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Effects of banana weevil damage on plant growth and yield of East African *Musa* genotypes

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ABSTRACT

Objective: Banana weevil has been reported as a serious pest on banana, an important staple and food crop in the east African region. This study was conducted to establish the impact of weevil infestation on *Musa* spp. growth traits during the first crop cycle.

Methodology and results: Experiments were carried out using eight *Musa* spp. comprising of the East African highland bananas (*Musa* spp, AAA-EAHB group); *Mpologoma*, *Lwadungu*, *Nakitembe*, *Mbwazirume* and *Kibuzi*; the dessert banana *Sukali Ndiizi* (AAB); the plantain *Gonja* (AAB) and the beer banana *Kayinja* (ABB). All genotypes were assessed at bunch maturity. Weevil build-up and subsequent damage to the banana corms during the first crop cycle was low, presenting an average cross-sectional corm damage of 1.2%. Consequently, hardly any significant negative effects on yield and growth traits were observed.

Conclusion and application of findings: The results suggest that several ratoon cycles may be required in order to achieve a high weevil population density build-up to cause substantial reduction in yield and plant growth. The results also show that genotypes with a 'B' genome such as *Sukali Ndiizi* and *Kayinja* are more tolerant to banana weevils than genotypes with only 'A' genomes.

Key words: *Cosmopolites sordidus*, *Musa* spp., root system, yield.

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INTRODUCTION

Bananas are of great economic importance in most regions of tropical and subtropical Africa. Their all year-round production ensures a continuous supply of food and income to the farmer, making bananas a major food security crop in the region. However, banana productivity has failed to keep pace with increasing food demand despite the steady increase in banana acreage over the past 30 years. The decline in yield, attributed to declining soil fertility, pests, diseases and socioeconomic problems, has aggravated the food security situation (Gold *et al*., 1999; Tushemereirwe & Bagabe, 1999). High productivity of *Musa* spp. also strongly depends on a healthy root system. The *Musa* root system consists of adventitious or cord roots, which are mainly responsible for anchorage and transport of water and nutrients (Price, 1995).

Major pests of banana that influence development of the corm and root system are the banana weevil, *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) (Gold *et al.,* 2001) and nematodes (Gowen & Quénéhervé, 1990; Speijer *et al*., 1998). The weevil has been implicated in the decline and disappearance of highland banana from traditional growing zones in East Africa (Bosch *et al.,* 1995; Gold *et al.,* 1999). The adults lay eggs at the base of the plant (Abera *et al*., 2000) and the larvae are the most destructive stage of the banana weevil. Damage is primarily due to destruction of the corm or rhizome tissue by the larvae, which tunnel through it as they feed (Gold *et al*., 2001). Tunneling interferes with root initiation and development, impedes water and nutrient uptake and eventually leads to weakening of the whole plant (Acland, 1971).

As cord roots are formed on the layer of mangin between the corms cortex and central cylindrical (Skutch 1932; Riopel & Steeves, 1964; Turner, 1970), it has been hypothesized that root initiation could be affected by severe weevil infestation. Internal damage is thought to root initiation; nutrient transport and stem growth, while peripheral damage may detach roots or adversely affect root development (Taylor, 1991; Gold *et al*., 1994). Corm damage thus interferes with water and nutrient uptake (Gold *et al*., 2001) and creates entry routes for secondary microorganisms.

In addition, damage reduces plant vigor and predisposes the crop to snapping and sucker mortality (Gold *et al*., 2001), prolonged bunch maturation period and shortened plantation life (Gold *et al*., 2004). Yield losses for plants assessed on station were reported to increase with ratoon cycles and may result in up to 50% yield losses after the 3rd ratoon cycle (Rukazambuga, 1996; Gold *et al*., 2004). Yield loss of up to 100 % has also been reported (Sengooba, 1986).

A wide range of *Musa* germplasm has been screened for weevil resistance in Africa and Asia (Fogain & Price 1994; Pavis & Lemaire, 1997; Kiggundu *et al*., 1999; Kiggundu *et al*., 2003b). Although plantains and east African highland bananas (EAHB) were found to be the most susceptible banana types, there were a few exceptions. For example, Kiggundu *et al*. (2003a) found that some east African highland banana cultivars including *Tereza*, *Nalukira* and *Nsowe* had intermediate resistance to weevils. The large variability in weevil response observed in *Musa* germplasm suggested that useful sources of weevil resistance are available in the *Musa* germplasm (Kiggundu *et al*., 2003b).

