

## RELATIVE PERFORMANCE OF ROOT AND SHOOT DEVELOPMENT IN ENSET AND EAST AFRICAN HIGHLAND BANANAS

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### ABSTRACT

East African highland bananas and enset belong to the genera *Musa* and *Ensete* (*Ensete ventricosum*), respectively. The root, corm and shoot growth of field-established enset and East African highland banana cultivars was assessed. Banana and wild enset plants were assessed in Uganda, while domesticated enset plants were assessed in Ethiopia. Growth traits of the enset and banana mats in Uganda were recorded at flower emergence of the banana plant crop, while enset plants in Ethiopia were assessed at 4 and 5 years after planting. The results obtained in Uganda indicate that enset had a significantly ( $P < 0.05$ ) shorter and thicker pseudostem compared to banana. In addition, enset had a larger root system with thicker cord roots. Results further showed that young enset plants had a significantly lower shoot-root ratio compared to the bananas. The shoot-root ratio in enset is, however, clone dependent and increases with an increase in age. The results also showed that root density in enset sharply decreases with increasing soil depth.

*Key Words:* *Ensete ventricosum*, Ethiopia, shoot-root ratio, Uganda

### RÉSUMÉ

Les bananes de montagne d'Afrique de l'Est appartiennent respectivement à l'espèce genera *Musa*, et *Ensete* (*Ensete ventricosum*). La croissance des racines, bulbes et rejets de champ-établi d'enset et de cultivars de banane de montagne d'Afrique de l'Est, ont été évaluée. La banane et les plantes d'enset sauvages ont été évaluées en Ouganda, pendant que les plantes d'enset domestiqué ont été évaluées en Ethiopie. Les traits de croissance des tapis d'enset et banane en Ouganda ont été enregistrés à l'apparition de fleur de la récolte de plante de banane, pendant que les plantes d'enset en Ethiopie ont été évaluées à 4 et 5 ans après la plantation. Les résultats obtenus en Ouganda indiquent que cet enset a eu significativement ( $P < 0.05$ ) pseudostem plus court et plus épais à comparer à la banane. Par ailleurs, enset a un plus grand système fondamental avec les racines de corde plus épaisses. Les résultats poussés ont montré que ces jeunes plantes d'enset ont une grande proportion des rejets en comparaison avec celle des bananes. La proportion des rejets de enset est cependant un clone dépendant des augmentations de l'âge. Les résultats ont montré aussi que la densité des racines de enset diminue avec l'augmentation de la profondeur du sol.

*Mots Clés:* *Ensete ventricosum*, Ethiopie, la proportion tire-fondamental, Ouganda

### INTRODUCTION

The Musaceae family is subdivided into the genera *Musa* and *Ensete* (Simmonds, 1966). While the banana fruit is known worldwide, enset (*Ensete ventricosum*) is only cultivated in

Ethiopia where products processed from the corm and the pseudostem are a major source of food for more than 12 million people (Barker and Simmonds, 1953; Bezuneh and Feleke, 1966; Westphal, 1975; CSA, 1997). Whereas the banana fruit is harvested within a relatively short period

of less than 2 years after planting (YAP), enset is usually harvested at the end of the vegetative stage between 5-7 YAP. The time to flower emergence in enset depends on climatic conditions, genotype and management level (Brandt *et al.*, 1997). Enset corms and pseudostems are normally processed at 5-7 YAP.

The production of both banana and enset is constrained by a number of factors including pests and diseases, and reduced soil fertility. Enset, being monocarpic and thus unbranched, has proven to be firmly anchored in the soil and toppling of field-grown pre-flowering plants is a rare occurrence (Price, 1995). In contrast, banana whose lateral shoots are expected to add to the plants' stability, is more susceptible to toppling. The aim of this study was to compare; root, corm and shoot growth of field-established enset and East African highland bananas, and to get insight into the shoot-root ratio of banana and enset to

better understand plant stability across the *Musaceae* family. This research could hence contribute to future banana and enset breeding work focussing on plant stability, shoot-root ratio and even research on plant response to nematode and weevil infestation.

