

**PERFORMANCE OF 15 INTRODUCED BANANA GENOTYPES IN
THREE AGRO-ECOLOGICAL ZONES OF UGANDA**

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(Reg. No 2004/HD02/679U)

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER
OF SCIENCE IN CROP SCIENCE OF MAKERERE UNIVERSITY**

DEPARTMENT OF CROP SCIENCE

FACULTY OF AGRICULTURE

OCTOBER, 2011

DECLARATION

This Thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

To my dear wife, Hellen and beloved children, Winnie, Nico and Marion

ACKNOWLEDGEMENTS

I am greatly indebted to my University supervisor, Dr. James .M. Ssebuliba of the Department of Crop Science, Faculty of Agriculture, Makerere University for his invaluable guidance through out the course of this study. I wish to thank Prof. W.K. Tushemereirwe, the team leader for the National Banana Research Programme, for initially securing the funding, from National Agricultural Research Organization (NARO), and from the CFC. This study would not have been possible without his parental guidance and advice.

I am grateful to Mr. Ragama for ably offering the vital help in data analyses and hereby acknowledge the input of all the scientists, who read through my scripts and provided constructive criticism.

Let me also express my gratitude to all the research technicians, drivers, secretaries, field assistants and farmers who contributed in one way or another towards the successful completion of this study. I say thank you to you all for having made this study possible.

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ABSTRACT

Almost all the farmers in Uganda have no idea which banana genotype is best suited for their location. Subsequently there is dire need for information on genotypes and their performance in the different Agro ecological zones of Uganda. This study was conducted to evaluate performance of 15 recently developed banana genotypes in three different agro ecological zones of Uganda between 2005 and 2007. The objectives of the study were to: (i) determine the agronomic and yield performance of recently developed banana genotypes across the three agro ecological zones of Uganda. (ii) determine the response of the recently developed banana genotypes to major production constraints namely : Sigatoka, banana weevil borers, and banana nematodes across the three agro ecological zones of Uganda. (iii) determine the bunch yield weight stability across the different agro ecological zones of Uganda.

The study was conducted in three locations/ districts of Uganda namely: (Ruhinda) Rukungiri located on high altitude with fertile soils, Bujumba Kalangala located on lake victoria islands with highly leached soils and (Zirobwe) Luwero located in medium altitude with highly weathered soils. Fifteen genotypes each planted in a line of ten plants were evaluated at three farms in each of the three different agro ecological zones. The experimental design was a completely randomized block design (CRBD) with plants spaced at 3m x 3m. Selection of farms was based on location, availability and willingness of the farmer to participate effectively.

Data were collected on plant height plant girth, days from planting to flowering, days from flowering to bunch harvesting, days from planting to bunch harvesting, bunch weight, number of hands/clusters, total functional leaves at flowering, total functional leaves at bunch harvesting, youngest leaf with Sigatoka spot, percentage weevil corm damage and nematode

root damage. Data were subjected to analyses of variance using the general linear model (GLM) on SAS. Data on damage by weevils was subjected to arcsine transformation and means separated using Tukey comparison test (SAS 1991). Nematode data was transformed using square root transformation. Stability analysis was done using bunch weight as a parameter; principal component analysis on bunch weights was conducted. Significance levels were set at ($p > 0.05$).

Results of the study indicate that there were highly positive correlations between bunch weight, plant girth, hands/ clusters and functional leaves at flower shooting and functional leaves at bunch harvesting. This implies that the yields of banana highly depend on these variables. Plants with the largest girths were recorded in Rukungiri followed by Luwero and Kalangala districts. Results on genotype stability on the basis of bunch weight across the three agro ecological zones indicated that genotypes FHIA 17, FHIA 23, FHIA 25 and SH 3436-9, Pisang ceylan and Yangambi KM 5 were high yielding with high resistance to pests and diseases. While genotypes GCTCV-119, CRBP-39, and FHIA 21 were very low yielding with poor resistance to pests and diseases. All genotypes took longer period to attain maturity compared to Nfuuka, the local banana used as a check in this study. Stability analysis revealed four categories namely: (i) high yielding and un stable (ii) high yielding and stable (iii) low yielding and un stable (iv) low yielding and stable. This suggests that that performance of the genotypes varies with location. This implies that such information could be used to select and recommend genotypes, based on their performance in various locations. Genotypes that exhibited superior agronomic performance, high and stable bunch yield with resistance to major pests and diseases, possess the potential for acceptability by the farmers and consumers. The recommendation is that such genotypes should further be evaluated on farm for consumer acceptability.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Origin of bananas and plantains

Banana and plantain belong to the family *Musaceae*; that comprises the genera, *Musa* and *Ensete* (Purseglove, 1985) of which *Musa* is the most widely cultivated. Bananas belong to the genus *Musa* and are said to have evolved from two wild species, *Musa balbisiana* Cole and *Musa accuminata* Colla. Their cultivation is limited to within 40° North or South of the Equator because of their poor adaptation to frost conditions (Purseglove, 1985).

Bananas are reported to have originated from Papua New Guinea region (Simmonds, 1966) from where they spread to South East Asia and Ocenia (Langdon, 1993). The Indian sub continent is thought to be the major center of hybridization of *Musa acuminata* and *Musa balbisiana*. The crop was then introduced to all tropical and sub tropical regions of the world where it gained importance and popularity (Valmayor, 1990).

The original banana clones in East Africa are believed to have been brought by Arab travellers between India and East Africa (Price, 1995). Somatic mutations are then thought to have taken place in the numerous banana cultivars making East Africa a center of diversity for the East African highland banana group (Simmonds, 1966). Three groups of banana are cultivated in Africa namely: (i) East Africa Coast and nearby Islands ABB (De Langhe *et al.*, 1994), (ii) African plantain AAB constituting the second main food crop in the humid forest lowlands of Tropical Central and West Africa, (iii) Highland banana (AAA- EA.) growing on the East African Plateau.

1.2 Importance of bananas and plantains

Banana and plantain are the world's second largest fruit crop with an annual production of 81 million metric tons (FAO, 1995). *Musa* (banana and plantain) constitute the fourth most important food crop after rice (*Oriza sativa*), maize (*zea mays*) and wheat (*Triticum spp*). (Frison and Sharrock, 1999).

Africa contributes 23 % of the world's total production; 53 % of which is produced by Uganda alone (Karamura, 1993). Uganda is the world's second largest banana producer with 9.84 million metric tons, obtained from 1.5 million hectares of land, (INIBAP, 2000). This accounts for 15 % of the world's total production of cooking bananas "matooke" (INIBAP, 1994). The leading producer being India with annual production of 13.5 million metric tons from 0.4 million hectares (FAO, 2003). Eighty five percent of the bananas grown in Uganda are East African highland bananas (*Musa spp.* AAA-group), the rest being either ABB or AAB genome groups (Karamura and Karamura, 1995). East African highland bananas (AAA, E.A.) are the staple food for at least 13 million people in Uganda (FAOSTAT, 2010) with per capita consumption estimated at 300kg per annum (Lescot, 1999).

The banana therefore is an important crop for food security from which farmers harvest fruits all the year around thus guaranteeing a regular source of food for farmers. The fruits can be steamed (Karamura et al., 1996) or cooked and consumed as part of the main meal (Swennen and Vuylsteke, 1991). The fruit could also be ripened and roasted or eaten directly as dessert. While juice from the bear types could be fermented to produce alcohol (Karamura, 1993). A large proportion of farmers rely heavily on bananas as a source of income. The banana pulp

may be dried and milled into flour for use in bakery products (Tajudeen, 1995). Besides the crop reduces soil erosion on steep slopes (INIBAP, 1986).

1.3 Banana plant morphology

The banana plant has been described as the largest herbaceous plant with a pseudo stem reaching a height of 2-8 m in cultivated varieties and up to 10-15 m in some wild species (Purseglove, 1972, Karamura and Karamura, 1995). The plant consists of an underground stem from which roots and shoots are initiated. The corm from whose edges the roots begin consists of a central bud while the shoot is made up of leaves and divided into an inflorescence with a compacted sheath, petiole and mid rib supporting blades. The inflorescence emerges from the center of the leaf cluster and gives rise to fruits (fingers) arranged in paired rows (hands) on the bunch. Morphological variability exists between cultivars, which may be used to distinguish between them. There are variations in length, disposition and colour. *Gros michel* may grow to 4-8 m, while *Nakyetengu*, a short “matooke” sub group cultivar grows up to 2-3 m (Karamura and Karamura, 1995). In general, short stem cultivars tend to be drought susceptible while tall ones are generally tolerant (Stover, 1991). The highland banana plants are adapted to between 890 and 2400 m.a.s.l (Speijer *et al.*, 1994) and require deep well drained soil with high humus content and warm climate (Tushemereirwe, 1997).

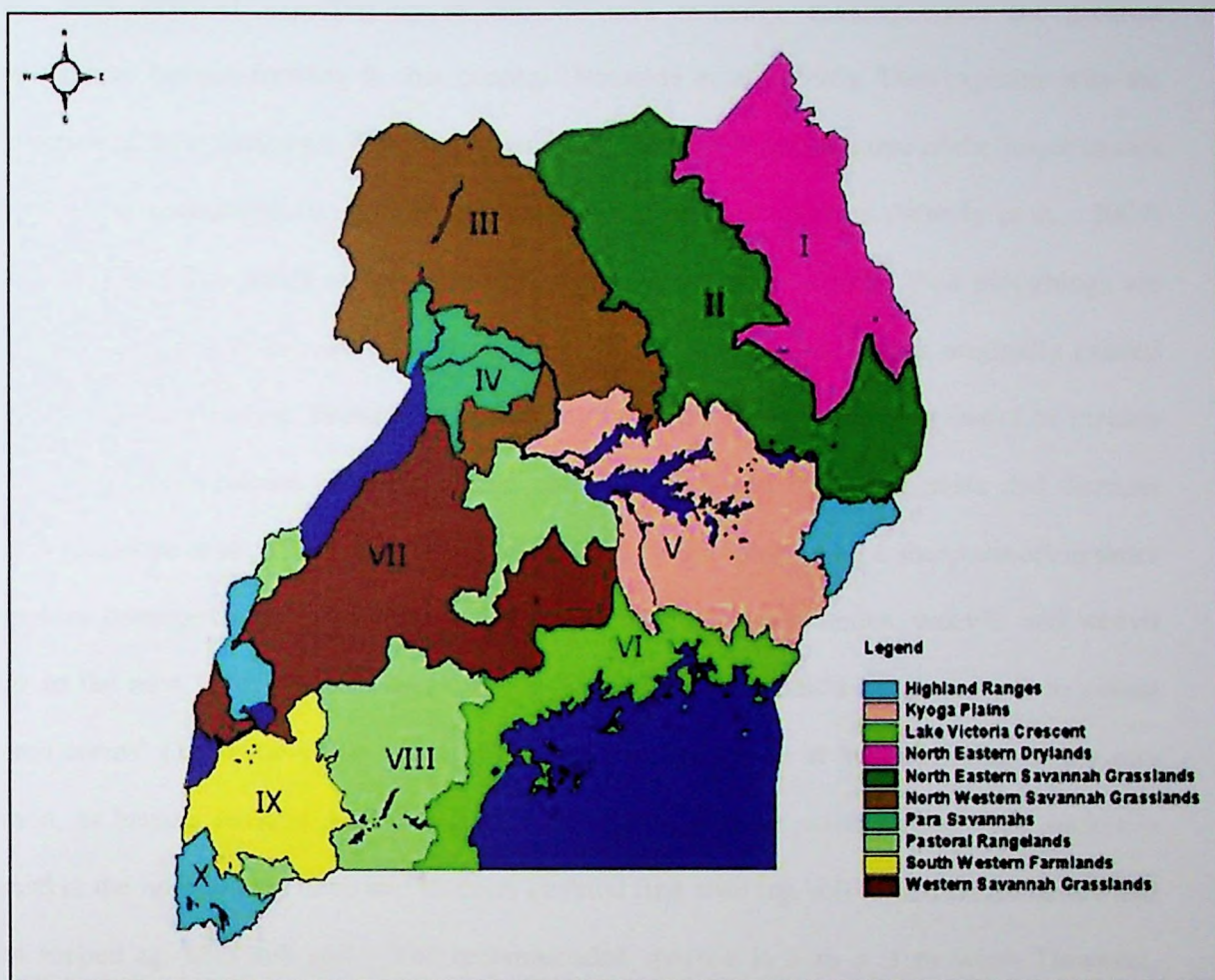


Fig 1: Map of Agricultural Production Zones in Uganda

Kalangala (Zone VI), Rukungiri (Zone IX) and Luwero (Zone VII)

Source: Ministry of Agriculture and Animal Industry and Fisheries Report, Uganda, 2008-2010.

1.4 The establishment and management of the highland banana plant

Bananas have been reported to be grown in all parts of Uganda. Banana plants however, have high water demand requiring up to 200-250 mm annually, making water the greatest limitation to banana farming in this country (Bekunda et al., 1996). This explains why the restriction of their farming is limited to high rainfall areas. Weeds are one of the major causes of yield loss accounting for 50% of the total banana production costs (Wendy et al., 2009) therefore weed free fields are preferred (Tushemereirwe et al., 1999). Two ploughings are generally sufficient to provide a good seed bed where, fallows and bushes originally existed and were simply slashed. Planting material may be in the form of reduced sword or maiden suckers, or tissue culture plantlets. These must be clean and free from pests and diseases (Tushemereirwe et al., 1999). Selected suckers may be uprooted using a sharp shovel in order to reduce damage to the mother plant. To avoid introducing nematodes, weevils and weevil eggs to the new field, all roots and outer layer of the corm should be peeled off to obtain 'pared corms' (Tushemereirwe et al., 1999). Planting should be at the beginning of the rain season, as banana suckers need 4-6 months of growth without water stress. The sucker is placed in the hole 3-4 cm deep and its corm covered first with top soil mixed with manure and then topped up with sub soil. The recommended spacing is 3 m x 3 m wide. However, spacing can vary from place to place depending on soil fertility and population density required. Some farmers requiring high population densities plants employ a close spacing of 2 m x 2.5 m. While those preferring lower population densities use 4.5 m x 4.5 m. Hole size varies in width and depth from area to area, at least (60 cm x 60cm x 60 cm).

The banana plant is highly sensitive to water stress therefore water conservation measures are imperative. These may be in the form of water harvesting trenches dug across the slope in the field. Weeds compete with banana plants for nutrients and water and must therefore be controlled either mechanically or chemically. If hand weeding is employed, residues should

be heaped together in the plantation in order to confine the weed. Hand weeding is most applicable where the weed density is very low like on mulched plantations. Using chemicals is the cheapest means of controlling weeds. In Uganda herbicides are obtained as concentrated liquids, which may then be mixed in water at recommended rates and applied to the weeds using a knapsack sprayer. Herbicides commonly used in Uganda include Grammaxone (non-selective-contact) and Round up (non selective-systemic). Foliar applications at the rate of 100-250 mls in 15 litres of water and 330-630 mls in 20 liters respectively are recommended.

Mulching reduces the amount of weeds in the plantation by choking the established weeds and denying light to those that require it for germination. Thicker mulch facilitates deeper penetration of water into soil and prolongs its retention. It also returns nutrients to soil as it rots. Sources of mulch include banana plant residues, annual crops residues and grasses. The recommended distance is 50 cm away from the mat. As a plant grows it takes away nutrients from the soil. A large amount of these nutrients taken up from the soil by the banana plant go to the fruits (bunch). So the only way of maintaining soil fertility is by regularly and continuously putting back nutrients in form of fertilizers (organic or inorganic). Farmers in Uganda commonly use farm yard manure or compost manure. Manuring replenishes nutrients, conserves moisture, and modifies soil structure and texture (Bwamiki et al., 1994).

Desuckering and detrashing are encouraged in order to check competition for nutrients and water while also reducing disease and pest build up. Leaf removal (de-trashing) is important for maintaining plantation hygiene and light penetration. It is necessary to disinfect the detrashing tools after every plant to minimize spreading of banana bacterial wilt from plant to plant. Dead hanging leaves cover young suckers while old sheaths at the base of the pseudo

stem provide a home for adult banana weevils. However as a general recommendation de-suckering should be done leaving 3-5 plants per mat, while only dead and hanging leaves should be de-trashed (Tushemereirwe, 1997). Removal of the male buds using forked sticks helps to reduce diseases like banana Bacterial wilt, Cigar rot, and Moko diseases which are transmitted by insects that visit the male inflorescence (Wardlaw, 1961). Propping or guying up banana plants aided by supporting poles and ropes is done in order to prevent the plants with maturing bunches from breaking or toppling.

The banana weevils (*Cosmopolites sordidus* Germar) causing bunch reduction by up to 40 45 % (Rukazanbuga et al., 2002) and plant parasitic nematodes are the most destructive pests of bananas in Uganda. The weevil damage arises from larva feeding and tunneling into banana corms and pseudo stems. Weevil damage interferes with uptake of nutrients and water. The banana weevil can be controlled by using cultural practices (clean planting material, proper field sanitation and trapping), chemical insecticides (dusban solution of 1.5 cc per litre of water for one hour), primicid and furadan 60 gms per stool, kill weevils (Tinzara et al., 1998). Good husbandry which involves clean weeding, sucker removal, pruning, manuring and mulching lead to production of vigorous plants, which are less affected by weevil damage compared to stressed (poorly managed) plants. In order to reduce hiding and breeding sites for adult weevils all harvested and toppled plants should always be split, chopped up into small pieces that can dry up quickly.

The nematodes are very small worms and can not be seen with naked eyes. They live and feed inside roots and the corm thus destroying them. Root necrosis by nematodes interferes with the water and nutrient movement in the plant resulting into wilting. The spread of nematodes

from one region to another is attributed to movement of infested planting material and this can be avoided by using nematode free planting material. Clean planting material can be obtained by corm paring, which could be followed by hot water treatment (at 52° C- 55 ° C for 20 minutes or currently IITA recommends put in boiling water for 2-5 seconds).The use of nematicides is currently the most efficient method for control of nematodes in established banana plantations. At present the recommended chemical is Furadan (Carbofuran) and is available in two formulations, 5G and 10G. For the 5G formulations, 60 gms are applied per mat while 30 gms are applied when 10G is used. Nematode populations should be regularly monitored through sampling and assessment of nematode damage in roots (Namaganda et al., 1996).

Bananas and plantains in Uganda are attacked by several pathogens some of which include Fungi (Sigatoka leaf spots, *Periconiella* leaf speckles, and *Fusarium* wilts) (Kangire et al., 1998), Bacteria (Banana bacterial wilt), and Viruses (Banana streak virus), Jones and Lockart, (1993). These cause leaf spots and vascular wilts (Leaky, 1990). The Sigatoka leaf spots and *Periconiella* leaf speckles kill leaf tissue and cause rapid discoloration and death of leaves, thus reducing the ability of the plant to manufacture the food needed for growth and filling of the bunch (Tushemereirwe et al., 1996). The cheapest and most effective method of controlling plant diseases is by use of resistant cultivars. But at the moment no highland bananas ('matooke') have been found to be resistant to these leaf spots. There is however proof that enhanced plant nutrition can tremendously reduce the damage effects of banana leaf spots leading to increased yields (Tushemereirwe 1997). Application of adequate fertilizers (especially organic manures), mulching (with the right material), keeping the plantation weed free, maintaining optimum plant population through timely desuckering, detrashing and optimum deleafing and control of other stress conditions will help control leaf spot diseases.

The race of *Fusarium* wilt currently present in Uganda, *Fusarium oxysporium f.s cubense*, causes wilting and eventual death of affected plants and attacks Bogoya (Gros michel), Sukali Ndizzi (Apple banana) and Kayinja (Pisang awak). All matooke cultivars are resistant to *Fusarium* wilt. There are no known therapeutic means of controlling this soil borne pathogen once the plant has already been attacked. However, there are a range of resistant cultivars available and these include Cavendish bananas, Yangambi KM₅ and Bluggoe, FHIA17, FHIA23, FHIA25 (Kangire et al., 1997). Banana bacterial wilt (Banana Xanthomonas wilt) caused by the bacterium *Xanthomonas campestris* p.v. *Musacearum*, is currently the most devastating disease of bananas (Eden, 2004). All known banana genotypes have been observed to be susceptible (Tushemereirwe et al., 2004). Affected plants wilt, leaves turn yellow and die. And the bunches prematurely ripen, rot and die (Thwaites et al., 2000). The pathogen is mainly transmitted through farm implements, infected plant or plant parts and insects frequently visiting banana floral parts (Yirgou and Bradbury, 1974). The recommended prevention and control measures include: avoiding transfer of disease through infected plants or plant parts, breaking off male buds using a forked stick, chopping down or rousing out infected plants and disinfecting all farm tools used with either fire flame or JIK detergent solution at the chemical to water rate 1:5. Glyphosate and 2, 4-D may be used (Okurut et al., 2006).