This study aimed to investigate the effects of weevil infestation on root, corm, shoot and bunch characteristics of eight East African *Musa* spp. genotypes.

MATERIALS AND METHODS

Site description: The study was carried out at Makerere University Agricultural Research Institute Kabanyolo (MUARIK) in Wakiso district, Uganda, 17 km north of Kampala. This research station is located at 0°28'N and 32°37'E, and at an elevation of 1,150 meters above sea level. The site has two rainy seasons (March to May and September to November) with a mean annual rainfall of 1,300 mm (Arnold, 1993). There is 12 hours day length throughout the year. The average daily temperatures in the field were 16 °C minimum and 29 °C maximum. The soils are classified as Eutric Ferralsols (Yost & Estwaran, 1990).

Genotypes assessed: Eight genotypes (Table 1) comprising the East African highland bananas (*Musa* AAA-EA group); *Mpologoma*, *Lwadungu*, *Nakitembe*, *Mbwazirume* and *Kibuzi*; the dessert banana *Sukali Ndiizi* (AAB); the plantain *Gonja* (AAB) and the beer banana *Kayinja* (ABB) were evaluated under field conditions. Selection of the AAA-EA genotypes was based on clone sets in order to include a representative genotype from each of the four clone sets (Karamura & Pickersgill, 1999).

Field management practices: The land used for the experiment was previously under a 5-year grass fallow and field preparation involved disc ploughing and harrowing. Planting holes of size 60 cm x 60 cm, spaced at 4 m x 4 m were used in order to avoid subsequent overlapping of adjacent *Musa* roots. Composted cow dung mixed with top-soil at a ratio of 1:3 was used to fill the planting holes during planting to improve soil fertility. In vitro-derived plantlets were used in order to avoid initial infestation by weevils or nematodes.

In addition, the plants in the control plots were protected against weevil and nematode infestation using Furadan (a.i. carbofuran) at a rate of 60 grams per mat (2 treatments $year^{-1}$). The first application was carried out at planting, while the second application was done at 6 months after planting. The plants were grown under monoculture and no mulch was applied. Weeds were controlled by spraying with the herbicide Touch down at a rate of 10 ml per litre of water applied at 3-monthly intervals, with additional monthly manual slashing.

Experimental design: A split plot within a randomized complete block design was used, with three replicates of four plants per genotype. The main plot treatment consisted of infestation level (infected versus non-infected), while the sub-plot treatment consisted of genotypes. Forty adult weevils (20 males and 20 females) per mat were released at 5 months after planting in infected plots. The weevils were captured using a 30 cm long split pseudostem trap (Mitchell, 1978) in farmers' fields close to the NARO Kawanda research station. Traps were visited for collection of weevils after three days. Weevil sex was determined using curvature of the last abdominal segment and punctuation on the rostrum (Roth & Willis, 1963). A 20 m wide weed free alley separated the infested and the non-infested plots to avoid cross-infestation.

Data collection: Twelve banana mats per genotype and per treatment were assessed for weevil damage at bunch maturity of the plant crop. Weevil damage on corms of freshly harvested plants was assessed using the cross section method by Gold *et al*. (1994). The assessment of various growth parameters was carried out after complete excavation of the entire mat. The suckers were separated from the mother corm to facilitate the removal of soil particles and subsequent assessment of the various characteristics.

