guide 4.2 software.

3 RESULTS AND DISCUSSION

The fresh weight and length of the cord roots measured on sub-plots tilled using blade hoe and forked hoe are shown in table 2. Irrespective of the soil depth, no significant difference was found between the two tillage methods, neither in terms of root fresh weight nor in terms of root length (Table 2), although sub-plots worked with a forked hoe had systematically higher values of root fresh weight or root length. Relatively higher values in sub-plots plowed with a forked hoe could be related to the fact that a hand hoe (tool with blade) irreversibly cut a root while the fork (tool with teeth) cut and / or injure, and exposes it at the soil surface. However, due to sunlight actions, roots exposed at the soil surface tend to wilt. Consequently, the effects of hoeing on root characteristics turn out to be similar across the two sub-plots.

For both tillage tools, root fresh weight and root length in the upper 10 cm soil depth are significantly lower ($P < 0.0001$) than those observed at 10-20 cm depth (Table 2). This may indicate that tillage using hand hoe or fork, as practiced in the study area, affected mainly banana roots located in the upper 10 cm soil layer. In a nitisol at Mulungu and Kabamba (Sud-Kivu in DR Congo), the authors reported similar results on plots tilled with hand hoe.

In the surface layers, [8] found that banana and plantain roots have a root length density (cm/cm^3) of about 1 cm/cm^3, that is similar to the root systems of trees. Very low values of root length density observed in this study (0.007-0.033 cm/cm^3) suggest that tillage had a negative effect on banana roots located within the first 20 cm of the soil. As the root length density reflects the capacity of the root system to explore soil volume, lower values of root length density in the upper 20 cm soil layer with high soil fertility (Table 1) could have negative impact on banana nutrition and growth.

Table 1. Soil physical and chemical properties of the Walungu study site

			Exchangeable cations										
Depth	pH_{H2O}	Org.C	Ca	Mg	K	Na	Al+H	Al^{3+}	CEC[1]	ECEC	Penetration resistance	P^2	Mn
(cm)		%	----------$cmol_c$/kg soil----------								Kg/cm^2	-----mg/kg-----	
0-10	6.1	3.04	11.54	5.29	0.41	0.03	0.14	0	27	19	13.07	2.4	144.5
10-20	5.8	3.01	11.26	5.04	0.20	0.03					14.13	2.0	115.8
20-30	5.9	2.49	10.05	4.52	0.13	0.02					21.26	1.4	171.2
30-40	6.1	1.56	8.8	4.3	0.10	0.02	0.15	0	21	14	26.76	0.9	227.1
40-50	5.9	0.91	6.39	3.17	0.10	0.02					28.52	1.2	223.4
50-60	6.1	0.78	6.82	3.13	0.08	0.02					28.16	1.3	177.6
60-70	5.8	0.74	5.99	2.66	0.11	0.02	0.47	0.06	18	10	28.78	1.4	145.9
Critical levels*	>5.2[3]	>1.74[3]	>6[4]	>2.5[4]	>1.5[4]	<1.0[4]					<20[5]		>200

1. CEC NH4OAc. pH7. 2. P available - Mehlich3. No value indicates that soil analysis was not done.
**Critical level as quoted by [9]3; [10]4; [11]5.*

Table 2. Root fresh weight and root length density (values are means ± standard deviation)

	Root fresh weight (g/dm^3)			Root length density (cm/dm^3)		
Soil depth	Hoe	Fork	*P*-value	Hoe	Fork	*P*-value
0-10 (cm)	0.68±0.65	1.13±0.95	0.14^{ns}	6.96±6.21	10.3±7.37	0.05^{ns}
10-20 (cm)	3.07±2.02	3.8±2.56	0.42^{ns}	27.4±16.47	32.8±18	0.40^{ns}

ns: not significant at 0.05 level.

4 CONCLUSION

In perennial the banana-bean intercropped systems, tilling soil with a forked hoe affected the banana root system to the same degree as a traditional hand hoe with blade, in the upper 20 cm soil layer. In this respect, blade or forked hoes with a 'depth' of 20 cm seem unsuitable for the adoption of minimum tillage in banana-bean cropping systems. Additional research on minimum tillage in banana-based systems should preferably focus on selecting lesser harmful tillage tools to the banana roots.

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