1.5 Constraints to Banana production in Uganda

Banana production in Uganda, has been experiencing a steady decline since the 1970's (Rubaihayo and Gold, 1993) to the extent that current productivity is as low as 6.3 tons /ha year compared to the potential yields of 60 tons /ha /year. Preliminary assessment of the primary production constraints sighted banana weevils, banana leaf spot diseases, *Fusarium* wilt, and nematodes, declining soil fertility, socio economic consideration (high production

costs and less returns) and the narrow genetic base as the major constraints (Rubaihayo and Gold, 1993). In 2001, an outbreak of banana bacterial wilt, a highly devastating disease was reported in Uganda (Tushemereirwe et al., 2004).

1.6 Problem statement

All Highland bananas are susceptible to most of the pests and diseases. The distribution and abundance of these pests and diseases vary in different agro-ecological zones in Uganda. For instance, the banana weevil is a serious problem in low and mid altitude areas and less of a problem in highland areas like Bushenyi (Gold et al., 1994). Although there appears to be a large number of cultivars, no one single banana cultivar performs well in all the agro-ecological zones of Uganda. The challenge to breeders is to produce banana plants that are stable, adapt to many agro-ecological zones, resistant to pests and diseases, mature early and are high yielding and yet command farmer socio economic acceptability.

1.7 Justification

Genetic improvement of the existing *Musa* germplasm and the introduction of superior foreign genotypes appeared to offer the best way forward (Karamura, 1993). Breeding activities aimed at generating genotypes resistant to pests and diseases had, to be initiated (Tushemereirwe et al., 2000). Bearing in mind the problem of narrow genetic base, conventional breeding activities commenced with the establishment of germplasm collection composed of both local and imported *Musa* germplasm (Karamura et al., 1996). In 1994 breeding of highland bananas by the National Banana Research Programme at KARI, started with two priority areas: screening of banana germplasm in the collection, for female fertility using an introduced wild diploid male, Calcutta 4 (AA) and development of superior male

diploids (Karamura et al., 1996). Some substantial progress has been made towards generation of “Matooke” hybrids resistant to Sigatoka leaf spot disease, banana weevil borers and nematodes (Sebuliba et al., 2006). The challenge however remains in developing genotypes that combine pest and disease resistance, high stable yields, fruit and product quality characteristics that are acceptable to end users (Nowakunda et al., 1998). Throughout this ‘matooke’ hybrid generation period, new genotypes have been developed and evaluated both on-station and on-farm. The International *Musa* Testing Programme (IMTP), through International Network for the Improvement of Banana and Plantains (INIBAP), has made available new banana genotypes from the *Foundacion Huondurena de Investigations Agricola* (FHIA). These materials have been evaluated on station under IMTP1, IMTP2 and IMTP3 projects (Orjeda, 1998). Some of these genotypes needed to be further evaluated on farm under different agro ecological zones.

Because genotypes adapt differently to environments, their performance inevitably differs with respect to agronomic, yield, disease and pest responses (De Cauwer et al., 1995). Information on agronomic potential of genotypes under different environments is necessary for further crop improvement. Data on growth and yield would provide useful information with reference to height, girth, leaf emission and bunch qualities acceptable to end users. Data on growth characteristics would provide information on maturity period. Pest and disease data would provide the breeders with important information on the adaptability of the genotypes in different environments, in relation to weevil and nematode resistance. This information is important in selection genotypes and choice of location by the farmer. Information on G x E interaction in bananas is very limited if not absent. Such information would provide a means to determine stability of yield, disease and pest resistance. Consequently, it would be used as a basis for giving cropping recommendations to farmers. Besides, a better understanding of G X

E interaction would lead to efficient allocation of resources in multi environment cultivar or genotype testing programs (Comstock and Moll, 1963).

1.8 Objectives of the study:

The general objective of this study was to evaluate the performance of introduced banana genotypes under different agro ecological zones of Uganda.

The specific objectives were to:

- (1) Determine the agronomic and yield performance of the introduced banana genotypes across three agro ecological zones of Uganda.
- (2) Determine the response of introduced banana genotypes to production constraints: Sigatoka, banana weevil and banana nematodes in the three agro ecological zones of Uganda.
- (3) Determine the yield stability of the introduced genotypes in the three agro ecological zones of Uganda.

1.9 Hypothesis:

- The agronomic performance and yields of the introduced banana genotypes varies across the different agro ecological zones.
- The response of the introduced banana genotypes to major diseases and pests varies from one agro ecological zone to the other.
- The introduced banana genotypes have stable yields across the different agro ecological zones.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Agronomic characteristics

The agronomic potential of land races and genotypes must be determined for an optimal utilization of genetic resources in *Musa* improvement (Baiyeri and Ortiz, 1996). Plant growth characteristics and yield have been reported to be very important in banana and plantain germplasm evaluation (Orjeda, 1998). There are three distinct phases defining the growth characteristics and yield (Gauhl *et al.*, 1995). The vegetative phase (planting – flowering), Production cycle (planting to harvesting) and the fruit filling phase (flowering to harvesting). Growth parameters of vegetative phase include sucker emergence, height of the plant at flowering, girth at flowering and total number of functional leaves (Gauhl *et al.*, 1995).

Height of the tallest sucker was used to indicate sequence of generation (Orjeda, 1998). According to (Njuguna *et al.*, 2008), genotype FHIA 25 was the tallest and also had the highest number of functional leaves at flower shooting. The taller genotypes do not necessarily have more leaves than the shorter ones. Nguthi (2001) concurred with (Njuguna *et al.*, 2008) by arguing that, taller genotypes do not necessarily have more leaves than the shorter ones since genotype Williams, the shortest (161.2 cm), had the highest number of functional leaves at flower shooting (12.7). FHIA 25 (289.6 cm) was the tallest with fewer functional leaves at flower shooting (11.7). Genotype therefore, could be a critical factor in determining yield potential of bananas. Generally shorter genotypes are more preferred than taller ones in areas that experience strong winds (Baiyeri and Ortiz, 1996). Studies conducted on five genotypes in Mozambique, reported a decrease in pseudo stem girth during all

reproductive cycles. Moreira (1987) indicated that there was a positive correlation between diameters of pseudo stem and bunch size.

Agronomic performance was defined by plant growth characteristics and yield. Yield was defined by bunch weight in kilogram's and number of hands or clusters (Gauhl *et al.*, 1995). According to Gauhl *et al.* (1995) high yield combined with a short production cycle and a fast sequence of generation leads to a high yield per area and time unit. Nguthi, (2001) suggested, that banana bunch yields do not necessarily depend on only pseudo stem height and total number of functional leaves at flowering. Early maturity is a desirable characteristic because such genotypes are more likely to give higher yields over time (Njuguna *et al.*, 2008).

Producers and consumers of cooking bananas and plantains prefer large size bunches with medium size fingers (Dazie and Orchard, 1996). However, presently there are no standard bunch and fruit sizes that are recommended in Uganda (Nowakunda *et al.*, 2000). Mode of transport for banana bunches to market would also influence the bunch sizes. In areas where bicycle are used for transport, traders prefer medium bunches of 18-30 kg. A larger bunch of over 70 kg from FHIA genotypes are likely to be avoided by bicycle traders (Mugisha *et al.*, 2008).

Several growth and yield parameters have been used in attempting to establish maturity and bunch size (Perez *et al.*, 2002). Maturity period (time from planting or sucker emergence to physiological fruit maturity) was considered very important in the evaluation of ten imported *Musa* germplasm in Kenya (Njuguna *et al.*, 2008). Physiological maturity was defined as the point of full fruit maturity nearing or at ripening of the first finger. Genotype SH 3640 took the shortest time (314.5 days) while SH 3436-9 took the longest time (648.7 days). In

Mozambique genotype FHIA 17, took the longest time from planting to flower shooting (401.1 days) while SH 3640 took the fewest days from planting to flower shooting (331.8 days) (Uazire et al., 2008). Genotype SH 3436-9 took the longest time from planting to flower shooting (484 days) while FHIA 18 took the shortest time to flower (255 days), in Rwanda (Gaidashova *et al.*, 2004). This implied that the time taken by different genotypes from planting to maturity varied within locations. Suggesting that the performance of banana genotypes varies with location.

Short maturity period, high yields and resistance to pests and diseases were considered important cultivar selection criteria by banana farmers in Rwanda (Gaidashova *et al.*, 2004). According to a study conducted in Rwanda, (Gaidashova *et al.*, 2004) all hybrids matured later than local cultivars 130-160 days compared to 97 days for genotype Barabeshya (AAA-EA). According to experiments conducted at National Horticultural Research Centre, (NHRC) at Thika in Kenya, from 2001 to 2004, cultivar GCTCV-119 and FHIA 23 matured in 148 days compared to FHIA 25 that took 201 days.

FHIA hybrids imported from Honduras are known to have superior yield and adaptability characteristics (Nowakunda *et al.*, 2000). However, FHIA hybrids have been reported to take longer time to attain maturity than local genotype (Baiyeri and Ortiz, 1996). According to Shepherd *et al.*, (1997) triploid genotypes, particularly those in commercial plantations, are generally superior to diploids in terms of vigour, productivity and acceptability. According to studies conducted on twenty six banana and plantain genotypes in Malawi, cooking bananas have a wider adaptation than others (Banda et al., 1996). Locally grown bananas and plantain

are low yielding and susceptible to the major pests and diseases like Sigatoka leaf spots, *Fusarium* wilt (Kangire, 1998), weevil borers and nematodes (Okech *et al.*, 2005).

2.2 Response to banana weevil borer attack

The banana weevil (*Cosmopolites sordidus Germar*) is found almost every where in East Africa and has been implicated in the disappearance of highland banana (AAA- E.A) stands in traditional banana growing areas of Uganda (Gold *et al.*, 1994) and Tanzania. In East Africa yield losses range from 50% under heavy attack (Sengooba, 1986) to 60% (Rukazambuga *et al.*, 2002). Adult weevils are free living but most often found at the base of the banana mat or associated with crop residues (Gold *et al.*, 1994). Population build up is slow and weevil problems become increasingly important in ratoon crops (Rukazambuga *et al.*, 2002). Damage is caused entirely by larval feeding. They damage by creating tunnels that disrupt water and nutrient uptake causing the infested plants to snap and topple.

Stressed plants in “poorly” managed banana plants are believed to be more susceptible to the banana weevil attack. More stressed plants are unable to compensate for damage and therefore suffer greater losses in yield (Bakyalire, 1992).

Weevil attack reflects weevil populations and abundance , which also gives an indication of the environmental conditions preferred by the pest (Gold *et al.*, 1994). Agronomic practices such as plant spacing, inter cropping and mulching, create micro environments which in turn may favor or discourage weevil fecundity, longevity and thus population build up (Ittyeipe, 1986). Several methods of prevention and control ranging from use of clean planting materials, chemicals, bio-control agents, tolerant cultivars laying weevil traps to numerous botanicals (concoctions) have been employed. However, banana weevil effects on yield have

increasingly manifested with rations (Mitchel, 1980). The banana weevil is currently being controlled through the practices:

- Use of clean or weevil free planting material obtained from weevil free fields or by paring/ trimming the suckers in order to remove un-hatched eggs and larvae before planting. To ensure a greater level of cleanliness the pared corms can be subjected to hot water treatment (52-55) °C for 20 minutes. Tissue cultured banana plants may be used where available (Tushemereirwe et al., 1999).
- Practicing good husbandry through, clean weeding, Desuckering, pruning, manuring and mulching (Tushemereirwe et al., 1996).
- Destruction of crop residues by removing and splitting of harvested banana pseudo stems (Rukazambuga *et al.*, 2002)
- Laying weevil traps (Gold *et al.*, 1994)
- Use of chemicals like Carbofuran (at the rate of rate of 60 grams per stool) to kill weevils to kill weevils or dipping in a solution of 1.5cc of dursban per litre of water for one hour to kill the remaining weevils larvae or eggs (Tinzara et al., 1998).

The use of Chemicals is the most effective but not cost effecting among the small holders typical of Uganda farmers. Besides, use of chemicals is prone to gross abuse rendering it environmentally risky. This suggests that use of resistant genotypes could offer the cheapest and environmentally safer option. This therefore explains why breeding activities aimed at generating genotypes with superior agronomic qualities and resistance to the banana weevil borer would provide an important solution (Tushemereirwe et al., 1999).

2.3 Response to banana nematodes attack

Nematodes are ubiquitous and have diverse feeding behaviors and life strategies ranging from colonizers to persistors (Bridge, 1993). Root damage due to nematodes and their population densities help to establish the status of resistance of *Musa* cultivars to nematode (Speijer *et al.*, 1994). The most damaging and widespread nematodes attacking bananas are the migratory endo-parasites that include burrowing nematodes (*Radopholus similis*), the root lesion nematodes (*Pratylenchus goodeyi* and *Pratylenchus coffea*), the spiral nematodes (*Helicotylenchus multicinctus*) and root knot (*Meloidogyne spp*) Okech *et al.*, (1994). With the exception of *Meloidogyne spp* the other migratory endo-parasites feed on roots and the corm tissues causing the formation of lesions that may enlarge and coalesce resulting in large necrotic areas (Speijer and De Waele, 1997). The banana nematodes damage plants thereby interfering with their root anchorage causing all heavily affected plants to uproot and topple (Shepherd *et al.*, 1997). However severity of attack appears to vary according to species and their densities which are directly influenced by crop management methods (Pinochet and Stover, 1980, Sarah *et al.*, 1993). Nematode damage is influenced by genotype specific adaptation to soil and climate conditions (Price, 1995). Distribution of nematodes parasitic to banana plants is influenced by altitude (Bridge, 1993). *Pratylenchus spp* are prevalent at high altitude areas. While *Helicotylenchus spp* and *Radopholus spp* are predominant at low altitude areas (Speijer *et al.*, 1994)

Banana nematodes can be reliably controlled by use of nematicides (Gowen and Queneherve, 1990). However, these chemicals have adverse environmental effects and are costly for the resource-poor farmers. The use of clean planting material, crop rotations, observing good crop husbandry and using break crops, have been reported as alternative nematode control measures (Gowen and Queneherve, 1990). Some plant species have for long been known to

possess nematocidal activity (Reynolds *et al.*, 2000), eg *Targetes spp.*(marigolds), also used as intercrops in banana fields to reduce the nematode populations of *Radopholus similes*, *Meloidagyne incognita*, *Helicotylenchus multicinctus*, *Radopholus reniformis*, *Haplolaimus indicus* and *Pratylenchus spp.* (Naganathan *et al.*, 1988). The use of nematode resistant cultivars is a promising alternative (Dochez *et al.*, 2000). Identification of genotypes with resistance to nematodes is an important management strategy. There is evidence that limited nematode resistance and tolerance, exists in *Musa* gene pool (Pinochet, 1996, De Waele and Elsen, 2002). Pisang Jari Buaya and Yangambi KM5 (Ibota bota), have been reported to be resistant and moderately resistant respectively (Rowe and Rosales, 1993). This suggests that more genotypes, especially hybrids could be a source of resistance to nematodes. The use of clean planting material, corm paring, hot water treatment, tissue culture, and break crops are some of the effective cultural banana nematode control methods (Sarah, 1989). However, the nematode free suckers or plants should be planted in nematode free fields where bananas have not been grown before. Fields where non host crops (break crops) have been grown for at least two years are recommended. Crops like cassava, sweet potatoes and pineapples are effective break crops (Namaganda, 1999).

2.4 Response to Black Sigatoka disease attack

Black Sigatoka caused by the fungus *Mycosphaerella fijiensis* Morelet is currently considered the most important disease on Highland (AAA- EA) bananas. It was first discovered in the early 1960s (Stover; 1972) and reported in Uganda in 1989 (Tushemereirwe *et al.*, 1996). Today the disease is found wherever East African Highland bananas are grown with the exception of a few altitudes above 2000 m.a.s.l. All highland bananas are susceptible. The disease causing ascospores are the major source of inoculums (Stover, 1991). Ascosporic release is determined by leaf wetness. When leaves are thoroughly wetted, ascospores

discharge begins within minutes reaching 85% of spores within 2 hours (Meredith, 1970). Ascospore dispersal by means of air currents is considered to move all directions of the atmosphere (Meredith, 1970). Optimum germination occurs within 6 hours at temperature ranges within 25- 29° C provided humidity is at or near saturation with little or no germination occurring at or below 12 °C or above 35 °C (Stover, 1972). In susceptible clones the infected tissue becomes increasingly necrotic after about 28-40 days. The disease causes premature drying of the leaves which in turn leads to incomplete filling of banana fingers (Tushemereirwe et al., 2004). Yield losses involving bunch weight reduction by 37% have been recorded (Tushemereirwe *et al.*, 2000). The disease develops faster where humidity and rainfall are high (Foure, 1987; Gauhl, 1994). Host plant response to disease has been determined at flowering by the recording of standing leaves, youngest leaves with symptoms, youngest leaf spotted, total leaf area attacked by black Sigatoka and index of leaves spotted (Craenen, 1994). Survey system based on the youngest leaf spotted has much lower levels of error than estimates of leaf area index (Stover, 1972). The youngest leaf spotted (YLS) correlates significantly with disease development time and other methods of assessing host plant response to black Sigatoka. Increasing YLS values indicates more fully functional leaves (Craenen, 1994). Host plant response to black Sigatoka was rated on the following scale:

Susceptible (S) – less than 8 leaves without spots.

Less susceptible (LS) – between 8 and 10 leaves without spots.

Partially resistant (PR) – more than 10 leaves without spots.

Highly resistant (HR) – no symptoms (hypersensitivity)

The disease may be controlled using fungicides like Bayfidan using the rate 50mls in 20litres of water and drenching 1litre of the solution per plant/mat. Cultural practices like, optimum

leaf pruning, enhanced nutrition involving the use of fertilizers and amendments like manures and mulches have been reported to improve plant health and vigor there by increasing plant resistance to pests and diseases and consequently resulting in increased yields (Tushemereirwe, 1997). The use of resistant and tolerant genotypes like FHIA hybrids has been reported to be effective (Vuylsteke *et al.*, 1993).

2.5 Use of Host plant resistance

All plantain and the East Africa highland banana cultivars are susceptible to the major banana leaf spot diseases, banana bacterial wilt diseases, banana virus diseases, banana weevils and banana nematodes. (Vuylsteke *et al.*, 1993). The highland bananas are highly resistant to the *Fusarium wilt* (Kangire, 1998) but are equally highly susceptible to leaf spot disease and bacterial wilt (Ploetz, 2004). No one particular banana cultivar is completely resistant to banana bacterial wilt disease (Tushemereirwe *et al.*, 2004), banana streak virus, (Kubiriba *et al.*, 2001), banana weevil and nematodes. The use of fungicides and pesticides to control these diseases and pests is not feasible in resource poor small holdings where the crop is grown mainly for home consumption (Tushemereirwe, 1997). Durable host plant resistance is generally considered as the most appropriate component of integrated pest management against pathogens (Ortiz *et al.*, 1996). There is evidence that some resistance exists in *Musa* gene pool and some of this has been introgressed into plants to obtain better genotypes that are now available for on farm evaluation.

2.6 Genotype x Environment interaction

Highland bananas are grown across a wide range of ecological zones. Because different genotypes adapt differently to various environments, performance differences inevitably occur in relation to agronomic, yield, disease and pest response. This relative performance of genotypes that often changes from one environment to another causing differential response of genotypes to change in environment is referred to as Genotype x Environment (G X E) interaction effects (Comstock and Moll, 1963). Variability may occur in data sets from different locations due to environments and genetic causes (Ortiz et al., 1996). The existence of a large G x E interaction poses a major problem in relation to phenotypic performance, genetic constitution and hampers effective discrimination among contending genotypes (Comstock and Moll, 1963). Local banana and plantain cultivars exhibited different performance under distinct environment according to a study conducted in Malawi (Banda et al., 1996).

Allard and Bardshaw (1964) categorized environmental factors which lead to G X E interactions as predictable and unpredictable. Predictable G X E interactions can be reduced by allocating specific cultivars to specific environments. The unpredictable G X E interactions are more difficult and often lead to large (Genotype X Year) and (Genotype X Year X Location interaction). Selection therefore of stable genotypes that perform consistently across environments can reduce the magnitude of these interactions.

Different attempts have been made to solve problems created by G x E interaction (Comstock and Moll, 1963) with almost all information obtained giving existence and magnitude but not measuring individual genotype with environment. Information on G x E interaction in banana

is very limited if not absent. It is important to obtain such information as it can be a basis for giving cropping recommendations to farmers. Besides, a better understanding of G X E interaction can lead to efficient allocation of resources in multi environment cultivar or genotype testing programs.

2.7 Stability Analyses

Stability Analysis involves using bunch weight as dependent variable with site mean as an independent response in a linear regression model and examination of the slope by method made popular in the 1980's by Hildebrand and others that were enhanced by AMMI models. The regression based fitting treatment response was made to site mean, and slopes examined. Stability can be defined as low variation in a particular trait when measured over numerous locations and/or years. The specific phenotypic response of each genotype at each site would be regressed against the environmental index for its respective site. After linear regression equations are calculated for each genotype, the regression coefficient (i.e., slope of the linear regression line or β) of each genotype can be compared to the overall average performance of all genotypes as a measure of its stability. The expected average regression coefficient for all genotypes always equals 1.0, so genotypes with $\beta < 1.0$ (i.e., flatter slopes) are considered more stable than the average genotype, while genotypes with $\beta > 1.0$ (i.e., steeper slopes) are considered less stable. Therefore, a more stable genotype is less responsive to changes in the environment than a less stable genotype. Sometimes the more stable genotype performs better than the less stable genotype under poor environmental conditions, but not as well under better conditions. An ideal genotype would perform better than most others in poor environments, while still performing well in good environments. Olien et al. (1991) used linear regression analysis to calculate stability indices for cumulative tree size.