Data was collected on: (a) Bunch parameters: the bunch fresh weight was measured with a weighing balance (BW, kg), days to flowering (DF), days of fruit filling (FF) and total days to maturity/harvest (DM) were recorded. (b) Shoot traits: leaf area of the mat (LA, m^2), dry weight of leaves of the mat (LW, kg), height of the mother plant (PH, cm), height of the tallest sucker (HS, cm), pseudostem circumference of the mother plant at soil level (PC, cm), pseudostem circumference of the tallest sucker at soil level (CS, cm), pseudostem dry weight of the mat (PW, kg) and corm dry weight of the mat (CW, kg). The leaf area was calculated using the formula: leaf length x leaf maximum width x 0.8 (Obeifuna & Ndubizu, 1979; Blomme & Tenkouano, 1998). (c) Root traits: cord root number of the mat (RN), root dry weight of the mat (RW, kg), average cord root diameter of the mother plant (RD, cm) measured using a vernier caliper and cord root length of the mat (RL, m) measured by using the line intersect method (Tennant, 1975). The line intersect method consists of scattering cord roots on a grid and counting the number of cord root grid-line interaction points. The numbers of interaction points were then multiplied by the conversion factor 2.3571 appropriate for the 3cm by 3cm grid used. Soil samples taken during the establishment of the trial were analyzed at the NARO Kawanda soil science laboratory for bases, nitrogen, pH and soil texture.

Statistical analysis: Statistical analysis was performed using the Genstat statistical package (Genstat, 1999). ANOVA was carried out to determine the effects of weevil damage on the root, shoot and bunch characteristics. The corm weevil damage data was log (x+1) transformed and the means separated using the least significant difference (LSD).

TABLE 1. Name, genome group and local use of the assessed genotypes.

Name	Genome group	Local use
Mpologoma	AAA-EAHB*	cooking
Lwadungu	AAA-EAHB	cooking
Nakitembe	AAA-EAHB	cooking
Mbwazirume	AAA-EAHB	cooking
Kibuzi	AAA-EAHB	cooking
Sukali Ndiizi	AAB	dessert
Gonja	AAB	Plantain -roasting
Pisang Awak	ABB	beer

*: East African Highland Banana

Source: Karamura & Pickersgill, 1999; Pillay *et al*., 2006

TABLE 2: Chemical and physical properties of the top soil (0-30 cm depth) of plots at the Makerere University Agricultural Research Institute Kabanyolo (MUARIK) research farm.

Physical and Chemical composition of the soil	*Soil depth 0-15 cm*	*Soil depth 15-30 cm*	*Critical level**
Calcium (Mg/1000g soil)	1.10	1.02	>4.0
Potassium (Mg/1000g soil)	0.4	0.5	>0.44
Nitrogen (%)	0.19	0.13	>0.2
Sodium (Mg/1000g soil)	0.2	0.4	<1.0
Organic Matter (%)	4.2	4.1	>3.0
Phosphorus (ppm)	11.3	6.3	>15
Sand	51	50	-
Silt	9	10	-
Clay	40	40	-
Soil pH	4.3	4.6	>5.2

*Critical values for banana nutritional requirements (Odeke *et al*., 1999)

RESULTS AND DISCUSSION

The study plots had low levels of Nitrogen, Calcium and exchangeable potassium (Table 2) but potassium, sodium, organic matter and pH were within the minimum requirements for banana plants. Low levels of N, P and K (below critical value) have been associated with slow growth and low yields of bananas (Tumuhairwe *et al*., 1994).

A significant (P < 0.001) effect of genotype was observed on all growth and yield traits (Table 3). Similar genotypic variation of shoot and root traits were reported by Blomme *et al*. (2000) and Sebuwufu *et al*. (2004). Furthermore, there was a strong genotypic effect of genotype on the weevil damage. A significant (P < 0.001) effect of infestation level was only observed on plant height of the mother plant, while bunch weight and other shoot and root traits of the mat were not affected (Table 3). Infestation level by genotype interaction significantly (P<0.05) influenced days to flowering, days of fruit filling and days to maturity.

Variable effects of weevil corm damage on days to flowering, days of fruit filling and days to maturity across the different genotypes were observed (Table 4). The duration of flowering and total days to bunch maturity of cultivars *Lwadungu*, *Mbwazirume* and *Kibuzi* was significantly (P<0.05) reduced. *Gonja* was observed to take longer to flower and to produce a ripe bunch in the weevil infested plots. In contrast, bunch weight and other shoot and root traits were not affected by weevil infestation. Rukazambuga *et al*. (2002) reported a reduction in maturation period (sucker emergence to harvest), plant height and plant girth during ratoon cycles due to banana weevil attack. Similarly, weevil damage was postulated to delay bunch maturity (Gold *et al*., 1994), while Jonnes (1986) implicated weevil damage (tunneling) as the cause of stunting, premature leave drop and delayed maturation of plants in old fields (later ratoon cycles).