## MATERIALS AND METHODS

Wild Ugandan enset plants (Photo 1) and East African highland bananas (cultivars 'Siira' and 'Entaragaza') (*Musa* AAA-EA group) were planted and assessed at the Makerere University Agricultural Research Institute, Kabanyolo (MUARIK) located in Central Uganda (0° 28' N, 32° 37' E, 1,150 m above sea level). The site has a mean annual rainfall of 1,300 mm, which is bimodally distributed. The soils are classified as Eutric ferralsols according to the USDA (Yost and Estwaraan, 1996). The trial site had been under a



Photo 1. A 16 months old wild enset plant assessed in Uganda.

grass fallow for a period of 5 years and was manually prepared in order to avoid soil disturbance.

Seeds of wild enset plants were collected from a swampy area 30 km north of Kampala in Uganda. The seeds were soil planted. Subsequently, the young wild enset plants were raised in a nursery for 8 weeks before field establishment. The field layout was a randomised complete block design and plant spacing was 4 m x 4 m. The banana and enset plants were planted in holes 60 cm wide and 60 cm deep.

For the East African highland bananas, two types of banana planting materials were used: pared suckers and *in vitro* plantlets. Six plants per banana genotype and planting material type were used, while 14 enset plants were assessed. To control nematodes and weevils, 20 g of

Furadan was applied on the soil around the mat at planting and at 14 WAP. No irrigation was carried out.

In addition, two clones of domesticated enset ('Yeka' and 'Masha Gamo') were assessed at the Southern Agricultural Research Institute (SARI) research station in Awassa, southern Ethiopia (7° 03' N, 38° 30' E, 1,700 m above sea level). The site has a mean annual rainfall of 1,046 mm, which is bi-modally distributed. The soils are classified as Eutric nitosols according to the USDA (Ethiopian Mapping Authority, 1988; Yost and Estwaran, 1996).

One year old plants of both enset clones were field established. Five plants per clone were assessed at 4 YAP, while an additional 2 plants per clone were assessed at flower emergence [5 YAP] (Photo 2). In Ethiopia, the enset plants were



Photo 2. A flowering 5 year old 'Mashagamo' enset plant assessed in Ethiopia.

planted in holes with a diameter and depth of 30 cm, at a spacing of 2 m between rows and 1.5 m between plants in a row.

Pesticides and chemical fertilisers were not applied. However, a single application of 0.5 kg composted manure was applied per plant at three months after planting. The plants were not irrigated. Regular weeding was carried out and old enset leaves were regularly pruned.

In Uganda, growth traits of the wild enset plants and banana mats (*i.e.* mother plant and lateral shoots) were recorded at flower emergence of the banana crop (*i.e.* 1.3 YAP), while 4 and 5 year old domesticated enset plants were assessed in Ethiopia.

Data were taken on shoot and root growth. The shoot parameters measured included plant height (PH), circumference of the pseudostem at soil level (PC) and leaf area (LA). Leaf length and leaf widest width were measured and LA was calculated according to Obiefuna and Ndubizu (1979). Leaf dry weight (LW) and pseudostem dry weight (PSW) were also recorded.

The plants were completely excavated and the following corm and root data was collected: corm dry weight (CW) number of adventitious or cord roots (NR), cord root length (LR), average diameter at the base of the cord roots (AD) and root dry weight (RW). Cord root length was measured using the line intersect method (Tennant, 1975), while the diameter of the cord roots was measured with a Vernier Caliper. The shoot-root ratio was calculated as the ratio of leaf, pseudostem and corm dry weight over root dry weight. In addition, root distribution down the soil profile was also assessed on one 4 year old 'Yeka' and one 4 year old 'Masha Gamo' enset plant in Ethiopia. Data were subjected to analysis using the Microsoft Excel and SAS (SAS, 1999) computer packages.

## RESULTS AND DISCUSSION

The results obtained in Uganda indicate that at 1.3 YAP enset had invested more in leaf biomass and had a significantly ( $P < 0.05$ ) shorter and thicker pseudostem compared to bananas (Table 1). In addition, enset had a larger root system with thicker cord roots (Table 1). Results further

showed that the corms of enset plants had a similar weight with the banana corms (Table 1). However, enset plants had a significantly lower shoot-root dry weight ratio than the bananas (Table 1). The lower shoot-root ratio probably indicates that young enset plants partition more assimilates towards root growth compared to bananas. This may be one of the reasons why enset has enhanced plant stability. In addition, the thick cord roots of the enset plants may enhance the plant's tolerance to nematodes and may enhance the plants anchorage strength.