Correlation matrix values are used for principal component analysis. The scree plot is used to confirm the number of principal components taken. The first principal component usually explains the largest proportion of the variance as result of the interaction between the genotype and the environment. The rest of the components account for the remaining variance. The first two principal components provide the best two dimensional summary of the data plot.

2.8 Principal Component Analysis

A Principal Component Analysis (PCA) is carried out on the correlation matrix based on bunch weight. The first principal component accounts for the greatest variance. The other principal components that explained the next highly positive variance were taken. The correlation matrix explained percentage contribution by each of the nine Principal components. However Principal component analysis reduced these components to only three most important ones. The Eigen values reveal that only these three had values above 1.0 and so these were the ones used in the bi plot.

The bi plot gives two sets of variables based on the major principal components. The first principal component explaining the most important set of variables accounting for variability in bunch yields on one axis. While the second principal component explained the second most important set of variables accounting for variability in bunch yields on the other axis.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1.0 Site selection

The study was conducted in three locations namely: Ruhinda sub- County in Rukungiri district. Bujumba Sub County in Kalangala district and Ziobwe Sub County in Luwero district. Ruhinda is located 450 km SW of Kampala and lies 1600 – 1900 m.a.s.l, with centre co-ordinates of 00 51'S., 300 17'E. The soils in this area have been described as fertile humic Acrisols (FAO-UNESCO). The area receives bimodal rainfall (annual precipitation 1250-2500 mm) with temperatures varying a little from 15 to 20 °C, recorded at the nearest meteorological site in Rukungiri town. Bujumba is located approximately 120 km south of Kampala, with centre co-ordinates of 00 25'S., 320 34'E., and 1200-1300 m.a.s.l. The soils in this area have been described as heavily leached Ferralic Arenesols (FAO-UNESCO) with medium fertility. This area receives bimodal rainfall (annual precipitation 1125-2250 mm), with the temperature extremes varying between (15 and 28) °C, as recorded at Kalangala. Ziobwe is located 40 km north of Kampala, with centre co-ordinates of 36' 620 E and 0' 40 N, lies 1200-1300 m.a.s.l and has soils that have been described as highly weathered red sandy clay loam, often under lain by soft laterites and classified as Rhod-humic farraic Acrisol (FAO-UNESCO). This area receives bimodal rain fall with the temperature extremes in the area varying between (15 and 32) °C as recorded at National Agricultural Crops Resources Research Institute (NaCCRI). These locations represent three different agro ecological zones in Uganda. Previous survey reports, have suggested that high altitude areas like Ruhinda have generally low disease and pest incidence and severity probably because the climate does not favour survival and multiplication of the pest and disease causing organisms. Besides, there is also the factor of enhanced nutrition as a result of high soil fertility in such areas since the soils are volcanic. These two factors help to explain partly the reason for the better performance of bananas in such areas. On the contrast lowland areas like Luwero have been reported to offer the most conducive conditions for pest and disease build up (Rubaihayo et al., 1993). Such areas have also been reported to have soils with very low fertility (Rubaihayo et al., 1993). Kalangala is situated in Sseese, an island on Lake Victoria therefore by virtue of its location it is closed and hence expected to have low disease and pest pressure. The soils characteristically contain a higher proportion of sand but are also expected to be mid-way

between those of Rukungiri and Luwero in fertility. These trials were planted in first rains season of (March-May), 2005.

3.1.1 Experimental design

Fifteen banana and plantain genotypes, introduced into Uganda from Fondacion Hondurena des Investigaciones Agricola (FHIA) International Network for Improvement of Banana and Plantain (INIBAP), International Institute of Tropical Agriculture , (IITA) and one developed by the National Banana Research Programme (NBRP) were used in the study. Tissue culture plantlets raised and weaned at National Agricultural Crops Research Institute (NaCCRI). Three farms representing a replicate were selected in each of the three agro ecological zones. Selection of the farms was based on location, availability and willingness to allow various stake holders to participate in joint management of the experimental trials. Field preparation was by the farmer, planting was done by researcher (student), and field trials were managed by the farmer and data collection by the student. Each banana genotype was planted on each farm in a row of ten plants in a randomized complete block design (RCBD). The banana genotypes used in the study are listed in table 1.

Table 1 Characteristics of the locations used in the study

Location	District	Distance from Kampala (km)	Centre coordinates	Altitude (m.a.s.l)	Temperature ranges (°C)	Soil type	Annual Rainfall (mm)
Kijumba	Kalangala	120	0° 25' S., 32° 34' E.,	1200-1300	15-28	heavily leached Ferralic Arenesols	1125-2250
Muhinda	Rukungiri	450	0° 51' S., 30° 17' E	1600-1900	15-20	fertile humic Acrisols	1250-2500
Obwe	Luwero	40	36° 62' E and 0° 4' N,	1080-1372	15-32	Rhod-humic ferraic Acrisol	900-1300

Table 2 Characteristics of the genotypes and hybrids used in the on farm study in the three agro-ecological zones of Uganda.

Genotype	Sub group/Ancstry	Genome	Origin	Sigatoka Response	Weevils Response	Nematode Response	Bunch Weight (Kg)
FHIA 17	High gate X SH 3362	AAAA	FHIA	R	T	T	43.9
FHIA 23	High gate X SH 3362	AAAA	FHIA	R	T	T	45.4
FHIA 25	SH 3648 X SH 3142	AAAA	FHIA	R	T	T	55.0
FHIA 18	Prata X Ana X SH 3142	AAAA	FHIA	R	T	T	29.0
FHIA 21# 68	AVP-67 X SH3142	AAAA	FHIA	R	T	S	12.5
WILLIAMS	Dwarf Cavendish mutant	AAA	INIBAP	S	T	T	12.0
BUROCEMSA	Blugoe Sub Group	ABB	INIBAP	T	T	T	16.5
YANGAMBI	Primitive wild local	AAA	INIBAP	R	R	R	25.1
SABA	Blugoe Sub Group	ABB	INIBAP	T	T	T	16.7
PISANG CEYLAN	Primitive wild local	AA	INIBAP	T	T	R	17.2
GCTC V 119	Giant Tissue Culture variant 119	AA	INIBAP	S	T	T	10.5
SH3640	Dwarf Prata X SH 3393	AAAB	FHIA	R	T	T	18.0
CRBP-39	French Clair X M 53 (4)	AAAB	IITA	R	T	T	16.5
SH3439-9	Somaclonal variant of SH 3436(High gate X SH3142	AAAA	FHIA	R	T	T	18.0
NFUUKA	Local East African High land (Matooke) check	AAA	LOCAL	S	S	S	16.1
660K	TMH X 660-1 and TMH 917K-2	AAAA	NBRP	R	S	T	18.5

S = Susceptible, T = Tolerant, R = Resistant.

NBRP =National Banana Research Programme

FHIA = Foudacion Hondurena Internationale Agricole

INIBAP = International Network for Improvement of Banana and Plantain

IITA = International Institute of Tropical Agriculture

LOCAL = Indigenous Bananas that have acceptability

3.1.2 Trial establishment and management

The plants were spaced 3 m X 3 m between and within rows. Farm Yard Manure (Kraal manure or cow manure) was applied at the rate of 20 kg per hole at the time of planting making it 20 ton/ha as recommended by the NARO (banana production manual, 2003). No inorganic fertilizers were used. All plots were mulched with locally available grass 5 cm thickness during the rain season (August to October) (Bekunda and Woomer, 1996). The choice of mulching grass depended on its availability of planting materials in the location. The trials were owned and managed by the farmers. The student played the guidance role.

3.2.0 Data collection

Data on plant growth characteristics, yield parameters and response to pests and diseases were collected as discussed below:

3.2.1 Plant growth characteristics

Date of planting and sucker emergence from the mother plant and the follower suckers, were recorded when the follower suckers emerged from the ground (Orjeda, 1999). The date of flowering was recorded as the inflorescence emerged from the tip (shooting stage), after the plant had produced the flag leaf and at that point no more leaves were produced by the plant (Orjeda, 1999). The number of standing fully functional leaves were counted and recorded (functional leaves were those with more than 50% green leaf lamina area). The leaves were counted from the youngest fully opened leaf (top) to the oldest still functional leaves (below) (Gauhl et al., 1995). Plant height were measured in centimeters from ground level to the point

of inflorescence emergence of the flowers using a graduated measuring stick or rod (Orjeda, 1999).

Plant girths at 100 (cm) from the ground were recorded from all flowering plants by measuring the circumference of the pseudo stem in centimeters using a graduated tape measure (Orjeda, 1999).

3.2.1.1 Plant Height

Plant heights were measured in centimeters from ground level to the point of inflorescence emergence of the flowers using a graduated measuring stick or rod (Orjeda, 1999). This was done by placing a graduated measuring rod vertically on the ground at the base of the flowered plant on which data were due to be recorded and the readings of the height taken from the graduated rod at the point of inflorescence emergence of the flower on the plant where leaves arise.

3.2.1.2 Plant Girth

Plant girths at 100(cm) from the ground were recorded from all flowering plants by measuring the circumference of the pseudo stem in centimeters using a graduated tape measure (Orjeda, 1999). Using a graduated measuring tape, girth of each flowered plants similar plants used for plant height measuring) were measured at 100cm above the ground.

3.2.1.3 Total Functional leaves

The number of standing fully functional leaves were counted and recorded functional leaves were those with more than 50% green leaf lamina area. The leaves were counted from the youngest fully opened leaf (top) to the oldest still functional leaf (below) Gauhl et al., (1995). This was repeated on all plants considered for plant height and girth measurements.

3.2.2.0 Yield data

3.2.2.1 Bunch Weight

Maturity period was recorded in days from shooting to the day when at least one finger showed signs of ripening (yellowing and softening) at which stage the bunch was harvested (Palmer, 1971). Harvesting of banana bunches was done when the fruits had attained fruit maturation and bunches were weighed (Kg) using a weighing scale (BFK-265-030B, 60, UK).

3.2.2.2 Number of Hands/Clusters

The number of hands was counted for each of the bunches harvested at physiological maturity (full maturity to ripening of first finger).

3.3.0 Determination of genotype response to Pests and Diseases attack

3.3.1 Response to Sigatoka disease

The same plants that were used for the determination of agronomic performance were used for the determination of Sigatoka response. Data for the assessment of Sigatoka disease severity

was scored from plants at flowering. The position of “Youngest leaf with mature Sigatoka spots” (YLS) and total number of functional leaves were counted from top to bottom and recorded. Similar data were recorded at harvest. The “Youngest leaf with mature Sigatoka spots” (YLS) were obtained by counting from the most recently expanded leaf with at least ten (10) fully developed spots. The positions of the leaf area showing symptoms were scored using Gauthl’s severity scoring method a modification of Stover’s method (Craenen, 1994).

The severity ratings according to this method are:

0 = no symptom

1 = < 1% showing symptoms

2 = 1-5% showing symptoms

3 = 6-15% showing symptoms

4 = 16-33% showing symptoms

5 = 34-50% showing symptoms

6 > 50% showing symptoms

These scores were used to compute the index of spotted leaf area (ISLS), which gives an indication of disease severity. The index of spotted leaf area provided an estimate of available photosynthetic leaf area at flowering (Ortiz et al., 1996) using the following Formula:

$$ISLS = 100 - \frac{100(YLS - 1)}{TL}$$

Where:

ISLS = Index of spotted leaf area (Sigatoka)

YLS = Youngest leaf spotted with Sigatoka

TL = Total number of functional leaves

3.3.2 Response to banana Weevil attack

Weevil damage on banana plants were recorded from recently harvested plants not later than 30 days from harvest. Banana weevil damage was assessed on the corm periphery and in 5 cm below the collar (i.e. corm pseudo stem junction). “Peripheral damage” (PD) was an estimate of percentage of corm surface tissue consumed by weevil larvae for both inner central cylinder (XI) and outer cortex (XO) cross sections. This method involves estimating percentage damage caused by banana weevils through tunneling. Cross section cuts were made on harvested pseudo stem and damage estimated at ground level and below ground level. At ground level both inner and outer pseudo stem diameters were measured (cm). The proportion of total percentage damage was estimated for each plant harvested. Surrounding rots arising from the galleries were included in cross section damage estimates. The mean of the two cross sections was calculated to form the derived total cross section score (XT).

Weevil damage proportions were transformed using angular transformation as described by (Gold et al., 1994)

$$Y' = 100 * \text{ArcSin}(\sqrt{(y + 0.5)/100}) * \frac{22}{28}$$

Where y is (%) Total cross sectional corm weevil damage (TX)

3.3.3 Response to banana plant parasitic nematode attack

Nematode infestation damage was estimated as described hereafter: A sampling area approximately (20 cm x 20 cm x 20 cm) was demarcated out from the base of the banana mat “due to flower, at flowering, or recently flowered Plant”. Soil was cut out from the demarcated area and all the roots (live and dead) were collected, counted and recorded in the field. Root health analyses involving determination of the proportion of live to dead roots were done. All roots collected from one flowered plant from each mat, were labeled and packed well in special light transparent polythene bags, kept and transported in cool boxes

prior to commencement of extraction and counting work. Nematode extraction, identification and counting were done on station and in the laboratory at Kawanda. This was done by taking five roots randomly then scoring for galling and root knot index. The five roots were then chopped into small pieces, from which 5 g portions were macerated. The macerated or blended samples were left to stand in sieves for 48 h. The filtrate was collected and from it 25 mls shaken and properly mixed. Then 2 mls samples of the mixture were used for Nematode identification and counting. Feeder roots were scored for nematodes using the following scale:

1 = A healthy, 2 = Mostly healthy, 3 = Mostly dead, 4 = All dead.

The significance tests were done at ($p > 0.05$) for all data collected. Nematode counts were transformed using square root $\sqrt{(y + 0.5)}$ transformation.

Where y is nematode population abundance.

3.4 Analysis of Variance

The data on plant growth characteristics described above and yield components were subjected to analyses of variance using the general linear model (GLM) on SAS (SAS Institute Inc, 1990). Significance was tested at $p > 0.05$.

3.4.1 Correlation/Regression Analysis

Correlation and regression analyses were done between bunch weight and plant girth, bunch hands, number of functional leaves at flower shooting, number of functional leaves at bunch harvesting, response to Sigatoka disease, index of non sported leaf, Weevil corm damage, live roots and Nematode damage in order to establish existing relationships amongst components.

3.4.2 Stability Analysis

The fifteen Genotypes were subjected to stability analysis using bunch weight as dependent variable and site mean as an independent response in a regression. The specific phenotypic

response of each genotype at each site was regressed against the environmental index for its respective site. Linear regression equations were calculated for each genotype, the regression coefficients (i.e., slope of the linear regression line or β) of each genotype were compared to the overall average performance of all genotypes as a measure of its stability. The expected average regression coefficient for all genotypes always equals 1.0, so genotypes with slopes, $\beta < 1.0$ (i.e., flatter slopes) are considered more stable than the average genotype, while genotypes with $\beta > 1.0$ (i.e., steeper slopes) are considered less stable.

3.4.3 Principal Component Analysis

A Principal Component Analysis (PCA) was carried out on the correlation matrix. Each principal component explains some proportion of variance. The first principal component accounts for the greatest variance. The proportion of total variance explained by the first principal component depends on the degree of correlation. The correlation matrix explained percentage contribution by each of the nine Principal components. However Principal component analysis reduced these components to only three most important ones. The Eigen values reveal that only these three had values above 1.0 and so these were the ones used in the bi plot. The Eigen values and the scree plot showed that the principal components give the most realistic information with respect to the bunch weight.

The bi plot gave two sets of variables based on the major principal components. The first principal component explaining the most important set of variables accounting for variability in bunch yields on one axis. While the second principal component explained the second most important set of variables accounting for variability in bunch yields on the other axis.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1.0 Agronomic performance

4.1.1 Growth characteristics

4.1.1.1 Plant Height

Results on plant height are presented in Table 3. The result indicated that, across the three agro ecological zones, Pisang ceylan (AA) and was the tallest 364.4 cm, followed by Nfuuka (346.4 cm) the AAA-East African highland banana used as check. The rest of the genotypes were significantly shorter than Nfuuka. Genotype Williams was the shortest, of all. The results showed that the tallest plants were in Luwero district, followed by Rukungiri and Kalangala least. By the time of flower shooting, the follower suckers of genotypes, FHIA 25 (AAAA), GCTCV 119 (AA), Buro cemsu (ABB), Saba (ABB), Pisang ceylan (AA), Yangambi KM5 (AAA) and FHIA 18 (AAAA) had attained at least 80 % of mother plant . While the rest of the genotypes were less than 79% the height of their mother plant.

These results agree with earlier findings from Kenya (Njuguna et al., 2008) and Rwanda (Gaidashova *et al.*, 2008). Where the lowest mean values for GCTCV 119 and CRBP-39 were reported. Gaidashova *et al*, 2008, evaluating nine genotypes for agronomic performance in Rwanda reported that FHIA 21 (AAAA) and Barabeshya AAA had significantly taller plants. While, Njuguna et al., 2008 evaluated ten genotypes at Kenya Agricultural Research Institute, Thika, for agronomic performance and obtained results that showed that FHIA 21#

68 (AA/AA), FHIA 23 (AAAA), FHIA 25 (AAAA) and GCTCV 119 (AA), had significantly taller plants.

Uazire (2008), evaluated five cultivars in Mozambique and reported that all FHIA hybrids were significantly taller than the rest of the banana genotypes. While the shortest plants were produced by Grand Naine (AAA). The East African highland banana, a local cultivars were the tallest 337 cm and 328 cm respectively.

The variation in the plant height from one agro ecological zone to the other could be linked to soil type and fertility in the area, altitude and weather. Highly fertile soils with higher soil organic matter content, stimulate root ramification, resulting in better water and nutrient up take and more vigorous growing plants with taller plant pseudo stems. Therefore plants growing in more properly well managed soils, produced bigger heights than those growing in poorly managed and less fertile soils (Bwamiki et al., 1994). The height of the plant depends on soils and the general plantation management. There is improved vigor and plant height stimulated by improved chemical and physical soil properties, which in turn stimulates secondary and tertiary root system development, leading to rapid plant growth (Robinson, 1998).

Table 3 Mean comparison of plant height (cm), of the fifteen banana genotypes evaluated in Kalangala, Rukungiri and Luwero, during 2005-2007, in Uganda.

DISTRICT							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall Mean
PISANG CEY	364.4a	372.3a	322.8b	337.8b	327.2b	367.9a	364.4a
NFUUKA	346.4b	366.3b	336.3a	337.9b	312.5c	360.6b	345.5b
FHIA 25	203.3h	297.6e	321.1b	340.7a	298.1e	295.7g	319.2c
FHIA 17	295.2d	295.3ef	315.0c	319.0d	287.0f	305.1f	314.0c
YANGAMBI	320.3c	306.6d	228.4l	288.1f	283.9f	305.7f	314.0c
SH 3460	286.7e	331.9c	310.4d	320.1d	355.7a	287.0h	307.9d
BUROCEMSA	264.5g	300.3e	270.1i	325.2d	297.8d	321.1d	307.4d
FHIA 23	286.2e	282.8g	316.2c	307.0e	302.1d	304.2f	306.4d
660K	282.3f	302.3d	292.6f	333.9c	259.7i	307.2f	306.4d
FHIA 21	267.3g	276.8h	294.6f	270.7g	303.3d	337.0c	306.4d
SABA	280.1f	274.6h	278.9h	274.1f	295.0e	342.4c	305.0de
CRBP 39	266.9g	272.6h	283.4g	330.0c	310.8c	314.4e	300.0e
SH 3439-9	265.4g	291.9f	301.7e	342.6a	260.5h	299.3g	299.5e
FHIA 18	279.4f	292.1f	261.4j	273.5f	270.0g	283.0h	291.0f
GCTCV 119	288.2e	299.2e	260.5j	249.8i	298.5e	297.1g	290.2f
WILLIAMS	136.6i	143.1i	246.9k	250.3h	173.0j	186.9i	192.2d
Mean	277.54	293.18	290.68	306.31	282.93	307.64	304.08
LSD(0.05)	6.83	6.85	6.83	6.76	6.55	6.84	5.76
CV (%)	13.74	13.57	11.32	11.73	14.56	14.54	11.58

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.1.1.2 Plant Girth

Genotypes, FHIA25 (AAAA), FHIA 18 (AAAA), SH 3640(AAAA), SH 3436-9(AAAA) and Pisang ceylan (AA) had significantly wider girth than Nfuuka AAA-East African highland banana (Table 4). Genotypes GCTCV 119 (AA), CRBP 39 (AAB), Burocemsa (ABB, Saba (ABB) and Yangambi KM5 (AAA) had girths of between 49.3-51.5 cm, which were significantly smaller than Nfuuka AAA-East African highland banana. Genotypes CRBP-39) had the smallest girth 49.3 cm. Plants evaluated in Rukungiri district had wider girths.