TABLE 3: Mean squares and significance for different growth and yield traits of *Musa* spp. genotypes assessed at bunch maturity of the mother plant.

Source	df*	Traits#					
		DF	FF	DM	BW	LW	PH
Replication	11	6,026***	363	4,235**	9.3	0.9	850
Genotype (Gen.)	7	45,893***	5,390**	48,680***	245.4***	33.6***	4,057***
Infestation (Inf.)	1	3,355	143	4,882	9.8	0.5	7,684***
Gen*Inf	7	5,314**	816**	3,686*	25.5	1.1	436
Residual	129	249	1517	4	12.8	1.6	504
Source	df	PW	CW	NR	RL	RW	WD
Replication	11	28	18.9	132,698	59,007	0.1	1.5
Genotype (Gen.)	7	9,570***	464.7***	1,855,794***	889,721***	11.0***	6.3***
Infestation (Inf.)	1	18	0.1	77,226	220	0.5	282.1****
Gen*Inf	7	22	1.2	45,561	64,481	1.1	5.8***
Residual	129	39	5.6	91,454	758,626	0.3	0.9

*: df: degrees of freedom; #: DF: days to flowering, FF: days of fruit filling, DM: days to maturity/harvest, BW: bunch fresh weight, LW: dry weight of leaves of the mat, PH: height of the mother plant (cm), PW: pseudostem dry weight of the mat (kg), CW: corms dry weight of the mat (kg), NR: number of cord roots of the mat, RL: cord root length of the mat (m), RW: root dry weight (kg) and WD: weevil corm damage (%); *, **, *** significant at P<0.05, 0.01 and 0.001, respectively.

The corm damage for the genotypes assessed ranged from 0.26-1.87 %, presenting a grand mean damage of 1.2 %. The insignificant impact of weevil damage on growth such as number of roots, cord root length and root weight of the mat, and yield was due to the low corm damage caused by the weevil larvae during the first crop cycle. Unlike nematodes, banana weevils cause indirect damage to roots of banana plants by damaging the corm from which the roots are formed. Several authors (Rukanzambuga *et al.*, 1998; Gold *et al.*, 2001) reported a slow weevil population build-up during the life span of a plantation. Damage is likely to become increasingly important during the ratoon cycles for fields with minor initial weevil infestation (Gold *et al.*, 2004). Similarly, in a trial with highland cooking banana, Rukazambuga *et al*. (1998) estimated yield loss to increase five-fold from the first to the third ratoon stage.

Variation in corm damage levels were observed across genotypes (Fig. 1). The lowest corm damage was recorded for *Sukali Ndiizi* and *Kayinja*, while the East African highland bananas, especially *Lwadungu* had the highest damage level. The plantain *Gonja* on the other hand recorded a moderate damage. In agreement with our results, Abera *et al*. (1997) and Kiggundu (2000) reported low corm damage in *Sukali Ndiizi* (AAB) and *Kayinja* (ABB), while Gold *et al*. (1994) reported high damage on the East African highland bananas (AAA-EA) and the plantain *Gonja* (AAB). The variation in damage within *Musa* genotypes was attributed to corm hardiness and chemical characteristics (antibiosis) (Abera *et al*., 1997). The results also clearly show that genotypes with a 'B' genome such as *Sukali Ndiizi* and *Kayinja* are more tolerant to banana weevils than genotypes with only A genomes. Kiggundu (2000) reported a moderate resistance to banana weevil infestation for *Mbwazirume*. In contrast, this study indicated that *Mbwazirume* was equally susceptible to banana weevils when compared with the other East African highland bananas.

Weevil damage to the banana corms during the first crop cycle was low. Consequently, hardly any significant negative effect on yield and growth traits was observed. Nonetheless, some growth characteristics including bunch maturity period, total number of fingers and pseudostem height of plant crop of a few genotypes were affected. The results suggest that several ratoon cycles may be required in order to have a substantial yield loss caused by weevils in newly established fields. There was a genotypic effect on weevil damage with *Sukali Ndiizi* and *Kayinja* (containing a B genome) showing minor corm damage, while the East African highland bananas (containing only A genomes), especially *Lwadungu* had the highest damage level. The plantain *Gonja* on the other hand had moderate corm damage.