The number of cord roots for the in vitro-derived Entaragaza plants and enset did not differ significantly (Table 1). The number of banana roots varies considerably depending upon the health status of the plant. A healthy corm of a mature plant can bear 200 to 300 primary cord roots with a total length of 230 m (Robin and Champion, 1962; Beugnon and Champion, 1966). However, a banana mat (*i.e.* mother plant and lateral shoots) at flowering of the mother plant can have over 600 cord roots (Blomme, 2000).

During the final stages of vegetative growth, the enset root system size stagnates or even decreases (Table 2). This may be partially linked to the observed 'high mat' phenomenon, whereby the corm and newly formed roots progressively grow above soil level. There is a clear increase in the enset shoot-root ratio with increasing age (Tables 1 and 2). This is in agreement with observations made for banana (Blomme, 2000). The enset shoot-root ratio also depends on the clone (Table 2). This is in contrast to observations made by Blomme (2000) on banana where similar shoot-root ratios were observed for the mats of several genotypes.

The root distribution down the soil profile assessed on 4- year old domesticated enset plants showed that the root density decreases with increasing soil depth (Fig. 1). About 89 and 96% of cord roots of, respectively, 'Yeka' and 'Mashagamo' plants were found within the upper 40 cm soil layer. Similarly, enset root system assessment conducted at Yirgacheffe in southern Ethiopia (6°12'N, 38°12'E, 1,847 m above sea level) on 2 year old 'Genticha' plants showed that 96% of the cord roots were found within the upper 40 cm soil layer (Addis, 2005).

TABLE 1. Plant growth traits of Musa and onset mother plants grown in Uganda and measured at flower emergence of the banana plant crop (1.3 years after planting)

Genotype	PH	PC	NL	LA	LFW	LDW	PSW	PSDW	CW	CDW	AD	NR	RFW	RDW	RL	S-R ratio	NS	HTS
Entaragaza (IV)	212.5a	55.0b	15.3b	4.42a	4216.7b	1124.8b	33500a	2914.5a	5975ba	999.6ba	0.60b	364.0c	3908.3b	394.7b	3982b	15.4ba	2.50a	112.8a
Entaragaza (SD)	208.7a	49.7b	12.3b	5.72a	4041.7b	1078.1b	20198bc	1757.3bc	7775a	1300.8a	0.58b	608.2ba	4516.7b	456.2b	3370b	9.8bc	3.33a	130.5a
Siira (IV)	182.2b	46.3b	13.5b	4.89a	4065.0b	1084.3b	36863a	3207.0a	6850ba	1146.0ba	0.54b	624.7a	3308.3b	334.1b	4391b	18.9ba	3.17a	136.0a
Siira (SD)	191.8ba	47.3b	12.0b	4.59a	3905.0b	1041.7b	27000ba	2349.0ba	7650ba	1279.8ba	0.55b	622.0a	3168.3b	320.0b	6024b	20.3a	3.17a	76.7a
onset	76.9c	90.7a	21.7a	NA	7606.1a	2028.9a	14386c	1251.6c	5495b	919.4b	1.15a	417.5bc	7548.1a	762.4a	20167a	3.7c	0	0

Means in a column followed by the same letter are not significantly different at  $p < 0.05$  according to Tukey's studentised range test; IV: in-vitro-derived plants; SD: sucker-derived plant; NA: not assessed; PH: plant height (cm); PC: pseudostem circumference at soil level (cm); NL: number of leaves; LA: leaf area (m<sup>2</sup>); LFW: leaf fresh weight (g); LDW: leaf dry weight (g); PSFW: pseudostem fresh weight (g); PSDW: pseudostem dry weight (g); CFW: corm fresh weight (g); CDW: corm dry weight (g); AD: average diameter at the base of the cord roots (cm); NR: number of cord roots; RFW: root fresh weight (g); RDW: root dry weight (g); RL: cord root length (cm); S-R ratio: ratio of leaf, pseudostem and corm dry weight over root dry weight; NS: number of suckers; HTS: height of the tallest sucker (cm)

TABLE 2. Mean values for shoot and root traits of domesticated onset plants assessed at 4 years after planting and at flowering stage (i.e. 5 years after planting) in Ethiopia