The consistently higher mean values for girth for FHIA hybrids across all the three zones could be linked to the genetic influence. These results agree with earlier findings from Kenya (Njuguna et al., 2008) and Rwanda (Gaidashova *et al.*, 2008) that showed that FHIA hybrids had the biggest girths. The low mean values for GCTCV 119 and CRBP-39 were also reported in Rwanda during an evaluation of nine genotypes for agronomic performance where results showed that Poyo (AAA) and Barabeshya AAA-East African highland banana had the smallest girths 49 and 53 cm respectively. In Kenya, agronomic evaluation of ten genotypes showed that FHIA 21# 68 (AAAA), FHIA 23 (AAAA), FHIA 25 (AAAA) and GCTCV 119 (AA), had significantly larger girths than other genotypes (Njuguna et al., 2008).

Uazire, (2008), evaluated five cultivars in Mozambique and reported that all FHIA hybrids had significantly bigger girths than the rest of the banana genotypes. The biggest girths were recorded in FHIA 17 (AAAA). The variation on the plant girths from one agro ecological zone to the other could be linked to soil type and fertility in the area, altitude and weather which ultimately influenced the agronomic performance of plants.

Rukungiri and Luwero zones are known to have more fertile soils than Kalangala and this probably explained why the plants grown in these places had bigger **girths** than those in Kalangala. Kalangala is an island on Lake Victoria and the soils are said to be heavily leached due to heavy downpour of rains and hence they are less fertile than those in Rukungiri and Luwero. The Lake Victoria zone is also heavily forested with natural tree species. This probably also explained why the differences in plants heights and girths in the first ratoon, did not significantly differ from those of Rukungiri and Luwero. During the first year of the trial the soils in Kalangala were more fertile than in second ratoon due to presence of more organic matter as a result of forest flora and fauna. This fertility got depleted in subsequent production ratoons. The Kalangala soils are also said to be predominantly sandy. The implication being that their capacity to hold soil moisture for appreciably long was low, because bananas are not efficient at extracting water from drying soils (Landon, 1991), therefore resulting in poor agronomic performance. The Rukungiri Zone has fertile soils, explaining the bigger plant girth. However, the higher altitudes could have limited plant vegetative growth through low temperatures.

These results therefore prove that the variation on the plant girths from one agro ecological zone to the other can be linked to soil type and fertility in the area, altitude and weather which ultimately influenced the agronomic performance of plants.

The highly positive correlation between the bunch yields and plant girth across all the three Agro ecological zones for all the genotypes implies that bunch yields are highly influenced by plant girth. And, since plant girth varies from location to location according to soil, climate and altitude, it follows that agronomic characteristics, yields and yield components also vary from place to place as a result of varying levels of management. Swennen and Vuylsteke,

(1991) observed, that yields of bananas and plantains were greatly influenced by plant girth and functional leaves, which were determined by levels of management.

Soil fertility influences banana and plantain growth and hence the size of the plant girth. More Fertile soils with higher soil organic matter content, stimulate root ramification, resulting in Better water and nutrient up take and more vigorous growing plants with bigger plant girths. Therefore plants growing in more properly well managed soils, produced bigger girths than those growing in poorly managed and less fertile soils (Bwamiki et al., 1994)

Generally, the plant girths varied with location, implying that the size of plant girths depended on soils and the general plantation management. There is improved vigour and plant girths growth rate, as a result of improved chemical and physical soil properties. This could have been responsible for the stimulated secondary and tertiary root system development, which equally stimulated rapid growth (Robinson, 1998).

Table 4. Mean comparison of plant Girth (cm), of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

DISTRICT							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall mean
PISANG CEY	54.6e	59.4d	62.0e	55.3e	62.9f	57.9fg	60.1e
NFUUKA	52.6f	54.4e	56.1f	54.6e	56.8h	59.2f	55.2b
FHIA 25	73.1a	71.7a	84.0a	90.1a	85.6a	79.0b	81.4a
FHIA 17	72.3a	71.3a	84.3a	90.1a	83.1b	77.0c	80.2a
YANGAMBI	50.3g	53.1e	46.0h	48.1g	56.3h	50.5i	51.5g
SH 3460	57.4d	59.8d	72.0c	66.7c	66.8d	66.1d	65.8d
BUROCEMSA	42.2i	45.7g	51.1g	54.5ef	58.6g	61.0e	51.4g
FHIA 23	72.4a	70.7a	83.0a	91.6a	79.7c	84.4a	78.3b
660K	52.4f	65.1c	57.4f	67.1c	54.3i	53.2h	54.7f
FHIA 21# 68	47.1h	55.7e	55.5f	52.0f	59.4g	61.7e	54.6f
SABA	44.7i	47.5f	47.1h	52.0f	55.2h	56.8g	49.7h
CRBP 39	43.5i	42.8h	49.5g	50.6f	51.6j	48.9j	49.3h
SH 3436-9	66.4b	67.7b	79.1b	84.0b	63.2e	59.4f	69.1c
FHIA 18	59.5c	62.9d	66.4d	60.5d	67.7d	61.2e	65.1c
GCTCV 119	49.8g	52.2e	51.8g	46.7h	48.3k	43.0k	50.1gh
WILLIAMS	46.4h	43.3h	62.2e	60.8d	56.3h	53.5h	55.3f
Mean	55.01	58.13	60.10	62.21	59.51	61.20	60.98
LSD(0.05)	1.85	1.80	1.83	1.84	1.93	1.87	1.61
CV (%)	18.60	18.93	18.58	18.85	18.60	18.10	16.10

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.1.1.3 Plant Height of Follower Sucker

The results on the plant heights of follower suckers of the genotypes are presented in Table 5. Overall, the results indicated that, across the three agro ecological zones of Uganda, genotype, Pisang ceylan (AA) was the tallest 263.0 cm, which was not significantly taller than Nfuuka (254.4 cm). The rest of the genotypes were significantly shorter than Nfuuka. Genotype Williams was the shortest (115.0 cm).

These results indicated that the tallest plants were recorded in Rukungiri followed by Luwero and Kalangala. By the time of flower shooting, the follower suckers of genotypes, FHIA 25 (AAAA), GCTCV 119 (AA), Buro cemsu (ABB), Saba (ABB), Pisang ceylan (AA), Yangambi KM5 (AAA), FHIA 18 (AAAA) had attained at least 80 per cent of mother plant growth. While the rest of the genotypes attained less than 79% by the same period. Genotypes, Williams (AAA), GCTCV119 (AA) and CRBP 39 (AAB) recorded the lowest (29-50%).

These results suggested that almost all genotypes grew significantly much more slowly than Nfuuka, except for Pisang ceylan. This implied that most of the genotypes matured later than the local check, Nfuuka. Such genotypes like GCTCV 119, which grew slowly wasted more assimilates in the growth process, thus making them less cost effective to produce. On the other hand such genotypes like Nfuuka that grew faster were more cost effective to produce.

Table 5. Mean comparison of plant height (cm) of follower sucker, of fifteen bananas Genotypes in Kalangala, Rukungiri and Luwero, Districts of Uganda, 2005-2007.

DISTRICT							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall mean
PISANG CEY	264.4b	288.5b	261.0f	259.3c	213.3a	187.4b	263.0a
NFUUKA	272.8a	315.7a	316.8a	195.5h	216.0a	191.3b	254.4a
FHIA 25	174.4e	232.1d	303.4b	294.4a	210.6b	164.6d	231.1c
FHIA 17	154.4g	201.6f	205.8l	220.9f	172.8e	116.1f	208.7fg
YANGAMBI	260.5b	243.0c	228.4l	232.2e	213.7a	237.6a	249.7b
SH 3460	206.4c	227.6d	281.8d	320.1d	124.3h	82.1g	206.6fg
BUROCEMSA	162.8f	199.1g	249.1g	339.1d	200.3c	143.7e	220.0de
FHIA 23	156.1g	186.0h	294.2c	209.0g	199.3c	171.1c	216.0def
660K	134.9h	190.8h	246.9g	185.0i	204.2c	211.0b	216.0def
FHIA 21# 68	133.2h	187.6h	219.7j	147.8k	151.0f	239.0a	213.8ef
SABA	209.4c	221.6e	212.1k	204.7g	174.2e	195.7b	207.1fg
CRBP 39	119.9i	149.0i	231.1i	164.7j	140.0g	135.0e	187.4h
SH 3436-9	177.0d	199.0g	267.0e	271.7b	130.5h	139.7e	199.4g
FHIA 18	181.1d	206.4f	238.3h	203.0g	129.3h	139.5e	200.1h
GCTCV 119	264.7b	238.2c	240.5h	221.8f	194.2d	174.5c	225.9de
WILLIAMS	83.7j	100.1j	196.4m	119.7l	84.4i	64.1h	115.0i
Mean	164.42	209.74	249.33	212.07	171.54	160.77	213.38
LSD(0.05)	10.40	10.41	10.45	10.69	10.41	10.42	9.92
CV (%)	31.01	31.85	31.65	31.04	31.71	31.00	31.42

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.1.1.4 Days from Planting to Flowering

Overall, all the introduced genotypes took significantly longer days from planting to flowering (vegetative), than Nfuuka (Table 6. All the introduced genotypes spent (409-484 days) in vegetative stage, which were significantly higher than Nfuuka (403 days).

Genotypes GCTCV 119, CRBP 39, FHIA18 (AAAA), FHIA21# 68 (AAAA), FHIA25 (AAAA) and SH3439-9 (AAAA) took 439 to 484.6 days to flowering. These were significantly higher than 463.9 for Nfuuka. Genotypes SH 3640 (AAAA), Saba, Pisang ceylan, Yangambi KM5, Williams and 660K were similar to Nfuuka

In Kalangala all introduced genotypes, except Saba flowered later than the local check (Nfuuka). In Rukungiri the introduced genotypes, Pisang ceylan, FHIA23 (AAAA) and FHIA17 (AAAA) took relatively shorter period from planting to flowering 333 to 388 days than Nfuuka (Table 6). Genotypes, SH3436-9 (AAAA), FHIA 25, FHIA 21, Yangambi (AAA), Saba (ABB), Burocensa (ABB), and 660K (AAAA) also took significantly longer time 440-503 days from planting to flowering than Nfuuka.

In Luwero genotypes Yangambi KM5 (AAA), SH 3640 (AAAA), Saba (ABB), Burocensa (ABB), 660K (AAAA), SH 3436-9 (AAAA), Pisang ceylan (AA), FHIA 25 (AAAA), FHIA 18 (AAAA), CRBP39 (AABB) reached flowering before Nfuuka. These results appear to suggest that under the conditions in which these genotypes were evaluated the rate of growth and maturity period were influenced by genotype and environment.

Table 6. Mean comparison of days from planting to flowering by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda during 2005-2007.

Genotype	DISTRICT						
	KALANGALA		RUKUNGIRI		LUWERO		
	CROP CYCLE						
Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Over all mean	
DAYS							
PISANG CEY	434.2de	531.0b	333.7h	346.8j	393.6e	547.0f	417.7ef
NFUUKA	395.0g	430.5gh	400.7ef	413.8f	450.8c	588.7d	403.4f
FHIA 25	449.3cd	473.6de	461.5c	495.3b	423.7d	584.4d	457.6bcd
FHIA 17	462.5c	438.9g	375.2g	388.3h	470.8b	629.5bc	435.9ed
YANGAMBI	429.7e	442.8g	441.0d	454.1d	381.7f	537.6f	418.2ef
SH 3460	387.7g	447.8g	414.5e	427.6e	363.4gh	499.8h	409.7f
BUROCEMSA	429.7e	494.5d	489.9b	503.0b	357.0h	499.2h	437.6ed
FHIA 23	443.5d	486.7d	363.6g	366.7i	480.2b	634.9ab	436.1ed
660K	359.5i	482.2d	525.1a	538.2a	384.4ef	522.8g	432.2e
FHIA 21# 68	457.6bc	464.7de	467.5c	480.6bc	462.3bc	621.1b	463.1abc
SABA	425.6ef	404.0i	407.3e	420.4e	371.0g	523.1g	409.0f
CRBP 39	493.3a	537.7b	462.4c	475.5bc	424.3cd	582.9d	479.0ab
SH 3436-9	410.3f	451.3f	487.5b	500.6b	418.8de	564.6de	439.5cde
FHIA 18	475.1ab	501.7c	477.0bc	490.1b	429.6de	594.1d	467.9ab
GCTCV 119	470.2ab	569.9a	390.5f	403.6g	516.5a	658.9a	484.6a
WILLIAMS	443.1ef	365.7j	418.2e	431.3e	457.2c	596.9d	421.3ef
Mean	435.54	464.36	431.46	466.23	436.56	576.53	436.56
LSD(0.05)	25.13	25.14	25.19	25.11	25.13	25.78	24.50
CV (%)	20.09	21.26	23.27	21.42	22.55	20.33	19.54

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.1.1.5 Days from Planting to Bunch Harvesting

Overall, Overall, all the recently introduced genotypes took significantly longer days from planting to flower shooting (vegetative), than Nfuuka (Table 7). All the introduced genotypes spent (544.4 - 628.0 days) in vegetative stage, which were significantly higher than Nfuuka (523 days).

Genotypes GCTCV 119, CRBP 39, FHIA18 (AAAA), FHIA21# 68 (AAAA) and FHIA25 (AAAA) took the longest (603.3 to 628.0) days. These were significantly higher than Nfuuka (463.9). Genotypes SH 3640 (AAAA), Saba, Pisang ceylan, Yangambi KM5, Williams and 660K did not significantly differ from Nfuuka, for mean number of days from planting to flower shooting (Table 7).

These results suggest that those genotypes that took a longer time to reach flowering and also a longer time between flowering and bunch harvesting also took the longest time to reach maturity. Similarly those genotypes that took shorter time between planting and flowering and also a shorter time between flowering and bunch harvesting, also took the shortest time to attain physiological maturity. Early maturity is a desirable characteristic, because such genotypes are more likely to give higher yields over time (Njuguna et al., 2006). These early maturing genotypes if high yielding are recommended for farmer adoption.

These results suggest that under the conditions in which these genotypes were evaluated the rate of growth and maturity period were influenced by genotype and environment.

Table 7. Mean comparison of days from planting to bunch harvesting of the plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

			DISTRICT				
			RUKUNGIRI		LUWERO		
			CROP CYCLE				
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall average
DAYS							
PISANG CEY	581.8f	676.9b	485.9g	498.6f	534.3d	547.0d	564.2cd
NFUUKA	501.6l	480.5g	526.5ef	539.2e	576.0c	588.7c	523.2e
FHIA 25	604.2c	614.5c	609.1c	645.5b	571.6c	584.4c	603.3ab
FHIA 17	600.3cd	584.1d	514.8	629.5b	616.7b	629.5b	578.3c
YANGAMBI	478.9m	566.0d	592.5c	605.2c	524.8	537.6e	566.2cd
SH 3640	526.6k	584.5d	559.9e	572.6d	487.1f	499.8f	534.9e
BUROCEMSA	577.5g	655.2bc	635.6b	499.2f	486.5f	499.2f	581.9bc
FHIA 23	592.6e	630.0c	511.8f	524.5e	622.1b	634.9ab	584.8bc
660K	501.3l	609.8c	675.8a	688.6a	510.1e	522.8e	573.4c
FHIA 21# 68	608.7c	611.5c	618.6b	631.4b	608.3b	621.1b	611.8a
SABA	570.3i	542.1e	560.8d	573.5d	510.4e	523.1e	544.4de
CRBP 39	641.5a	689.9b	612.1bc	624.8bc	570.2c	582.9c	628.0a
SH 3436-9	563.2i	576.6d	636.0b	648.7b	551.8d	564.6d	580.7c
FHIA 18	619.5b	647.7c	626.3b	442.7g	581.4c	594.1c	616.1a
GCTCV 119	623.7b	721.8a	511.6f	524.4e	646.2a	658.9a	623.7a
WILLIAMS	592.4e	505.5f	570.1d	582.8cd	584.3c	596.9c	563.4cd
Mean	579.49	606.05	549.49	576.95	549.49	570.34	579.48
LSD(0.05)	25.61	25.68	25.42	25.50	25.11	25.79	24.80
CV (%)	15.45	14.98	11.34	14.98	11.28	14.98	14.98

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.1.1.6 Days from Flowering to Bunch Harvesting

Overall, all the recently introduced genotypes took significantly longer days from flower shooting to bunch harvest compared (Table 8). Results indicated that from flowering to bunch harvesting, all the genotypes took longer than 125.8 days, days taken by Nfuuka. Genotypes FHIA 25 (AAAA), Pisang ceylan, FHIA 23, CRBP 39 (AABB), FHIA 18 (AAAA), FHIA 17 (AAAA) and SH 3636-9 (AAAA) took longest period (147-154 days respectively) Table 8. In Kalangala all introduced genotypes matured later than the local check (Nfuuka). In Luwero genotypes Yangambi KM5 (AAA), SH 3640 (AAAA), Saba (ABB), Burocensa (ABB), 66OK (AAAA), SH 3436-9 (AAAA), Pisang ceylan (AA), FHIA 25 (AAAA), FHIA 18 (AAAA), CRBP39 (AABB) reached flower shooting before Nfuuka.

These results appear to suggest that those genotypes which took longer from flower shooting to bunch harvest also took longer to attain physiological maturity. This implies that such genotypes utilized more resources during their growth period than those which took a shorter period. On the other hand, genotypes that took a shorter time to attain maturity between flower shooting and bunch physiological maturity, were more cost effective to produce compared with those that took a longer time to attain maturity. Under the conditions in which these genotypes were evaluated, the rate of growth and maturity period were influenced by genotype and environment.

In this respect, Genotype Nfuuka was the most desirable. Genotype GCTCV 119 and FHIA group of Genotype took too long to mature.

Table 8. Mean comparison of days from flower shooting to bunch harvest by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

Genotype	DISTRICT							
	KALANGALA		RUKUNGIRI		LUWERO		Overall mean	
	CROP CYCLE							
	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon		
	DAYS							
PISANG CEY	150.4a	145.9c	155.2a	157.2b	145.9d	137.0f	150.2b	
NFUUKA	122.2e	130.3g	131.4e	136.9g	123.5f	114.9h	125.8j	
FHIA 25	151.1a	140.9e	156.8a	160.8a	154.2a	147.8d	154.2a	
FHIA 17	144.4c	146.2c	145.4d	144.9e	151.2b	154.0a	147.0defgh	
YANGAMBI	149.1a	153.7b	143.7de	137.2g	149.6b	151.6b	147.6edef	
SH 3460	144.0c	136.7f	148.9c	142.3f	145.3d	151.8b	148.5bcdef	
BUROCEMSA	152.0a	160.6a	148.3c	144.7e	142.5e	128.8g	147.4defg	
FHIA 23	148.3b	143.2d	148.4c	152.7cd	152.2ab	154.1a	149.1defg	
660K	136.6d	136.7f	149.4c	141.2f	141.1e	130.6g	142.4i	
FHIA 21# 68	145.2c	146.8c	146.3d	155.7c	143.3de	135.5f	144.9h	
SABA	143.6c	138.1e	145.5d	148.5d	149.1b	146.1d	146.5fgh	
CRBP 39	150.7a	152.1b	151.0b	154.4c	146.3c	154.7a	149.1bcd	
SH 3436-9	145.6b	127.2h	152.2b	160.5a	147.7c	149.2c	146.0gh	
FHIA 18	145.4b	146.0c	149.7c	154.0c	150.9b	138.2f	148.9	
GCTCV 119	147.7b	151.9b	130.9e	133.2h	147.2c	143.5e	124.6i	
WILLIAMS	145.9b	139.8e	147.1cd	148.4d	147.3c	154.5a	146.9efgh	
Mean	145.26	145.42	146.90	148.46	146.12	143.94	146.06	
LSD(0.05)	2.21	2.45	2.00	2.28	2.30	2.22	2.21	
CV (%)	9.24	9.33	9.22	9.31	9.23	9.26	9.24	

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.1.2.0 Bunch Yields and Yield Components

4.1.2.1 Bunch Weight

The results of bunch weight the study are presented in Table 9. Different bunch weights were observed among genotypes in all sites. Over all genotypes FHIA 25, FHIA 17, FHIA 23, FHIA 18, SH3436-9, SH3640 and Pisang ceylan produced significantly heavier bunches (26.16-45.7 kg) than the local check Nfuuka(22.13kg) Table 9. The rest of the genotypes produced bunches significantly smaller than Nfuuka (8.39-21.49 kg). The smallest bunches were produced by genotype GCTCV 119 (8.39 kg). Over all, plants in Rukungiri produced bunch weights with significantly higher mean than those in Luwero and Kalangala. The higher temperatures, high rainfall and fertile soils could have favoured banana production more in Rukungiri district Njuguna et al., 2008, evaluated ten genotypes for agronomic and yield performance in Kenya and reported that the most promising cultivars in terms of yield potential were FHIA 17, FHIA 18 and FHIA 25. While GCTCV-119 was the least promising. Similar results on impressive performance of FHIA 17, FHIA 18, FHIA 25, FHIA 23 and SH3640 against the poor performance of GCTCV-119 were observed in Sirilanka (Rishab, 2004). The higher bunch weight for the FHIA hybrids could be linked to their ability to produce many large leaves (plate 1), high growth rates before flowering, implying higher leaf area index and higher resistance to Sigatoka which is one of the greatest constraints to banana farming. Sweenen and De Langhe (1985) reported that leaves, bunches were a result of greater active leaf area which leads to high total dry matter production. The larger leaf area index (plate 1) in genotypes like FHIA hybrids, KM 5 and Pisang ceylan, accounted for the better yields than in the other genotypes under this study. However the variation in performance from one environment to another suggests that agronomic and yield performance is determined by genotypic constitution and environmental factors.