Kiggundu *et al*. (2003b) reported that Kayinja (or *Pisang Awak*) is a possible source of banana weevil resistance. Also in agreement with our observations, Mesquita *et al*., (1984) reported that the AA genome progenitor *Musa accuminata* is more susceptible to weevils than the BB progenitor *Musa balbisiana*. High-performance liquid chromatography (HPLC) chromatograms from corm extracts of weevil-resistant AB (*Kisubi*) and ABB (*Pisang awak*) cultivars showed peaks that were absent when compared not only to susceptible clones, but also to some resistant clones of the AA (*Calcutta 4*) and AAA (*Yangambi km5*) genome group cultivars. This result possibly indicates a type of antibiotic mechanism that may be based on toxic compounds. These compounds are seemingly present in weevil resistant cultivars with the BB genome suggesting that a different form of resistance may be present in weevil resistant AA cultivars (Kiggundu, 2000).

The present study indicates that several ratoon cycles may be required in order to achieve a high weevil population density build-up to cause substantial reduction in yield and plant growth. The results also show that genotypes with a 'B' genome such as *Sukali Ndiizi* and *Kayinja* (also known as *Pisang Awak*) are more tolerant to banana weevils than genotypes with only 'A' genomes.

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TABLE 4: Growth parameters and percentage difference between non-infested and weevil infested plants for eight *Musa* spp. genotypes assessed at bunch maturity of the mother plant.

	Mpologoma			***Lwadungu***			***Nakitembe***			***Mbwazirume***		
Traits	NI	I	%	NI	I	%	NI	I	%	NI	I	%
Days to flowering	333±12	341	2	450±11	380	-16***	375±20	378	1	413±16	339	-18**
Days to fruit filling	131±9.4	114	-13*	110±5.5	120	9	119±8.3	128	8	111±7.4	130	17
Days to maturity	464±11	455	-2	560±11	500	-12**	494±15	506	2	524±3.4	469	-10*
Bunch fresh weight (kg)	17.8±2.4	18.3	3	13.9±0.7	13.6	-2	14±1.7	12.3	-12	12.7±0.82	12.6	-1
Leaf dry weight (Kg)	3.1±0.2	3.4	8	3.6±0.7	4	11	3.2±0.2	2.8	-15	3.6±0.4	3.1	-14
Mother plant height (cm)	270±12	262	-3	320±12	287*	-10	288±8.3	269	-7	314±9.2	291	-7
Pseudostem girth of plant crop (cm)	66±7.5	66	0	53±7.5	62	17	70±1.8	65	-7	61±1.2	58.0	-3
Pseudostem dry weight (kg)	7.2±0.7	7.4	3	9.94±1.9	8.8	-12	7.6±1.4	6.7	-12	14±1.2	15	6
Corm dry weight of the mat (kg)	3.16±0.32	2.85	-10	4.3±0.4	3.8	-12	4.32±0.43	4.0	-7	2.6±0.34	2.6	0
Number of roots of the mat	1,252±119	1,299	4	1,854±131	1,631	-12	1,275±90	1,279	0	1,863±117	1,720	-8
Tallest sucker's pseudostem girth (cm)	70±2.6	75	7	82.4±2.6	78.4	-5	77±2.14	73	-5	72±5.5	70	-2
Root length of the mat (m)	205±29	189	-8	283±36	291	3	246±18	260	6	287±29	274	-5
Root dry weight (kg).	1.4±0.24	1.5	8	2.1±0.2	2.0	-5	1.4±0.2	1.5	3	1.4±0.22	1.5	4