Plant age	Number of plants assessed	Clone	PH	PC	LA	LW	PSW	CW	RW	NR	RL	AD	S-R ratio
4 YAP <sup>#</sup>	5	Yeka	1.69 <sup>a</sup>	1.26 <sup>a</sup>	1.46 <sup>a</sup>	1.63 <sup>a</sup>	5.91 <sup>a</sup>	3.25 <sup>a</sup>	1.01 <sup>a</sup>	502.20 <sup>a</sup>	357.77 <sup>a</sup>	0.80 <sup>a</sup>	10.87 <sup>a</sup>
4 YAP	5	Mashagamo	2.24 <sup>b</sup>	1.27 <sup>b</sup>	2.50 <sup>b</sup>	2.17 <sup>b</sup>	7.50 <sup>b</sup>	5.40 <sup>b</sup>	0.46 <sup>b</sup>	419.80 <sup>b</sup>	354.28 <sup>b</sup>	0.64 <sup>b</sup>	32.89 <sup>b</sup>
5 YAP	2	Yeka	2.09 <sup>a</sup>	1.73 <sup>a</sup>	1.83 <sup>a</sup>	4.19 <sup>a</sup>	15.44 <sup>a</sup>	8.06 <sup>a</sup>	1.26 <sup>a</sup>	505.00 <sup>a</sup>	361.57 <sup>a</sup>	1.10 <sup>a</sup>	22.60 <sup>a</sup>
5 YAP	2	Mashagamo	2.87 <sup>b</sup>	1.58 <sup>b</sup>	1.73 <sup>b</sup>	3.39 <sup>b</sup>	12.06 <sup>b</sup>	7.81 <sup>b</sup>	0.62 <sup>b</sup>	269.33 <sup>b</sup>	224.86 <sup>b</sup>	0.80 <sup>b</sup>	37.87 <sup>b</sup>

Means in a column (analysis was done per age group) followed by the same letter are not significantly different at  $p < 0.05$  according to Tukey's studentised range test; YAP: Years after planting; PH: Plant height (m); PC: Pseudostem circumference at soil level (m); LA: Leaf area (m<sup>2</sup>); LW: Leaf dry weight (kg); PSW: Pseudostem dry weight (kg); CW: Corm dry weight (kg); RW: Root dry weight (kg); NR: Number of cord roots; RL: Cord root length (m); AD: Average diameter at the base of the cord roots (cm); S-R ratio: Ratio of leaf, pseudostem and corm dry weight over root dry weight

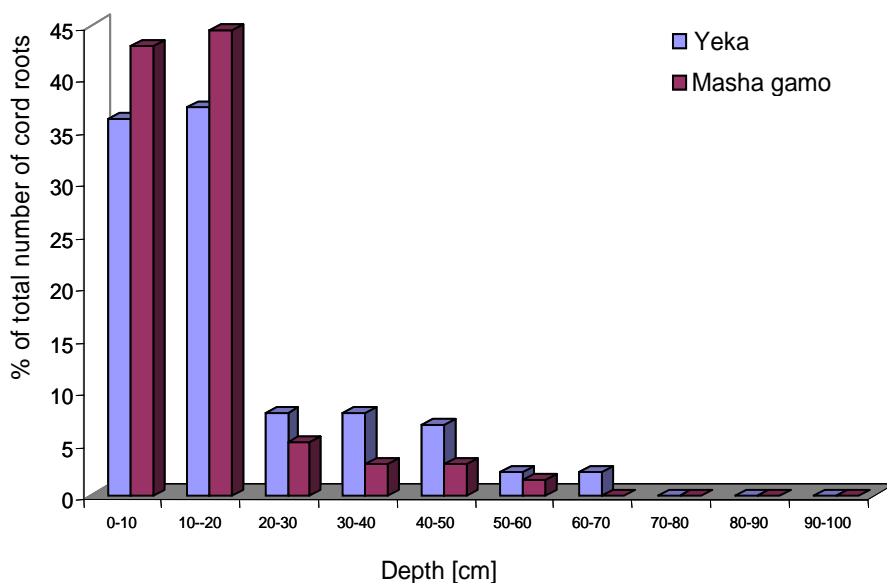


Figure 1. Distribution of enset roots down the soil profile for 4 year old plants of the clones 'Yeka' and 'Mashagamo' assessed in Ethiopia.

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