Table 9. Mean comparison of bunch weights (kg) produced by plant and first ratoon crops of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts of Uganda from 2005-2007.

Genotype	DISTRICT							
	KALANGALA		RUKUNGIRI		LUWERO		Overall Average	
	PLANT CYCLE							
	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon		
KGS PER BUNCH								
PISANG CEY	20.7d	20.9c	21.0h	29.0f	19.1e	23.5f	26.5e	
NFUUKA	21.3d	15.9f	25.0f	30.6f	13.9g	22.2f	22.1f	
FHIA 25	34.6a	29.8a	40.6c	53.9a	37.8b	49.7a	45.7a	
FHIA 17	30.4b	31.1a	47.3a	55.1a	38.6a	46.1b	42.9b	
YANGAMBI	15.0f	19.3d	19.3i	22.8h	19.4e	21.2f	20.0g	
SH 3460	18.7e	21.2c	30.8e	35.9d	21.3c	27.1d	26.2e	
BUROCEMSA	9.7i	9.6i	13.8k	22.3h	10.2i	17.7h	17.2h	
FHIA 23	31.2b	29.8a	44.4b	52.8a	37.7b	39.2c	42.2c	
660K	10.4h	16.0e	23.6gh	29.2f	13.4g	15.2j	21.5f	
FHIA 2i# 68	11.7h	16.3e	25.4f	26.2g	20.0d	22.9f	17.8h	
SABA	10.6h	11.7h	13.8k	19.6i	11.9h	18.5g	17.2h	
CRBP 39	11.1h	11.0h	24.8g	23.3h	14.5f	16.4i	14.6i	
SH 3436-9	26.8c	26.7b	36.3d	45.9c	21.7c	25.4e	42.2c	
FHIA 18	17.2e	21.4c	25.0f	29.3f	22.8c	27.4d	27.9d	
GCTCV 119	3.3j	4.5j	18.0j	18.4j	4.1k	5.3l	8.4j	
WILLIAMS	12.4g	13.7g	30.4e	32.4e	7.5j	7.0k	18.3h	
Mean	22.17	24.96	22.17	24.06	22.17	24.96	25.23	
LSD(0.05)	1.15	0.94	1.19	1.20	1.16	1.14	29.40	
CV (%)	27.91	22.64	25.23	26.24	27.88	25.24	22.64	

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.1.2.2 Hands/Clusters per Bunch

The results of the number of hands/clusters per bunch are presented in Table 10. Genotypes FHIA 25, FHIA 17, FHIA 23, FHIA 18, SH3436-9 and SH3640 produced significantly higher number of hands per bunch (8.94-14.11) than the AAA-East African highland banana Nfuuka (9.14), Table 10 and plate 1. Genotype GCTCV 119 produced the fewest hands significantly lower than Nfuuka.

Genotype GCTCV 119 produced the fewest number of hands, significantly lower than Nfuuka. Over all, plants in Rukungiri produced significantly more hands than those in Luwero and Kalangala. The higher temperatures, high rain fall and fertile soils could have favored banana production.

Njuguna et al., 2008, evaluated ten genotypes for agronomic and yield performance in Kenya and reported that the most promising cultivars in terms of yield potential were FHIA 17, FHIA 18 and FHIA 25. While GCTCV-119 was the least promising. Similar results on impressive performance of FHIA 17, FHIA 18, FHIA 25, FHIA 23 and SH3640 against the poor performance of GCTCV-119 were observed in Sirilanka (Rishab, 2004). The higher cluster/hands values for the FHIA hybrids could be linked to their ability to produce many large leaves, high growth rates before flowering, implying higher leaf area index and higher resistance to Sigatoka which is one of the greatest constraints to banana farming. Sweenen and De Langhe (1985) reported that leaves, bunches were a result of greater active leaf area which leads to high total dry matter production. However the variation in performance with environment suggests that agronomic and yield performance is determined by genotypic constitution and environmental factors.

Table 10. Mean comparison of number of hands/clusters per bunch at harvest time, produced by plant and first ratoon crops of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

DISTRICT							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall Average
CLUSTERS PER BUNCH							
PISANG CEY	11.0c	10.4d	11.7d	12.6c	11.2e	8.6f	11.8c
NFUUKA	9.7e	9.3f	9.3h	9.6d	8.6h	9.2e	9.1ef
FHIA 25	12.8a	13.3a	14.0b	15.4a	13.7a	14.5a	14.1a
FHIA 17	11.7b	12.7b	13.7c	14.5b	12.6d	14.0b	13.2b
YANGAMBI	8.7f	9.7e	8.3j	9.7d	8.0i	8.4f	8.9f
SH 3460	7.4g	8.3g	9.3h	10.5e	8.8h	8.1g	8.9f
BUROCEMSA	5.3k	5.4j	7.0l	7.2g	6.1k	6.6i	7.1j
FHIA 23	11.5b	12.1c	14.3a	14.6b	12.9c	13.9b	13.3b
660K	8.7f	7.2i	9.0i	9.0f	6.8j	7.7h	8.1h
FHIA 21# 68	7.1h	5.3j	10.6e	10.8d	9.2g	8.5f	7.9i
SABA	5.6j	5.4j	6.4m	6.4h	7.0j	6.5i	6.5k
CRBP 39	6.6i	5.4j	7.2k	6.8i	6.9j	6.7i	6.4k
SH 3436-9	10.0d	7.3i	10.1g	12.4c	9.6f	7.7h	9.3e
FHIA 18	8.4f	9.1f	10.3f	11.0d	9.8f	9.7d	10.1d
GCTCV 119	4.6l	4.7k	6.5m	6.0j	5.0l	4.8j	5.4i
WILLIAMS	8.8f	7.9h	10.7e	9.3e	13.4b	12.1c	8.4g
Mean	9.32	9.20	9.32	9.20	9.32	9.20	9.38
LSD(0.05)	0.25	0.11	0.13	0.27	0.22	0.23	0.22
CV (%)	16.56	14.58	16.55	15.11	16.52	14.18	14.58

Means with the same letter in the same column are not significantly different ($p>0.05$)



Plate 1. Very high yielding genotype FHIA 25, with high bunch weight, many hands, and Sigatoka disease resistance

4.2.0 Leaf production and Emission

4.2.1 Number of Functional Leaves at Flowering

Over all, genotypes FHIA17, FHIA23, FHIA25, FHIA18, FHIA21, Pisang ceylan, SH3436-9, SH3640, 660K, Saba, Burocensa, Williams, and Yangambi KM5 had significantly higher total number of functional leaves (TL) than Nfuuka AAA-East African highland banana (Table 11). The rest of the genotypes had significantly lower total functional leaves (TL) values. Genotype GCTCV- 119, had the lowest total functional leaves at flowering (7.5-8.9) compared to Nfuuka (8.9-9.8). Genotypes FHIA17, FHIA23, FHIA25, FHIA18, FHIA21, Pisang ceylan, SH3436-9, SH3640, 660K, Saba, Burocensa, Williams, and Yangambi KM5 also had significantly higher total number of Youngest Leaf with Sigatoka (YLS) than Nfuuka AAA-East African highland banana. The rest of the genotypes had significantly lower total Youngest Leaf with Sigatoka (YLS) than Nfuuka. Genotype GCTCV 119, also had the lowest Youngest leaf with Sigatoka and also the lowest Index of non spotted leaf area (3.5-4.0) and (32.8-55.7) respectively.

Swennen and De Langhe (1985) reported that the larger bunch weights and higher yields were as a result of the higher growth rates before flower shooting and the higher number of functional leaves at flower shooting, and at the time of bunch harvesting. They observed that the heavier bunches were as a result of greater active leaf areas, which lead to higher total dry matter production. On the other hand the low bunch yields were probably as a result of reduced leaf area as a result of reduced soil nutrients. Poorly growing plants always had few and small functional leaves, leading to low yields.

Table 11. Mean comparison of number of functional leaves at flowering time produced by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts of Uganda, 2005-2007.

Genotype	DISTRICT							
	KALANGALA		RUKUNGIRI		LUWERO		Overall Mean	
	CROP CYCLE							
	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon		
NUMBER OF LEAVES								
PISANG CEY	11.4a	11.1a	13.5d	11.5d	11.2b	11.0e	12.ob	
NFUUKA	9.4c	9.6d	9.6h	11.8d	7.1h	12.9b	9.3h	
FHIA 25	11.6a	10.3b	14.5c	12.7b	13.7a	11.6d	12.8a	
FHIA 17	11.3a	10.1b	14.2c	11.5d	12.5b	12.2c	11.5c	
YANGAMBI	11.8a	11.2a	11.2f	10.3f	11.1d	11.3c	11.3cd	
SH 3460	9.8c	10.1c	13.5d	10.2f	9.5e	12.0c	10.7e	
BUROCEMSA	7.8d	7.6f	12.2f	11.8d	9.6e	11.7c	10.3fg	
FHIA 23	10.4b	10.3b	13.1e	12.2c	12.9b	13.4a	11.1d	
660K	10.7b	10.5b	10.9f	9.7g	9.1f	10.5f	10.1g	
FHIA 21# 68	9.5c	9.7d	11.2f	8.0i	11.6c	9.7g	9.5a	
SABA	6.8f	7.0g	10.2g	10.4f	9.9e	13.7a	10.3fg	
CRBP 39	10.1bc	8.1f	10.7f	8.7h	9.6e	9.6g	8.8i	
SH 3436-9	10.1c	10.1b	12.5f	13.2a	9.8e	11.0e	10.3ef	
FHIA 18	10.6b	10.1bc	15.9a	11.5d	13.5a	12.3b	11.9b	
GCTCV 119	7.5e	7.8f	8.9h	8.5h	8.3g	8.9h	7.9j	
WILLIAMS	9.5c	9.2e	15.4b	10.9e	8.2g	10.7f	10.0g	
Mean	9.93	9.59	12.38	10.84	10.70	11.45	10.55	
LSD(0.05)	0.35	0.39	0.45	0.33	0.34	0.36	0.31	
CV (%)	20.47	17.94	21.44	19.11	20.17	17.17	17.94	

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.2.2 Number of Functional Leaves at Harvesting

Genotypes FHIA 25, *Pisang ceylan*, FHIA 18, FHIA 17, Yangambi KM 5, FHIA 23, 660K, FHIA 21# 68, Saba, Burocensa retained significantly ($p < 0.05$) higher number of functional leaves at harvest (3.3-6.5) than the local check Nfuuka (2.9) Table 12. The rest of the genotypes retained significantly ($p < 0.05$) fewer leaves (1.3-2.8) than Nfuuka. Genotype GCTCV 119 retained the fewest (1.3) leaves. Rukungiri produced leaves at harvest with significantly higher mean than those in Luwero and Kalangala. The higher temperatures, high rain fall and fertile soils could have favoured banana production.

Njuguna et al., 2008, evaluated ten genotypes for agronomic and yield performance in Kenya and reported that the most promising cultivars in terms of yield potential were FHIA 17, FHIA 18 and FHIA 25. While GCTCV-119 was the least promising (Plate 2). Similar results on impressive performance of FHIA 17, FHIA 18, FHIA 25, FHIA 23 and SH3640 against the poor performance of GCTCV-119 were observed in Sirilanka (Rishab, 2004). The higher bunch weight and cluster/hands values for the FHIA hybrids could be linked to their ability to produce many large leaves, high growth rates before flowering, implying higher leaf area index and higher resistance to Sigatoka which is one of the greatest constraints to banana farming. Sweenen and De Langhe (1985) reported that leaves, bunches were a result of greater active leaf area which leads to high total dry matter production.

However, the variation in performance with environment suggests that agronomic and yield performance is determined by genotypic constitution and environmental factors.

Table 12. Mean comparison of number of functional leaves at bunch harvest time produced by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

DISTRICT							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall mean
NUMBER OF LEAVES							
PISANG CEY	4.29b	3.7b	8.9b	8.7b	6.2c	3.4g	6.5a
NFUUKA	2.6de	3.1cd	4.6h	4.4i	1.5k	3.1h	2.9g
FHIA 25	3.3c	2.9cd	9.1b	9.2a	7.1a	6.9c	6.8a
FHIA 17	2.6de	2.5e	7.4c	7.3e	6.5b	6.4d	5.6bc
YANGAMBI	4.6a	4.4a	6.8d	8.4c	4.6e	4.2f	5.4c
SH 3460	0.9k	0.8i	4.6h	6.2f	1.4jk	2.7j	2.2i
BUROCEMSA	0.3l	0.4k	6.2e	6.1f	2.8h	2.5jk	3.3f
FHIA 23	2.8d	2.8d	5.5f	6.6f	6.5b	7.3a	5.1d
660K	3.3c	3.3c	5.1fg	5.0g	5.6d	5.1e	4.8e
FHIA 21# 68	1.2i	2.8d	5.4f	6.6f	3.4f	7.3a	3.4f
SABA	1.0ij	1.5h	5.2fg	3.8k	3.1g	3.0i	3.3f
CRBP 39	2.4e	2.2f	2.7f	2.6l	2.5i	2.4k	2.6h
SH 3436-9	2.0g	2.5e	5.1fg	4.6h	1.6j	3.0i	2.8g
FHIA 18	2.1f	2.0g	7.6c	7.5d	7.1a	7.0b	5.8b
GCTCV 119	0.0m	0.0l	4.3i	4.5h	0.1l	0.1m	1.3j
WILLIAMS	1.3i	0.5j	12.7a	4.1j	5.5d	0.5l	2.3i
Mean	2.27	2.31	6.43	5.96	4.14	4.19	4.04
LSD(0.05)	0.23	0.25	0.22	0.24	0.20	0.23	0.23
CV (%)	34.48	34.55	34.41	34.44	33.33	35.09	34.48

Means with the same letter in the same column are not significantly different ($p>0.05$)

4.3.0 Response to Plant Diseases and Pests

4.3.1 Response to Black Sigatoka Leaf Spot Disease

Over all genotypes FHIA17, FHIA23, FHIA25, FHIA18, FHIA21, Pisang ceylan, SH3436-9, SH3640, 660K, Saba, Burocemsa, Williams and Yangambi KM5 had significantly higher index of non spotted leaf area (INSL) than Nfuuka AAA-East African highland banana Table 14. The rest of the genotypes had significantly lower index of non-spotted leaf area (INSL) values. Genotype GCTCV 119, had the lowest index of non-spotted leaf area compared to Nfuuka (Table 14). Over all, plants in Rukungiri, recorded the highest YLS and INSL (Tables 13 and 14). This was followed by Luwero. The lowest YLS and INSL levels were registered in Kalangala. There were significant differences across the three agro ecological zones and between cycle one and two.

All genotypes were observed to have developed Sigatoka symptoms in all agro ecological zones. Craenen (1994) Youngest Leaf with Sigatoka (YLS) score correlates significantly with Sigatoka disease, but Index of Non Spotted Leaf gives the actual proportion of the leaf without Sigatoka disease. Craenen (1994) suggested four categories of response of banana and plantain plants to black Sigatoka disease as follows:

Host response	Code	Number of leaves without spots
The susceptible plants	(S)	< 8
The less susceptible plants	(LS)	8-10
The partially resistant	(PR)	> 10
The Highly resistant	(HR)	no necrosis

Genotypes GCTCV-119, Williams, including Nfuuka, scored YLS (< 8) and is categorized as susceptible. Genotype FHIA 25, FHIA 23, FHIA 17, FHIA 18, 660K, Yangambi KM5, Pisang ceylan was categorized as Resistant. These results confirm earlier findings about susceptibility to black Sigatoka disease in Kenya (Njuguna et al., 2008) and Rwanda (Gaidashova et al., 2008). The consistent poor performance of GCTCV-119, in all agro ecological zones is most probably linked to its genetic constitution that renders it susceptible to black Sigatoka.

Fouré (1987) correlated positively, Index of Non Spotted Leaf (INSL to response to Sigatoka disease. The high number of functional leaves is an indication of the high capacity of those plants to carry out photosynthesis (Gauhl et al., 1995), the implication being higher vigour in plants and therefore less disease manifestation. Plants growing in good fertile soil have lower disease severity than plants in poor soils (Tushemereirwe et al., 1993, Mobambo et al., 1994).

Diagnostic survey studies data in Uganda (1993) revealed that relative leaf spot impact was most severe in areas where banana plants appeared to be under severe nutrients, water and defoliation stresses. Stress influences leaf spot expression directly through suppression of leaf emergency. This probably explains the higher leaf spot severity for the second ratoon crop in Kalangala.

Stover (1972), suggested that variation in micro climate influences disease severity. Soil fertility influences banana and plant growth and hence severity to black Sigatoka. Fertile soils with higher organic matter stimulates root ramification, resulting in better water and nutrient uptake and more vigorous plants that carry more functional leaves, emit new leaves more rapidly resulting in lower damage from Sigatoka (Craenen, 1994). Mobambo et al., (1993) made a similar observation while working on plantains in West Africa.

Sigatoka has been reported to be present in many parts of Uganda at altitudes above 2000m.a.s.l. This probably explains why Sigatoka was absent on some genotypes in Rukungiri, that even showed the disease in Luwero. Genotype Williams, which was highly susceptible in several farms, consistently retained the highest mean number of functional leaves both at flower shooting and at bunch harvest, but also recorded a high index of non spotted leaf (Tables. 10, 11 and 13) in Rukungiri.

There were however some areas of Kalangala that did not show the disease, despite the fact that their soils appeared to be nutritionally deficient. The most likely explanation could be that Kalangala is an island on Lake Victoria and therefore its location might have impeded movement of Sigatoka spores. Furthermore the dense forest could have restricted movement of the ascospores from place to place, therefore suggesting that the two year investigation period was too short to reveal infection. These results further suggest that, under the condition in which this experiment was conducted, the response of the various genotypes to Sigatoka leaf spot damage was influenced by genotype and environmental factors.