	Kibuzi			***Sukali Ndiizi***			***Gonja***			***Kayinja***		
Traits	NI	I	%	NI	I	%	NI	I	%	NI	I	%
Day to flowering	429±4	406	-6***	327±12	326	-0.3	451±8	514	14**	383±19	386	1
Days to fruit filling	106±3.3	117	11*	158±8	139	-12*	148±3	138	-7*	160±3	149	-7
Days to maturity	535±4	523	-2	485±14	464	-5	599±10	652	9***	543±16	535	-2
Bunch fresh weight (kg)	12.7±0.7	11.2	-12	6.4±0.6	6.03	-6	15.5±0.9	13.9	-11	14.8±1.0	13	-12
Leaf dry weight (Kg)	2.3±0.5	2.5	-9	5.8±0.7	5.0	-14	2.1±0.4	1.8	-14	5.3±0.5	4.9	-8
Mother plant height (cm)	313±9.2	290	-7	271±14.8	266	-2	299±8	294	0	308±10	291	-6
Pseudostem girth of plant crop (cm)	60.5±1.2	58	-4	62.7±1.7	62.9	-1	71±3.8	69	-3	71±1.4	68	-5
Pseudostem dry weight (kg)	14±1.8	15	10	14±1.9	13	-10	5.05±0.28	4.49	-11	69.3±5.2	65.7	-5
Corm dry weight of the mat (kg)	7.5±0.43	9.9	-6	8.9±0.7	8.4	-5	2.06±0.34	1.89	-8	14.7±0.96	14.7	0
Number of roots of the mat	1,863±90	1,835	-2	1,757±169	1,723	- 2	1,337±133	1,300	-3	2,003±66	2,015	1
Tallest sucker's pseudostem girth (cm)	71.7±2.7	70	-2	77±3.8	71	-8	65±3.1	70	7	92±2.5	86	-7
Root length of the mat (m)	330±54	379	2	308±31	275	- 11	308±13	275	-12	328±20	289	-12
Root dry weight (kg).	1.8±0.15	2.0	11	3.5±0.2	3.5	1	1.0±0.08	0.9	-10	3.0±0.3	2.7	-10

#: NI: non-infested; I: Infested and %: percentage difference between infested and non-infested plot.
*, **, *** significant at P<0.05, 0.01 and 0.001, respectively.

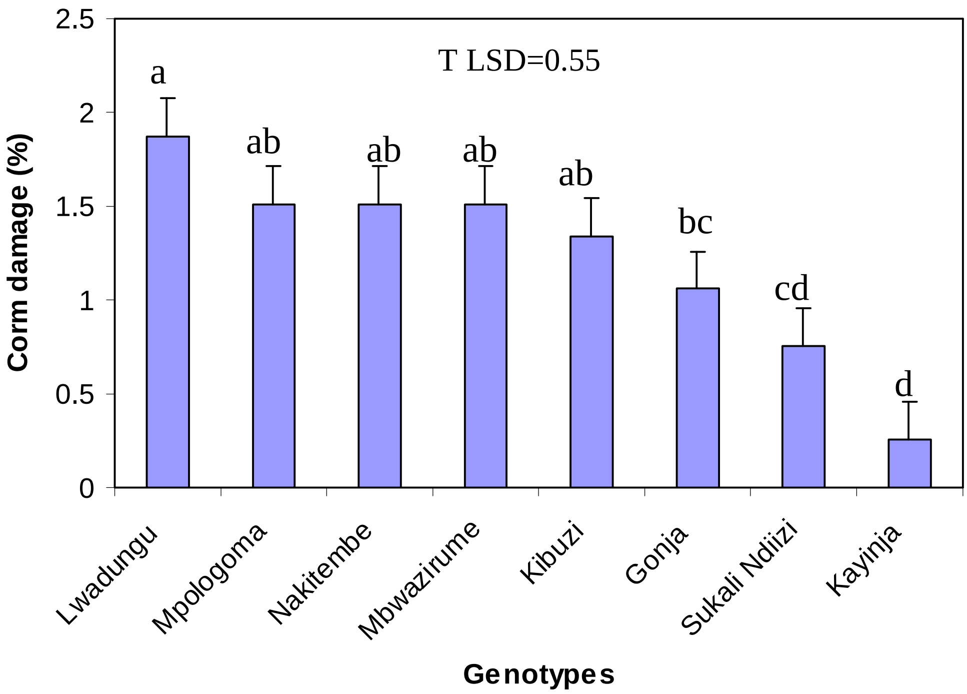

Figure 1: Weevil corm damage levels (%) according to genotype.

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