Table 13. Mean comparison of position of youngest leaf with Sigatoka at flowering time by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

DISTRICTS							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall mean
LEAF POSITION							
PISANG CEY	9.2c	9.2a	12.8c	10.7b	10.1d	8.3d	10.4c
NFUUKA	7.2d	7.3e	7.7j	8.8d	5.1i	10.6b	7.0if
FHIA 25	9.2c	7.3e	13.8b	10.2c	11.2b	11.6a	11.1a
FHIA 17	8.7c	7.5e	11.0d	9.9c	10.3d	10.0c	8.5e
YANGAMBI	10.9a	8.9b	11.2d	11.3a	9.6e	10.0c	10.8ab
SH 3460	6.8e	7.1e	9.0h	8.3d	6.7g	8.5d	7.6h
BUROCEMSA	5.8f	5.1g	9.5g	8.7d	6.8g	9.0d	8.0fg
FHIA 23	8.3d	7.6e	11.2d	10.6b	10.8c	10.5b	8.5e
660K	9.6b	8.4c	8.3i	8.5d	7.9f	8.7d	8.9b
FHIA 21# 68	7.9d	7.0e	10.2e	7.0e	10.1d	7.6e	8.1f
SABA	6.8e	7.0e	8.1i	8.1d	6.6g	9.0d	8.1f
CRBP 39	8.3d	6.5f	9.7f	7.2e	7.5f	7.6e	7.7gh
SH 3436-9	7.5d	7.6e	9.0h	8.9d	6.4g	8.3d	7.2i
FHIA 18	8.9c	8.1d	14.6a	10.8b	12.4a	10.4b	10.7bc
GCTCV 119	3.1g	3.3h	5.9k	5.4f	5.8h	4.6g	4.4k
WILLIAMS	7.3d	5.3g	12.7c	8.1d	5.5h	6.7f	6.8j
Mean	7.88	7.12	10.36	8.96	8.33	8.88	8.40
LSD(0.05)	0.37	0.35	0.38	0.37	0.36	0.35	0.32
CV (%)	26.71	26.75	26.48	26.33	26.00	26.66	23.23

Means with the same letter in the same column are not significantly different ($p>0.05$)

Table 14. Mean comparison of index of non spotted leaf area at flowering time produced by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

DISTRICTS							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall mean
INDEX OF NON SPOTTED LEAF AREA							
PISANG CEY	72.3c	73.3a	87.3c	84.3b	74.2d	62.8f	77.5bc
NFUUKA	65.8f	64.9c	71.1h	66.4f	57.3g	71.4d	67.0h
FHIA 25	70.3d	59.6e	89.3a	74.2d	74.2d	71.0d	77.6b
FHIA 17	68.1e	62.2d	70.6h	77.9c	74.1d	75.0b	64.6gh
YANGAMBI	83.9a	70.2b	90.1a	90.1a	78.0b	79.9a	86.4a
SH 3460	58.4g	59.7e	60.8j	71.7e	57.9g	62.7f	61.1i
BUROCEMSA	59.8g	52.3f	69.9h	65.3f	59.6f	70.4d	66.7ef
FHIA 23	70.5d	62.4d	78.2f	78.7c	76.6c	70.7d	66.4fg
660K	80.4b	70.6b	67.9i	77.0c	76.0c	73.7c	77.4bc
FHIA 21# 68	72.4c	61.7d	82.7e	72.9e	68.1e	61.7f	72.9d
SABA	64.0f	62.8d	66.8i	67.4f	54.8h	58.8g	68.5e
CRBP 39	72.2c	66.6c	81.4e	71.7e	67.0e	67.0e	75.6c
SH 3436-9	64.4f	65.7c	65.1i	60.1h	54.2h	66.7e	58.1i
FHIA 18	73.5c	69.9b	84.8d	85.5b	85.2a	76.8b	79.3b
GCTCV 119	28.3h	29.8h	55.0k	52.5i	57.5g	39.6i	42.1l
WILLIAMS	64.9f	46.0g	75.6g	63.0g	56.9g	56.3h	54.8k
Mean	67.50	62.41	74.83	73.99	66.12	72.83	66.75
LSD(0.05)	2.19	2.07	2.45	2.40	2.15	2.32	1.94
CV (%)	19.58	17.34	19.79	19.77	19.11	19.71	19.60

Means with the same letter in the same column are not significantly different ($p>0.05$)



Plate 2. Genotype Pisang ceylan, with good Agronomic, yield characteristics and very high resistance to Sigatoka



Plate 3. Genotype GCTCV 119, very low yielding, poor Agronomic characteristics, low yield and yield components and highly susceptible to Sigatoka and Weevil damage

4.3.2 Response to Banana Weevil

The results suggest that the genotypes displayed varying levels of response to weevil attack (Tables 15, 16 and 17) Plate 3. Overall total cross section damage was low, although significantly higher in the first production ratoon than the plant crop. The results, however showed that, across the three different agro ecological zones, genotypes FHIA21# 68, GCTCV 119, CRBP 39 had significantly higher percent total weevil damage(TX), inner corm cross section damage(XI), outer corm cross section damage(XO) than Nfuuka 6.8, 10.9, 9.3 for XI, XO and TX respectively. The rest of the genotypes had significantly ($p < 0.05$) lower percent total weevil damage (TX), inner corm cross section damage (XI), outer corm cross section damage (XO) than Nfuuka. Genotype FHIA 21# 68 recorded the highest percent damage levels 9.2, 14.7 and 12.5 for XI, XO and TX respectively, while GCTCV 119, had the lowest damage levels 5.6, 6.7 and 6.2 for XI, XO and TX respectively (Tables 14, 15 and 16). The highest damage was recorded in Luwero, TX (16.3). This was followed by Rukungiri, TX (14.6). The lowest percent damage levels were registered in Kalangala TX (6.1). Although there were significant percent weevil damage differences at zone level for XO, for XI percent damage were not significantly different.

Those genotypes that had high levels of damage such as FHIA21, GCTCV 119, and CRBP 39 were the most susceptible. Whereas those with low levels were less susceptible. The results also showed that genotype Yangambi KM5 was the least damaged and therefore the most resistant genotype to weevil attack (Table 17). The results confirm earlier findings, (Gold et al., 1994) indicating variable damage among banana cultivars, with the introduced beer type (AB, ABB) being relatively resistant, and in which it was suggested that they could be producing some chemicals responsible for attraction. The variability in weevil damage might also be linked to acceptance survivorship of weevils being different among the genotypes

(Budenberg et al., 1991). The presence, abundance and preference of a particular banana genotype by weevils, *Cosmopolites sordidus*, could be linked to presence of volatile chemicals that attract them to the banana plants. The results obtained agree with the earlier results from surveys on distribution of weevils, which revealed different levels of attack of different banana clones in Uganda (Gold et al., 1994). Genotypes KM 5 and Pisang ceylan appeared not to have been preferred by *Cosmopolites sordidus*. These two genotypes have very hard corms, which could have discouraged the banana weevils from getting attracted to these particular genotypes.

In Uganda, maximum weevil movement has been recorded as 35 m in three days (Gold and Bagabe, 1997). The very low weevil damage levels in Kalangala, suggests presence of weevils in low populations. But also that the Lake Victoria waters and dense forests might have impeded weevil movement. Besides, the environment could be hosting natural enemies including entomopathogenic fungi *Baurveria bassiana*. The absence of significant difference in weevil damage amongst genotypes and across all the agro ecological zones could be linked to the period of study which was too short and therefore implying the need for further investigation time.

Generally *Cosmopolites sordidus*, corm damage, varied from genotype to genotype, from location to location over time. There is need for further studies to investigate the possible presence of volatile chemicals that might be the cause for preference in some genotypes, while not in others. Further studies are also necessary, in order to investigate the possible presence of natural enemies in some soils that could be responsible for low *C. sordidus* presence and abundance. The period available for this study was not sufficiently long enough so further investigation is required.

Table 15. Mean (%) Outer corm cross section damage at harvesting time by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

DISTRICTS							
KALANGALA			RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall Mean
OUTER CORM CROSS SECTION (%)							
PISANG CEY	5.89(0.25)	5.56(0)	5.56(0)	6.19(0.66)	5.56(0)	5.56(0)	6.7t
NFUUKA	5.56(0)	5.56(0)	7.10(0.39)	8.89(0.75)	6.24(0.21)	7.75(0.58)	10.9c
FHIA 25	5.56(0)	5.56(0)	5.80(0.17)	7.76(0.77)	5.56(0)	5.56(0)	8.4e
FHIA 17	5.56(0)	5.56(0)	5.56(0)	12.35(1.52)	5.56(0)	5.56(0)	8.0e
YANGAMBI	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.73(0.17)	5.56(0)	5.9g
SH 3460	5.56(0)	5.56(0)	5.56(0)	11.40(1.48)	5.56(0)	5.64(0.08)	9.3d
BUROCEMSA	5.56(0)	5.56(0)	5.56(0)	7.51(0.56)	5.56(0)	5.92(0.21)	6.9f
FHIA 23	5.65(0.09)	5.56(0)	5.56(0)	12.61(1.79)	5.56(0)	5.56(0)	9.1d
660K	5.98(0.42)	5.56(0)	5.56(0)	6.77(0.66)	5.65(0.09)	7.75(0.58)	8.3e
FHIA 21# 68	5.56(0)	5.56(0)	5.56(0)	17.15(2.11)	9.62(0.72)	8.58(0.62)	14.7a
SABA	5.56(0)	5.56(0)	5.56(0)	6.60(0.69)	5.56(0)	5.64(0.08)	6.5f
CRBP 39	5.56(0)	5.56(0)	5.56(0)	8.85(0.64)	10.52(0.7)	11.30(1.48)	12.0b
SH 3436-9	5.56(0)	5.56(0)	5.56(0)	10.29(1.32)	5.56(0)	6.05(0.24)	8.0e
FHIA 18	5.56(0)	5.56(0)	5.56(0)	8.32(0.77)	5.93(0.13)	6.63(0.40)	9.2d
GCTCV 119	5.56(0)	5.56(0)	5.56(0)	14.69(2.61)	8.79(0.69)	11.93(1.56)	12.2b
WILLIAMS	5.56(0)	5.56(0)	5.56(0)	9.86(0.69)	5.56(0)	5.65(0.09)	8.2f
Mean	5.56	5.56	5.66	9.67	6.41	6.92	8.89
LSD(0.05)	0.69	0.66	0.67	0.68	0.69	0.70	0.17
CV (%)	49.68	49.51	49.63	49.98	49.69	49.67	44.76

Means with the same letter in the same column are not significantly different ($p>0.05$)

Table 16. Mean (%) Inner corm cross section damage at harvesting time by plant and first ratoon crops, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda 2005-2007.

DISTRICTS							
	KALANGALA		RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall mean
INNER CORM CROSS SECTION (%)							
PISANG CEY	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.6f
NFUUKA	5.56(0)	5.56(0)	5.56(0)	5.81(0.14)	5.64(0.09)	6.13(0.26)	6.8b
FHIA 25	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.56(0)	6.97(0.97)	6.3c
FHIA 17	5.56(0)	5.56(0)	5.56(0)	6.32(0.41)	5.56(0)	5.56(0)	5.8ef
YANGAMBI	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.65(0.09)	5.6f
SH 3460	5.56(0)	5.56(0)	5.56(0)	6.07(0.29)	5.56(0)	5.56(0.38)	6.4c
BUROCEMSA	5.56(0)	5.56(0)	5.56(0)	6.46(0.50)	5.56(0)	5.56(0)	5.7f
FHIA 23	5.56(0)	5.56(0)	5.56(0)	6.89(0.79)	5.56(0)	6.56(0.38)	6.2cd
660K	5.56(0)	5.56(0)	5.56(0)	8.99(0.87)	5.56(0)	6.33(0.44)	6.1cde
FHIA 21# 68	5.56(0)	5.56(0)	5.56(0)	7.17(0.55)	7.28(0.51)	7.37(0.47)	9.2a
SABA	5.56(0)	5.56(0)	5.56(0)	6.94(0.96)	5.56(0)	5.64(0.08)	5.8ef
CRBP 39	5.56(0)	5.56(0)	5.56(0)	6.96(0.97)	6.45(0.30)	7.68(0.21)	6.8b
SH 3436-9	5.56(0)	5.56(0)	5.56(0)	6.00(0.23)	5.56(0)	5.56(0)	5.8ef
FHIA 18	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.56(0)	6.32(0.34)	5.7f
GCTCV 119	5.56(0)	5.56(0)	5.56(0)	5.56(0)	6.27(0.26)	7.26(0.650)	7.1b
WILLIAMS	5.56(0)	5.56(0)	5.56(0)	5.74(0.19)	5.56(0)	5.65(0.09)	5.9def
Mean	5.56	5.56	5.56	6.32	5.77	6.27	6.25
LSD(0.05)	0.34	0.33	0.34	0.35	0.35	0.37	1.10
CV (%)	33.26	33.55	33.28	34.12	33.89	33.92	32.65

Means with the same letter in the same column are not significantly different ($p>0.05$)

Table 17. Total corm cross section (%) damage at harvesting time by plant and first ratoon crop, of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

DISTRICTS							
	KALANGALA		RUKUNGIRI		LUWERO		
CROP CYCLE							
Genotype	Plant crop	First ratoon	Plant crop	First ratoon	Plant crop	First ratoon	Overall Mean
TOTAL CORM CROSS-SECTION (%)							
PISANG CEY	5.73(0.07)	5.56(0)	5.56(0)	5.88(0.18)	5.56(0)	5.56(0)	6.2g
NFUUKA	5.56(0)	5.56(0)	6.33(0.42)	7.35(0.48)	5.94(0.19)	6.94(0.34)	9.3c
FHIA 25	5.56(0)	5.56(0)	5.68(0.09)	6.66(0.57)	5.56(0)	6.27(0.41)	7.6ef
FHIA 17	5.56(0)	5.56(0)	5.56(0)	9.34(0.61)	5.56(0)	5.56(0)	7.1f
YANGAMBI	5.56(0)	5.56(0)	5.56(0)	5.56(0)	5.65(0.09)	5.61(0.25)	5.8h
SH 3460	5.56(0)	5.56(0)	5.56(0)	8.74(0.63)	5.56(0)	6.60(0.48)	8.2d
BUROCEMSA	5.56(0)	5.56(0)	5.56(0)	6.98(0.38)	5.56(0)	5.74(0.10)	6.4g
FHIA 23	5.61(0.06)	5.56(0)	5.56(0)	9.75(0.73)	5.56(0)	6.06(0.28)	7.9ed
660K	5.77(0.16)	5.56(0)	5.56(0)	7.88(0.59)	5.61(0.25)	7.04(0.41)	7.5ef
FHIA 21# 68	5.56(0)	5.56(0)	5.56(0)	12.16(1.78)	8.45(0.59)	7.98(0.61)	12.5a
SABA	5.56(0)	5.56(0)	5.56(0)	6.77(0.66)	5.56(0)	5.64(0.08)	6.2g
CRBP 39	5.56(0)	5.56(0)	5.56(0)	7.91(0.61)	8.49(0.60)	9.49(0.63)	10.0b
SH 3436-9	5.56(0)	5.56(0)	5.56(0)	8.15(0.44)	5.56(0)	5.83(0.08)	7.1f
FHIA 18	5.56(0)	5.56(0)	5.56(0)	6.94(0.36)	5.75(0.18)	6.48(0.43)	7.8ed
GCTCV 119	5.56(0)	5.56(0)	5.56(0)	10.13(1.31)	7.53(0.57)	9.60(0.66)	10.1b
WILLIAMS	5.56(0)	5.56(0)	5.56(0)	7.80(0.58)	5.56(0)	5.65(0.09)	7.3f
Mean	5.59	5.56	5.62	8.00	6.13	6.57	7.84
LSD(0.05)	0.24	0.24	0.24	0.24	0.24	0.24	0.24
CV (%)	36.83	36.83	36.83	36.83	36.83	36.83	36.83

Means with the same letter in the same column are not significantly different ($p>0.05$)



Plate 4 Genotype Nfuuka, highly susceptible to the banana weevil *Cosmopolites sordidus*

4.3.3 Response to Plant parasitic nematode

Overall the most predominant nematode species was *Helicotylenchus multicinctus*, followed by *Radopholus similis*, *Pratylenchus goodeyi* and then *Meloidogyne spp* (Table 18.). Where ever *Meloidogyne* appeared they were present in the juvenile stage. Although nematode population densities in cycle two were higher than those in production cycle one, only *Helicotylenchus multicinctus*, and *Radopholus similis* were significantly higher in production cycle two than in production cycle one.

Across the different agro ecological zones genotypes FHIA 21, FHIA 25, Burocemsa hosted significantly more *Pratylenchus goodeyi* than Nfuuka. The rest of the genotypes were not significantly different from Nfuuka. All the other genotypes hosted nematodes in significantly more numbers than Nfuuka. Genotypes FHIA 21# 68, FHIA 25, Burocemsa, Williams, SH 3640 hosted significantly more *Radopholus similis* than Nfuuka and the rest of the genotypes. Genotypes Williams hosted more *Meloidogyne spp*, mainly in the juvenile stage but not significantly higher than Nfuuka and the rest of the genotypes. With the exception of FHIA 21# 68, the rest of the genotypes did not differ significantly from Nfuuka for root necrosis index (RNI). Genotypes FHIA 18, Yangambi KM5 and Pisang ceylan registered significantly higher live root (LR) than dead root (DR) compared to Nfuuka and the rest of the genotypes.

These results confirm the earlier findings that the most important nematodes affecting bananas and plantains in Uganda are *Helicotylenchus multicinctus*, *Radopholus similis*, *Pratylenchus goodeyi* and *Meloidogyne spp* (Bridge, 1993; Namaganda, 1996). In the interaction of different nematode species migratory endo parasitic nematodes tend to suppress sedentary

forms such as root knot nematodes (Pinochet, 1996). This probably explains the abundance of particular nematodes in some locations and their absence in others. The results presented indicate abundance of *Helicotylenchus multicinctus* followed by *Radopholus similis* and *Pratylenchus goodeyi*. *Meloidogyne spp* was present in very low numbers. The abundance of *Helicotylenchus multicinctus* in the soils may suggest that the nematodes being semi endo nematodes and also migratory ecto parasites may be able to feed and move out of the root tissue. The predominance of juvenile stage of *Meloidogyne spp* the root knot nematode probably accounts for the very small and insignificant root knot damage.

Nematode populations are influenced by many edaphic factors (Norton, 1998). This probably, partly explains the variation in nematode densities from one environment to the other. Different soil characteristics (texture, organic matter content, PH, soil biota) and type of banana attract a peculiar nematode. Sandy soils are known to suppress higher nematode population densities than clay soils (Koenning et al., 1988).

In Kalangala the predominant nematodes were male *Radopholus similis* and the fact that Kalangala soils are predominantly leached sandy silts suggests that they might have provided a hostile environment for the female *Radopholus similis*. Davide (1992) observed that although *Radopholus similis* and *Meloidogyne spp* occur in a wide range of soils, their reproduction rates were better in sandy loam soils than in fine texture types.

The wide distribution of nematodes on all the banana genotypes across the various crops confirms findings by Namaganda (1996) that nematode species infected and multiplied in all host crops regardless of whether they are mono crops or intercrops, although they exhibited preference for the intercrops.

All migratory endo species that invade the plant tissues, remain migratory moving from place to place. This therefore explains the occurrence of *Helicotylenchus multicinctus*, *Radopholus similis* and *Pratylenchus goodeyi* in fairly bigger numbers than *Meloidogyne spp*. The sedentary endo parasitic nematodes like *Meloidogyne spp* invade the plant tissues with the females becoming immobile and feeding on special cells inside. This too, explains the presence of only juvenile stages and males of *Meloidogyne spp* in very few numbers in all the three agro ecological zones under which the genotypes were studied.

Forgain, 2001, evaluated plantain and banana genotypes for resistance to nematodes and weevils and found *Radopholus similis* to be the most predominant species. The findings also indicated that genotype Yangambi KM5 was resistant to *Radopholus similis* and *Pratylenchus goodeyi*.

The higher nematode populations in Rukungiri and Luwero were probably due to the more favourable soil and environmental conditions. The overall low population densities and low root necrosis index might be linked to environmental conditions like presence of certain micro organisms in the soil (Namaganda, 1996) or genotype resistance (Gowen and Queneherve, 1990). Absence of interaction between cycle on genotype and agro ecological zone on genotype might be explained by the fact that the period of two years, was too short to influence significant differences.

Results of this study suggest that all the banana genotypes hosted nematodes in all the three agro ecological zones but no significant differences in damage levels could be detected between the genotypes.

Table 1. Assumed percentage of dead roots (DR), live roots (LR), root knots (RK), root necrosis index (RNI) nematode damage of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

Genotype	DISTRICTS											
	KALANGALA				RUKUNGIRI				LUWERO			
	DR	LR	RK	RNI	DR	LR	RK	RNI	DR	LR	RK	RNI
PERCENTAGE												
PISANG CEY	1.53	2.84	0.86	1.08	1.16	2.60	0.78	0.78	1.16	3.00	0.77	0.78
NFUUKA	1.67	1.35	0.86	0.99	1.59	2.70	0.77	0.82	1.57	2.70	0.77	0.82
FHIA 25	1.47	2.55	0.86	0.77	1.47	2.77	0.71	0.71	1.60	2.77	0.71	0.71
FHIA 17	1.41	2.94	0.77	1.00	1.43	2.53	0.71	0.71	1.47	2.53	0.71	0.71
YANGAMBI	1.54	2.64	1.01	0.89	1.24	3.00	0.77	0.78	1.16	3.00	0.77	0.78
SH 3460	1.49	2.21	1.07	1.22	1.76	2.68	0.78	0.99	1.34	2.68	0.78	0.99
BUROCEMSA	1.84	2.53	0.96	1.10	1.17	2.80	0.78	1.14	1.56	2.80	0.78	1.14
FHIA 23	1.86	3.03	0.82	0.71	1.42	2.78	0.71	0.83	1.40	2.78	0.71	0.83
660K	1.66	2.52	0.84	0.75	1.46	2.61	0.91	1.13	1.67	2.61	0.91	1.13
FHIA 21# 68	1.68	2.44	0.83	1.47	1.68	2.52	0.80	0.89	1.54	2.52	0.80	0.89
SABA	1.56	2.23	0.96	1.18	1.52	2.87	0.79	0.85	1.36	2.87	0.79	0.85
CRBP 39	1.74	2.39	0.78	0.89	1.39	2.80	0.77	0.81	1.39	2.80	0.77	0.81
SH 3436-9	1.81	2.47	0.96	0.89	0.94	2.64	1.06	1.02	1.54	2.64	1.06	1.02
FHIA 18	1.28	3.16	0.86	0.86	1.29	2.78	0.82	0.86	1.40	2.78	0.82	0.86
GCTCV 119	1.58	1.85	0.77	0.71	1.68	2.61	0.84	0.71	1.58	2.61	0.84	0.71
WILLIAMS	1.73	3.21	0.78	0.71	1.48	2.45	0.90	0.96	1.54	2.45	0.90	0.96
Mean	1.48	2.21	0.84	0.90	1.42	2.71	0.81	0.87	1.46	2.72	0.81	0.87
LSD(0.05)	0.17	0.15	0.07	0.16	0.17	0.15	0.07	0.16	0.17	0.17	0.15	0.07
CV (%)	36.1	18.4	27.7	57.8	36.1	18.4	27.8	57.8	36.1	18.4	27.7	57.8

Table 19. Transformed Nematode counts in 100g of banana roots extracted from plants with mixed populations of *Pratylenchus goodeyi* (Pg), *Helicotylenchus multinctus* (Hm), *Radopholus similis* (Rs) and *Meloidogyne spp*(MI) of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2004-2007.

Genotype	KALANGALA					RUKUNGIRI					LUWERO				
	Pg	Hm	Rs	MI	Pg	Hm	Rs	MI	Pg	Hm	Rs	MI	Pg	Hm	Rs
PISANG CEY	1.3(20)*	5.8(280)	1.0(0)	0.7(2060)	0.8(0)	8.2(100)	0.7(0)	0.7(540)	2.1(0)	5.0(1340)	0.8(0)	0.7(540)	2.1(0)	5.0(1340)	0.8(0)
NFUUKA	0.7(0)	7.1(200)	1.0(1820)	0.7(340)	0.7(0)	2.9(100)	0.7(40)	0.7(540)	1.1(0)	5.8(2400)	0.9(200)	0.7(0)	1.1(0)	5.8(2400)	0.9(200)
FHIA 25	0.7(0)	8.4(740)	0.9(1200)	0.7(140)	1.1(0)	0.9(0)	0.7(0)	0.7(0)	1.1(20)	5.2(1100)	0.8(0)	0.7(0)	1.1(20)	5.2(1100)	0.8(0)
FHIA 17	0.7(200)	3.8(460)	0.9(0)	0.7(40)	0.7(0)	1.6(0)	0.7(0)	0.7(0)	0.7(120)	4.2(2580)	0.8(0)	0.7(0)	0.7(120)	4.2(2580)	0.8(0)
YANGAMBI	1.1(0)	8.5(1540)	0.9(0)	0.7(80)	0.7(0)	4.8(0)	0.8(0)	0.7(40)	0.7(0)	5.9(780)	0.9(0)	0.7(60)	0.7(0)	5.9(780)	0.9(0)
SH 3460	0.7(0)	6.4(60)	1.0(140)	0.7(2400)	2.1(0)	3.1(0)	0.7(0)	0.7(1600)	1.0(0)	5.5(4700)	0.8(0)	0.7(0)	1.0(0)	5.5(4700)	0.8(0)
BUROCEMSA	0.7(0)	7.3(1400)	0.9(140)	0.7(0)	0.7(0)	4.2(0)	0.8(0)	0.7(0)	0.7(0)	5.9(8400)	0.8(0)	0.7(100)	0.7(0)	5.9(8400)	0.8(0)
FHIA 23	1.1(0)	11.5(2000)	0.9(20)	0.7(80)	0.7(0)	3.1(40)	0.8(0)	0.7(0)	0.7(0)	6.2(3540)	0.8(0)	0.7(0)	0.7(0)	6.2(3540)	0.8(0)
660K	0.7(320)	5.9(3140)	0.9(40)	0.7(100)	0.7(0)	3.1(0)	0.9(0)	0.7(0)	0.7(0)	4.9(2580)	0.9(20)	0.7(0)	0.7(0)	4.9(2580)	0.9(20)
FHIA 21# 68	0.7(120)	4.1(9140)	0.8(0)	0.7(0)	0.8(720)	1.7(340)	0.8(0)	0.7(60)	1.4(0)	4.5(3180)	0.8(0)	0.7(0)	1.4(0)	4.5(3180)	0.8(0)
SABA	0.7(200)	8.4(1700)	1.0(100)	0.7(60)	1.3(0)	3.6(0)	0.7(440)	0.7(220)	0.7(0)	7.1(2960)	0.8(0)	0.7(960)	0.7(0)	7.1(2960)	0.8(0)
CRBP 39	1.0(40)	7.2(816)	0.9(280)	0.7(60)	0.7(0)	4.6(0)	0.7(0)	0.7(0)	0.7(0)	4.9(2220)	0.8(0)	0.7(20)	0.7(0)	4.9(2220)	0.8(0)
SH 3436-9	0.8(580)	7.2(4180)	1.0(0)	0.79(120)	2.2(0)	3.1(20)	0.8(20)	0.7(100)	1.5(580)	5.8(4180)	0.9(0)	0.7(120)	1.5(580)	5.8(4180)	0.9(0)
FHIA 18	0.7(60)	6.3(2380)	1.0(0)	0.7(140)	1.3(0)	3.2(0)	0.8(0)	0.7(0)	0.7(3800)	2.1(258)	0.8(0)	0.7(200)	0.7(3800)	2.1(258)	0.8(0)
GCTCV 119	0.7(0)	5.4(960)	0.8(120)	0.7(620)	0.7(0)	1.7(0)	0.7(0)	0.7(40)	1.3(0)	2.99268)	0.7(0)	0.7(0)	1.3(0)	2.99268)	0.7(0)
WILLIAMS	0.7(00)	9.4(4600)	0.9(760)	0.7(200)	0.7(0)	1.8(0)	0.7(0)	0.7(0)	0.7(0)	6.6(4040)	0.79(340)	0.7(80)	0.7(0)	6.6(4040)	0.79(340)
Mean**	0.93	4.83	0.83	0.72	0.93	4.83	0.83	0.72	0.93	4.83	0.83	0.72	0.93	4.83	0.83
LSD(0.05)	0.47	2.10	0.09	0.02	0.47	2.10	0.09	0.02	0.47	2.10	0.09	0.02	0.47	2.10	0.09
CV (%)	308.40	265.96	68.60	14.35	308.40	265.96	68.60	14.35	308.40	265.96	68.60	14.35	308.40	265.96	68.60

* The numbers in parentheses are the actual nematode counts

** The means are averages of two assessments i.e., 2006 and 2007



Plate 5 Genotype KM 5 highly resistant to Sigatoka leaf spot disease, weevils borers and plant parasitic nematodes

4.3.0 Correlation and Regression analyses

The highly positive correlation value (Table.20 for bunch weight and plant girth suggests that the bigger the plant girth the bigger the bunch weights. On the other hand the smaller the plant girth, the smaller the bunch.

The high positive correlation value ($r = 0.80$) (Table 20) for bunch weight and functional leaves at flowering also suggests that the higher the number of functional leaves at flowering the bigger the bunch size. Similarly the fewer the functional leaves at flowering the smaller the bunch size. Genotypes that had a large number of functional leaves also had a higher leaf area index and were therefore able to more efficiently carry out photosynthesis. This implies that the low emission of functional leaves enabled maximization of assimilates to the sink resulting in high bunch yields. The very highly positive correlation value ($r = 0.95$) (Table 20) for bunch weight and hands also suggests that the bigger the bunch the higher the number of hands. Similarly the smaller the bunch the fewer the number of hands.

The correlation coefficient value for girth and functional leaves at flowering was highly positive ($r = 0.70$) (Table 20). This suggested that the bigger the girth, the more the total functional leaves at flowering. On the other hand the smaller the pseudo stem girth the less the number of function leaves. This had direct effect on photosynthesis and the subsequent assimilate accumulation in the sink. Genotypes with larger pseudo stem girth and more functional leaves appear to have grown faster with greater vigour than those with smaller girths with fewer functional leaves.

The higher positive correlation coefficient value ($r = 0.89$) (Table 20) for girth and number of hands per bunch suggests that the bigger the plant girth the more the number of hands per

Table 20. Correlation matrix of Yield, yield components, pest and disease response of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

	BWT	GIRTH	TL	INSL	LVS-HAV	HANDS	tXO	tLR	tFHM	tMML
BWT	1.00									
GIRTH	0.96**	1.00								
TL	0.80**	0.70**	1.00							
INSL	0.39	0.19	0.66*	1.00						
LVS-HAV	0.63	0.50	0.84**	0.79**	1.00					
HANDS	0.95**	0.89**	0.86**	0.52*	0.75**	1.00				
tXO	-0.25	-.17	-.54	-0.22	-0.41	-0.29	1.00			
tLR	0.29	.26	0.59*	0.45	0.45	0.39	-.60	1.00		
tFHM	-.020	-.22	-.15	-0.01	-0.03	-.016	0.21	-.39	1.00	
tMML	-0.04	-0.11	-.16	-0.06	-0.16	-0.01	-.09	-.20	-0.24	1.00

BWT = Bunch weight, TL = Total functional leaves at flowering, INSL = Index of non spotted leaves, LVS-HAV = Leaves at harvesting, Hands = Clusters per bunch, T_{xo} = Total outer cross sectional corm weevil damage, t_{LR} = Total live roots, T_{fhm} = Total female *Helicotylenchus multicinctus*, Total male Meloidegynae species

* *Highly significant (p>0.05)

*Significant (p>0.05)

bunch. On the other hand the smaller the plant girth, the less the number of hands per bunch.

Therefore the size of a bunch depends on the size of the pseudo stem.

The higher positive correlation value ($r = 0.84$) (Table 20) for Total functional leaves at flowering and index of non spotted area suggests that the genotypes that had a higher index of non spotted area had more leaf area index available for photosynthesis. The development of disease on hypersensitive/ highly resistant genotypes suggests that the disease is unable to reach the final stages of necrosis. There was restricted development of the Sigatoka leaf spots symptoms probably attributed to physiological and biochemical factors following penetration of host tissues by fungal hyphae. Vuylsteke and Ortiz (1993) suggested that the less leaf spot damage is attributed to slow or delayed disease symptoms. This implies that the age of the leaf on which mature lesions appear is an important criterion for host response to Sigatoka leaf spot disease in the banana plant.

The higher correlation value ($r = 0.86$) (Table 20) for Total functional leaves at flowering and number of bunch hands suggests that the higher the total functional leaves at flowering, the higher the number of bunch hands. The fewer the functional leaves the fewer the number of hands on the bunch.

The positive but not very strong correlation values ($r = 0.59$) (Table 20) for total live roots and functional leaves at flowering, suggests that the higher live root value, the higher the number of functional leaves at flowering and vice versa. This implies, that bunch size and number of hands on the bunch, depend on the health of the roots. Similarly the weak correlation value ($r = 0.29$) (Table 20) for total live roots and bunch weight, suggests that although there was contribution of live roots to bunch weight, it was insignificant.

4.6.0 Genotype Stability

4.6.1 Stability Analysis

The results of stability analysis for cycle*variety levels for sixteen banana genotypes in the study are presented in (Table 21). Stability Analysis was carried out on bunch weight as dependent variable and site mean as an independent response in a regression model. Considering overall analysis, stable genotypes that had slope coefficients <1.00 were FHIA 17, FHIA 18, FHIA 21# 68, FHIA 25, GCTCV 119, CRBP 39, WILLIAMS, SABA, SH 3436-9 and PISANG CEY. Some of these genotypes exhibited stability in all the two crop cycles considered, namely, FHIA 21# 68, WILLIAMS, SABA, SH 3436-9, GCTCV 119 and CRBP 39 (Table 8). During the first production ratoon all genotypes were stable ($-0.01-0.98$) except FHIA 17, FHIA 25, NFUUKA and YANGAMBI KM5. Genotype instability increased with increased crop cycles. Nfuuka, the local control was slightly unstable (1.10) (Table 21). Results on genotype stability on the basis of bunch weight across the three agro ecological zones produced four major categories namely: Genotypes that were high yielding and were unstable included: FHIA 17 (1.09), FHIA 23 (1.60), FHIA 25 (1.05) and SH 3436-9. Genotypes that were high yielding but stable included: FHIA 18, Pisang ceylan and Yangambi KM 5. Genotypes that were low yielding and were stable included: Williams, 660K, Saba and Burocensa. Genotypes that were low yielding and were not stable included: GCTCV-119, CRBP-39, FHIA-21 # 68, SH 3640 and Nfuuka. (Table 21).

The general observation was that most small bunch genotypes like GCTCV-119, CRBP-39 and the heaviest bunch genotypes were the most unstable genotypes. The most unstable bananas were FHIA 17. Bayeri et al.; 2000, conducted stability studies on thirty six genotypes in Nigeria using AMMI and indicated that FHIA 23 was high yielding and had stable bunch weights. This results showed that FHIA 23 was only stable in cycle one.

Genotypes that had a stability index of above 1.0 were scored as unstable. Whereas those with a figure less than 1.0 were said to be stable. On this basis four categories of genotypes were arrived at as follows: (i) high yielding and unstable, (ii) high yielding and stable, (iii) low yielding and unstable (iv) low yielding and stable.

These results suggest that those genotypes that had highest coefficient of variation values exhibited the greatest variability from location to location as compared to those that had the lowest coefficient of variation values. This implies that such genotypes were highly sensitive to environmental interactive effects.

Stability can be defined as low variation in a particular trait when measured over numerous locations and/or years. The expected average regression coefficient for all genotypes always equals 1.0, so genotypes with $\beta < 1.0$ (i.e., flatter slopes) are considered more stable than the average genotype, while genotypes with $\beta > 1.0$ (i.e., steeper slopes) are considered less stable. Therefore, a more stable genotype is less responsive to changes in the environment than a less stable genotype. Sometimes the more stable genotype performs better than the less stable genotype under poor environmental conditions, but not as well under better conditions. An ideal genotype would perform better than most others in poor environments, while still performing well in good environments. Olien et al. (1991) used linear regression analysis to calculate stability indices for cumulative tree size.

Table 21 Stability analysis for cycle*genotype levels of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts, Uganda, 2005-2007.

Genotype	OVER ALL			Ratoon 1			Ratoon 2		
	mean	slope (b)	Pr > t	mean	slope (b)	Pr > t	mean	slope (b)	Pr > t
FHIA 21# 68	21.49	0.98	<.0001	16.11	0.93	<0.0001	19.25	0.28	<0.0001
GCTCV 119	17.22	0.92	<.0001	11.35	0.28	0.0002	17.12	0.98	<0.0001
CRBP 39	14.55	0.69	<.0001	16.68	0.95	<0.0001	16.52	0.88	<0.0001
NFUUKA	42.90	1.72	<.0001	39.10	1.26	<0.0001	42.51	1.82	<0.0001
SH 3640	21.37	1.13	<.0001	21.92	0.60	<0.0001	26.10	0.63	<0.0001
FHIA 25	17.78	0.81	<.0001	19.33	1.05	<0.0001	21.81	0.77	<0.0001
FHIA 23	42.24	1.34	<.0001	38.02	0.98	<0.0001	39.67	1.60	<0.0001
660K	46.07	1.61	<.0001	37.81	0.45	0.0015	43.60	1.95	<0.0001
WILLIAMS	8.39	0.79	<.0001	8.57	0.92	<0.0001	9.57	0.93	<0.0001
FHIA 17	22.14	0.82	<.0001	20.08	1.14	0.2332	23.76	1.09	<0.0001
SABA	26.54	0.60	<.0001	20.27	-0.01	0.8926	24.33	0.56	<0.0001
SH 3436-9	17.18	0.68	<.0001	12.25	0.24	0.0082	16.89	0.64	<0.0001
BUROCEMSA	30.50	1.25	<.0001	27.90	0.49	<0.0001	31.25	1.25	<0.0001
FHIA 18	26.16	0.06	<.0001	23.47	0.83	<0.0001	27.25	1.01	<0.0001
YANGAMBI	18.28	1.39	<.0001	18.84	1.21	<0.0001	18.67	1.12	<0.0001
PISANG CEY	19.93	0.30	<.0001	17.90	0.35	<0.0001	21.01	0.26	0.0004

Not stable=>1.0

Stable=<1.0

Table 22 Yield and Stability categories of fifteen banana genotypes in Kalangala, Rukungiri and Luwero, Districts of Uganda, 2005-2007.

High yielding, high resistance , unstable	High yielding, high resistance, stable	Low yielding, low resistance, stable	Low yielding, low resistance ,unstable
FHIA 25	Pisang ceylan	Williams	GCTCV-119
FHIA 17	KM 5	660 K	CRBP 39
FHIA 23	FHIA 18	Saba	FHIA 21# 68
FHIA 18		Burocemsa	
SH 3439-9			

4.6.2 Principal Component Analysis

The correlation matrix of observations revealed highly significant coefficients between bunch weight and plant girth, number of clusters on the bunch, total functional leaves at flowering and functional leaves at bunch harvesting (Table. 22). Positions of genotypes on the first, second and third principal components from pair wise comparison of bunch weight were plotted. Principal component analysis reduced the observations to three major components that together accounted for 79% of the original variability. The first principal (PC1) accounted for 50.8 % of the total variability. The second principal component (PC2) accounted for 14.8 % of the total variability. The third principal component (PC3) accounted for 13.4 % of the total variability (Figure 2).

The first Principal component highly accounts for yield and yield components, plant girth, Total functional leaves at flowering, and functional leaves at harvest. The second Principal component accounts for plant girth and Weevil corm damage. Principal component three, accounts for Nematode damage. This implies that plant girth, bunch hands and Functional leaves at flowering are the most important variables contributing to bunch yields. The Eigen vector values (5.08), (1.46) and (1.34) respectively (Table. 22) supported by the scree plot, showed that these components give the most realistic information with respect to bunch yields.

The plot of PC1 against PC2 revealed four quarters as follows:

Quadrant I grouping together genotypes FHIA 25, FHIA 17, FHIA 23 and SH 3439-9 (Figure 3) representing high yielding genotypes, Plants with biggest plant girths, the heaviest bunches with the biggest bunch weights, the largest number of bunch hands and the largest number of functional leaves. These genotypes also had high disease and pest resistance. They however appeared to be unstable across all the three agro ecological zones .

Quadrant II grouping genotypes Pisang ceylan, Yangamb KM 5, and FHIA 18, (Figure 2) that represent high yielding genotypes with very high resistance to pests and diseases. These genotypes were high yielding, had the highest total number of functional leaves at flowering and also at bunch harvesting. These genotypes displayed high disease and pest resistance.

Quadrant III grouping together genotypes 66Ok, Burocensa, Saba and Williams, (Figure 2) that were low yielding. Genotype 660K had good resistance to Sigatoka but susceptible to Weevil and Nematode damage. Williams was highly susceptible to Sigatoka damage. These genotypes had high number of functional leaves at flowering but quickly lost them to Sigatoka disease. At high altitudes where Sigatoka was either low or absent these genotypes displayed good performance.

Quadrant IV representing very low yielding genotypes, GCTCV 119, CRBP 39, FHIA 21, SH 3640 and Nfuuka (Figure 2), with the smallest bunches that also had the lowest bunch weights, the smallest number of bunch hands and the smallest number of functional leaves at flowering and at bunch harvesting. These genotypes were the most be highly susceptible to pests and diseases.

A plot of Principal component one against Principal component three, revealed that Genotype, Pisang ceylan and Yangambi KM 5, had the greatest resistance to weevil damage. Despite the fact that these genotypes had small girths, Weevil damage was the lowest. This could be explained by the fact that genotypes Pisang ceylan and Yangambi KM 5 have very hard corms that weevils find unattractive compared with Nfuuka the local Matooke check. Genotype Nfuuka displayed the highest levels of both internal and external corm damage (Gold et al., 2002). . These findings also concur with (Price, 1994) which suggested that Yangambi KM 5, was the most resistant banana genotype. Therefore, making it a good source of multiple resistance genes for banana improvement.(Vuylsteke et al., 1997)

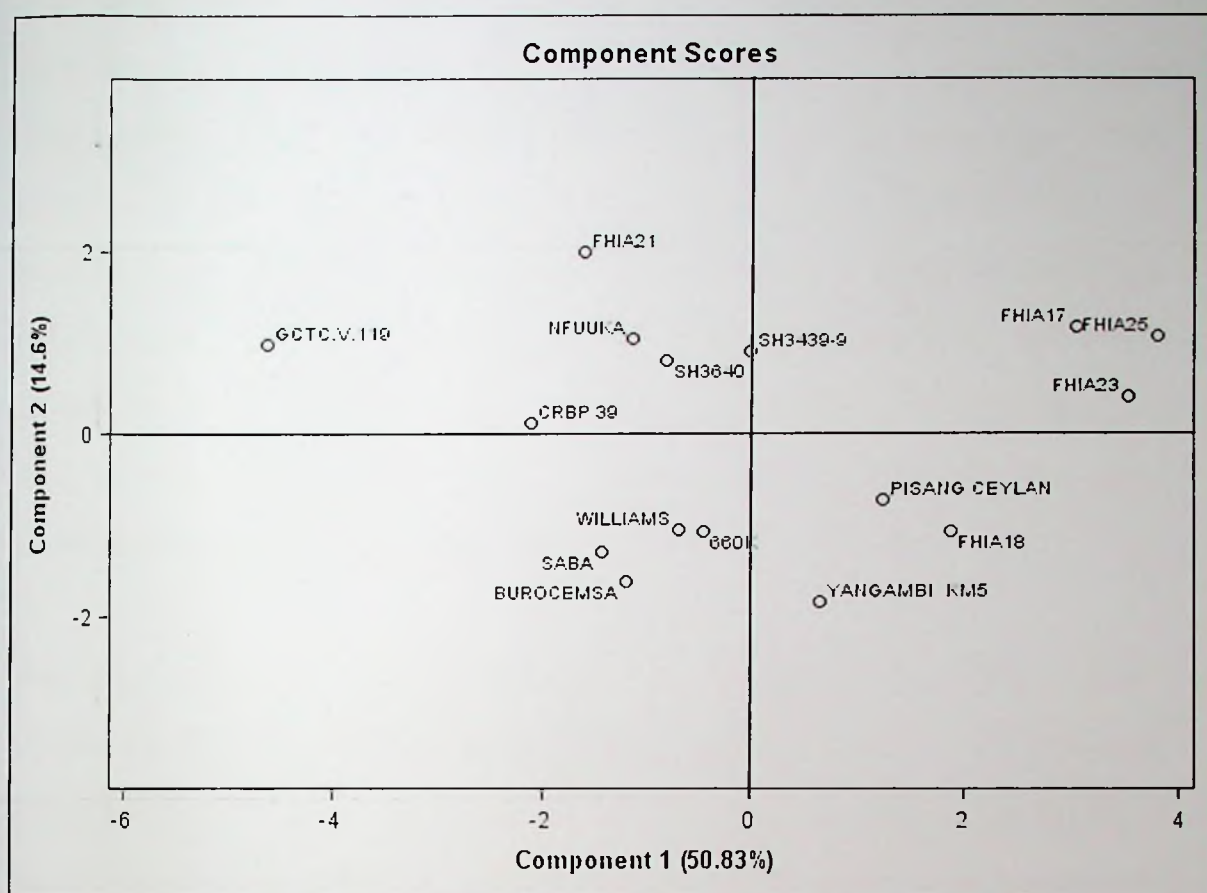
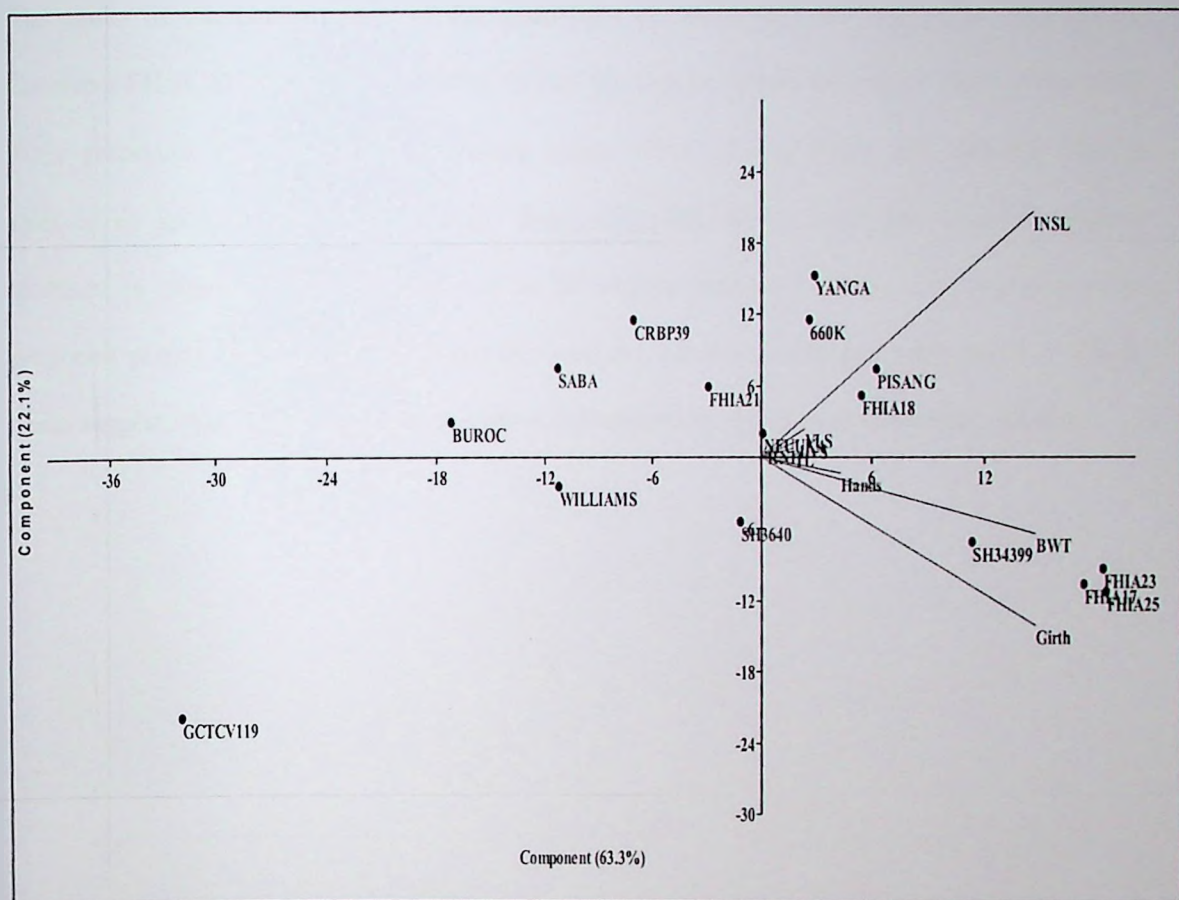


Figure. 2 A plot of the scores of the first principal component (PC1) and the second Principal component (PC2) from a principal analysis of 15 Genotypes with Bunch yields and yield components, plant girth, functional leaves , Sigatoka disease, Banana weevil and parasitic Nematodes across three agro ecological zones of Uganda, 2005-2007.

4.6.2. 1 Performance of the 15 introduced genotypes in Kalangala

The results of the performance of the genotypes in Kalangala are shown in (Figure 3). Genotypes FHIA 25, FHIA 17 and FHIA 23 and SH 3439-9 had the highest yields. These genotypes also had the heaviest bunches with the largest number of clusters. This was reflected in the fact that they had the largest plant girth (Figure 3). Genotypes Yangambi KM 5, Pisang celan, Yangambi KM 5, 660K, and FHIA 18, had the highest index of no spotted leaf spot. Suggesting that these genotypes had the highest resistance to Sigatoka leaf spot disease in Kalangala district. The rest of the genotypes performed poorly. The poorest performance was shown by genotype GCTCV-119 (Figure 3).

These results suggest that the most suited genotypes for Kalangala district are FHIA 25, FHIA 17, FHIA 23, SH 3439-9, Yangambi KM 5, 660K, Pisang ceylan FHIA 18. Performance of these genotypes in Kalangala over the two cropping cycles was consistent suggesting that it was not influenced by season and location. This implies that under good management practice: farmers would be assured of good yields irrespective of time or season as long as there is adequate moisture



Key:

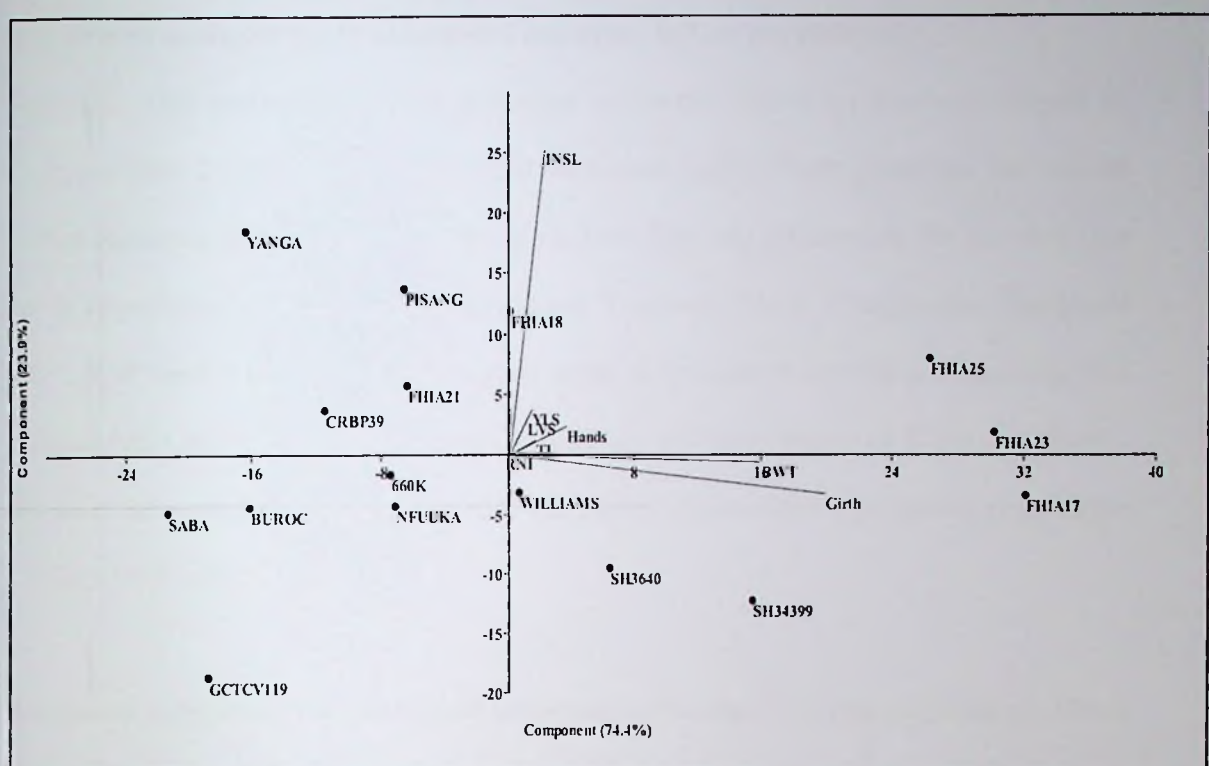
* Genotypes: FHIA 25, FHIA 23, FHIA 21, FHIA 18, FHIA 17, SH 3439-9, SH 3640, Yangambi KM 5, Pisang ceylan, Burocems, Saba, 660K, Williams, CRBP-39, GCTCV-119 and Nfuuka

→Genotype growth characteristics: Bwt (Bunch weight), Girth, Total functional leaves at flowering (TL), Index of non spotted leaf area (INSL) and Hands (Clusters)

Figure. 3 Correlation between genotypes and genotype agronomic and yield performance characteristics against genotypes in Kalangala district. Uganda, 2005-2007.

4.6.2. 2 Performance of the 15 introduced genotypes in Rukungiri district

The results of the performance of the genotypes in Rukungiri are shown in (Figure 4). Genotypes FHIA 25, FHIA 17 and FHIA 23 had the highest yields and the biggest plant girth. While genotypes Yangambi KM 5, Pisang celan, FHIA 21 and FHIA 18, had the highest index of no spotted leaf spot (INSL). Suggesting that these genotypes had the highest resistance to Sigatoka leaf spot disease in Kalangala district. The rest of the genotypes performed poorly. Genotype GCTCV-119, was the poorest performer (Figure 4). These results suggest, that these genotypes are the most suitable for growth in Rukungiri district..



Key:

*Genotypes: FHIA 25, FHIA 23, FHIA 21, FHIA 18, FHIA 17, SH 3439-9, SH 3640, →Yangambi KM 5, Pisang ceylan, Burocems, Saba, 660K, Williams, CRBP-39, GCTCV-119 and Nfuuka

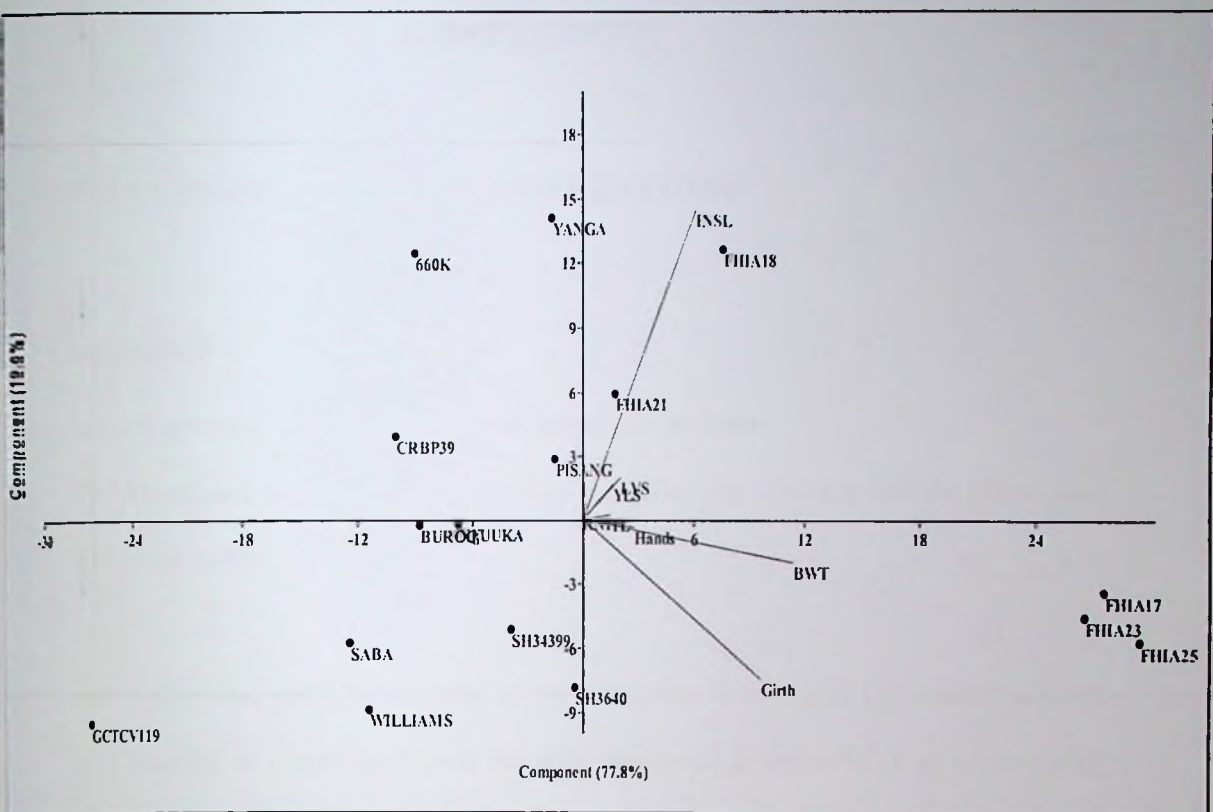
Genotype growth characteristics: Bwt (Bunch weight), Girth, Total functional leaves at flowering (TL), Index of non spotted leaf area (INSL) and Hands (Clusters)

Figure. 4 Correlation between genotypes and genotype agronomic and yield performance characteristics against genotypes in Rukungiri district. Uganda, 2005-2007.

4.6.2.3 Performance of the 15 introduced genotypes in Luwero district

The results of the performance of the genotypes in Luwero district are shown in (Figure 5). Genotypes FHIA 25, FHIA 17 and FHIA had the highest yields. These genotypes also had the heaviest bunches with the largest number of clusters. This was reflected in the fact that they had the largest plant girth (Figure 5). Genotypes Yangambi KM 5, Pisang celan, Yangambi KM 5, 660K, and FHIA 18, had the highest index of no spotted leaf spot. Suggesting that these genotypes had the highest resistance to Sigatoka leaf spot disease in Kalangala district. The rest of the genotypes performed poorly. The poorest performance was shown by genotype GCTCV-119 (Figure 5).

These results suggest that the most suited genotypes for Kalangala district are FHIA 25, FHIA 17, FHIA 23, SH 3439-9, Yangambi KM 5, 660K, Pisang ceylan FHIA 18.



Key:

Genotypes: FHIA 25, FHIA 23, FHIA 21, FHIA 18, FHIA 17, SH 3439-9, SH 3640,

Yangambi KM 5, Pisang ceylan, Burocemsa, Saba, 660K, Williams, CRBP-39, GCTCV-119 and Nfuuka

Genotype growth characteristics: Bwt (Bunch weight), Girth, Total functional leaves at flowering (TL), Index of non-spotted leaf area (INSL) and Hands (Clusters)

Figure. 5 Correlation between genotypes and genotype agronomic and yield performance characteristics against genotypes in Luwero district. Uganda, 2005-2007.

CHAPTER FIVE

0 CONCLUSIONS AND RECOMMENDATIONS

1 Conclusions

From the results presented, the following conclusions can be drawn.

The Agronomic and yield performance of the genotypes varied across the three Agro ecological zones.

Bunch yield and yield components of the genotypes were highly influenced by plant girth, number of hands per bunch and total number of functional leaves at flowering and fruit filling stages.

The number of live roots, Sigatoka disease, and the banana weevil and banana plant parasitic nematodes also influenced yields of the genotypes but not highly significantly.

The study revealed that the FHIA hybrids were the heaviest yielders. However, the FHIA hybrids also had the most unstable bunch weights.

The study also established that the worst performing genotype across the three agro ecological zones were GCTCV-119, CRBP-39 and FHIA 21# 68. These genotypes had the lowest bunch weights, the fewest number of hands per bunch and the lowest number of functional leaves at flowering.

6. GCTCV-119, FHIA 21# 68 and CRBP 39 were observed to have exhibited stem doubling in the field (plants pseudo stems Broke in the middle prematurely) before harvesting. The leaves of these genotypes drooped (collapsed prematurely) before senescence time.
7. All the new genotypes matured later than Nfuuka (local check) and Genotypes in Rukungiri had heavier bunches compared to those at the other altitudes.
8. Genotypes GCTCV-119, FHIA 21# 68 and CRBP 39 were the most susceptible to Weevil and Nematode attack. Whereas Genotype Yangambi KM 5, was resistant to weevil attack.
9. Genotypes GCTCV-119, Williams, FHIA 21# 68 and CRBP 39 were the most susceptible to Black Sigatoka leaf spot disease. Whereas Genotypes Yangambi KM 5, Pisang ceylan and FHIA hybrids showed significant resistance to Black Sigatoka compared to the Nfuuka (local check).
10. Genotypes Pisang ceylan, KM 5, FHIA 18, Williams, 660K, Saba and Burocemsu had stable bunch weights across the three Agro ecological zones.
11. The positive correlation between the bunch weight and plant girth, number of hands/ clusters on the bunch, functional leaves and live roots, implies that enhancing the nutritional status of the soil is one way that farmers can improve plant growth and therefore leading to increased bunch yields.

5.2 Recommendations

1. All these high yielding genotypes namely: , FHIA 25, FHI 17, FHIA 23, Pisang ceylan and KM 5, which were also quick maturing and had good response to Sigatoka, weevil and nematode are recommended for adoption by the farmers.
2. Genotypes GCTCV-119, FHIA 21# 68 and CRBP 39 did not perform well in the three environments and need to be tested in other environments.
3. Since the performance of genotypes varies with location, farmers are advised to make the right choice of genotypes to grow in a particular locations based on the performance recommendations.
4. It is recommended that further studies be conducted in order to determine the socio economic acceptability of these genotypes that were found to be possessing good agronomic performance in addition to pest and disease resistance attributes.
5. Further Genotype by Environment studies are required to determine the stability and adaptability of these genotypes in other Agro ecological zones of Uganda not covered in this study.
6. There is need for further studies to establish factors responsible for the higher selective preference of pest (weevils and nematodes) to some genotypes compared to the others.

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APPENDIX

Annex 1. Growth parameters and yield components data sheet

Date..... Zone..... Farmer.....

Pe	PNT	Cycle	Date flower	TL	Height (cm)	Girth at (100cm)	Ht fol (cm)	Date harv	BWT (Kg)	Hands	LVS harv

Total functional leaves at flower shooting

F= Bunch weight

FOL= Height of follower

LHarv= Leaves at Harvest

Appendix 2. Sigatoka leaf spot disease severity data sheet

Date..... Zone..... Farmer.....

Genotype	PNT	Cycle	Height (cm)	Girth at (100cm)	TL	YLS (Flow)	YLS (Harv)

YLS (Flow) = Youngest leaf with Sigatoka spot at flower shooting

YLS (Harv) = Youngest leaf with Sigatoka spot at bunch harvest

Annex 3. Banana weevil damage assessment data sheet

Date..... Zone..... Farmer.....

Type	PNT	Cycle	Height (cm)	Girth at (100cm)	Diameter		Upper		Lower	
					OD	ID	XI	XO	XI	XO

Overall corm diameter

Inner corm diameter

Inner cross section corm damage

Outer cross section damage

Appendix 4. Banana nematode assessment data sheet

Date..... Zone..... Farmer.....

Field root health assessment sheet

Genotype	PL	RAT	LR	DR	RK	FR	RNI

Plant number

Ratoon number

Live roots

Dead roots

Root knots

Feeder roots

Root necrosis index

Date..... Zone..... Farmer.....

Laboratory nematode identification and count sheet

EN	PNT	RAT	FPG	MPG	JPG	FHM	MHM	JHM	FRS	MRS	JRS	MM	JM

EN= Genotype

NT=Plant number

AT=Ratoon

PG=Female *Pratylenchus goodeyi*

PG= Male *Pratylenchus goodeyi*

G= Juvenile *Pratylenchus goodeyi*

FM=Female *Helicotylenchus multicinctus*

HEM=Male *Helicotylenchus multicinctus*

JM=Juvenile *Helicotylenchus multicinctus*

S=Female *Radopholus similis*

RS=Male *Radopholus similis*

S=Juvenile *Radopholus similis*

M=Male *Meloidegynae*

J=Juvenile *Meloidegynae*