BANANA FIELD TRIALS DATA COLLECTION PROTOCOLS MANUAL

THE EVALUATION OF NARITA HYBRIDS IN UGANDA AND TANZANIA FOR THE PROJECT "IMPROVEMENT OF BANANA FOR SMALLHOLDER FARMERS IN THE GREAT LAKES REGION OF AFRICA"

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BREEDING BETTER BANANAS

THIS IS A DRAFT DOCUMENT!!

Extra info

Crichton, R. and Van den Bergh, I. 2016. Banana field trials data collection protocols manual - The evaluation of NARITA hybrids in Uganda and Tanzania for the project “Improvement of banana for smallholder farmers in the Great Lakes region of Africa”. Bioversity International, xxx p.

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Logos …

ACKNOWLEDGEMENTS

To come

TABLE OF CONTENTS

INTRODUCTION TO THIS MANUAL

Banana is the main staple food in the East and Central Africa region, where over 50% of the cropping area is under permanent banana cultivation and per capita consumption can be as high as 300 kg per year. However, the yield gap, i.e. the difference between attainable and actual yields, is often large. Major production constraints include low soil fertility and limited rainfall, diseases (such as Xanthomonas wilt, black leaf streak and bunchy top) and pests (such as nematodes and weevils). The International Institute of Tropical Agriculture (IITA) and the National Agricultural Research Organisation - Uganda (NARO) have jointly developed **27 high-yielding hybrid East African Highland Bananas (EAHB), called NARITAs**, that have good tolerance/resistance to some pests and diseases.

As part of a Bill and Melinda Gates Foundation (BMGF) and CGIAR Research Program on Roots, Tubers and Bananas (RTB) funded project "Improvement of Banana for Smallholder Farmers in the Great Lakes Region of Africa" running from 2014-2019, Bioversity International and partners will **evaluate the NARITAs for their agronomic performance, host reaction to important pests and diseases in the region, and consumer acceptance in a range of expected end-user environments and target markets in Uganda and Tanzania, using a participatory varietal selection methodology.** The ultimate objective is to identify NARITAs that are well adapted to, and can be integrated into, existing EAHB farming systems.

Two types of trials will be run consecutively: **on-station trials** to gain accurate data on cultivar performance (mother trials) and **on-farm participatory selection trials** to facilitate access to and testing of the new material by end-users (baby trials). **This manual specifically focuses on the standardized data collection protocols and tools for the on-station trials**, and is a supporting document to the "Banana field trial data collection protocols workshop", organized at Kawanda, Kampala, 19-22 September 2016.

PART A – ABOUT BANANAS

THE BANANA PLANT

The banana plant is a tree-like perennial herb. It is an herb because the aerial parts of the parent plant die down to the ground after the growing season. It is a perennial because one of the offshoots growing at the base of the plant, the suckers, then takes over. The mat, also called stool, is the term used to designate the parent plant and its suckers, which are connected to each other through the underground rhizome. What looks like a trunk is in fact a pseudostem made from tightly packed leaf sheaths.

The variability observed in morphological traits is used to characterize banana plants[1].

ROOT SYSTEM

The root system is the means by which the plant takes up water and nutrients from the soil.

The roots are produced by the underground structure called a rhizome[2]. The primary roots originate from the surface of the central cylinder (see below), whereas secondary and tertiary roots originate from the primary roots.

RHIZOME

The rhizome is the banana plant's true stem. It is commonly referred to as a corm, and occasionally as a bulb, but the botanically correct term is rhizome[3]. Rhizomes are characterized by horizontal underground growth; production of roots from multiple nodes; and production of clonal plants[4]. Corms, on the other hand, are vertical enlarged compact stems with a tunic of thin leaves and roots arising from a single node; features that do not describe well the banana plant's underground structure.

The terminal growing point of the rhizome, the apical meristem, is a flattened dome from which the leaves and the inflorescence are formed.

PSEUDOSTEM

The part of the plant that looks like a trunk is actually a false stem, called pseudostem. The pseudostem is formed by the tightly packed overlapping leaf sheaths. The pseudostem continues to grow in height as the leaves emerge one after the other and reaches its maximum height when the aerial true stem[5] — usually called the floral stem because it supports the inflorescence — emerges at the top of the plant.

Even though the pseudostem is very fleshy and consists mostly of water, it is quite sturdy and can support a bunch that weighs 50 kg or more.

LEAF

The leaf is the plant's main photosynthetic organ. Each leaf emerges from the center of the pseudostem as a rolled cylinder (see cigar leaf below). The distal end of the elongating leaf sheath contracts into a petiole, that is more or less open depending on the cultivar. The petiole becomes the midrib, which divides the blade into two lamina halves. The upper surface of the leaf is called adaxial while the lower one is called abaxial.

The first rudimentary leaves produced by a growing sucker are called scale leaves. Mature leaves that consist of sheath, petiole, midrib and blade are called foliage leaves.

Lamina veins run parallel to each other in a long S shape from midrib to margin. Veins do not branch, which results in leaves tearing easily.

Cigar leaf

The cigar leaf is a recently emerged leaf still rolled as a cylinder.

The lapse of time in which a leaf unfolds varies. Under favourable climatic conditions, it takes about seven days, but it can take up to 15 to 20 days under poor conditions.

The new leaf is tightly coiled, whitish, and particularly fragile.

The extension at the tip of the leaf is called the precursory appendage. After emergence, it withers and falls off.

SUCKER

A sucker is a lateral shoot that develops from the rhizome and usually emerges close to the parent plant. Other names for sucker are keiki (in Hawaii) and pup.

A sucker that has just emerged through the soil surface is called a peeper. A full grown sucker bearing foliage leaves is called a maiden sucker.

Morphologically, there are two types of sucker: sword suckers (right on the photo), characterized by narrow leaves and a large rhizome, and water suckers (left on the photo), which have broad leaves and a small rhizome. Water suckers have a weak connection to the parent plant and as such will not develop into a strong plant.

The number of suckers produced varies with the type of cultivar. The sucker selected to replace the parent plant after fruiting is called the follower or ratoon.

INFLORESCENCE

The inflorescence is a complex structure that includes the flowers that will develop into fruits. It is supported by the aerial true stem, which is usually called the floral stem[5]. The aerial true stem is produced by the terminal growing point on the rhizome. It grows through the pseudostem and emerges at the top of the plant soon after the last cigar leaf.

The female (pistillate) flowers appear first. In cultivated bananas, the ovary develops into a seedless fruit by parthenocarpy (without being pollinated). As it lifts, the bract (a modified leaf) exposes a cluster of female flowers that are normally arranged in two rows. These flowers will develop into a hand of fruit. The number of hands in the bunch depends on the number of female clusters in the inflorescence, and varies depending on the genotype and environmental conditions.

As the female flowers develop into fruit, the distal portion of the inflorescence elongates and produces clusters of male (staminate) flowers, each subtended by a bract. The male flowers in the male bud produce pollen that may or may not be sterile. A third type of flowers called hermaphrodite, or neutral, may be present on the stalk between the female flowers and the male bud, usually called the rachis. They generally do not develop into fruit and their stamens do not produce pollen.

Peduncle

The peduncle is the stalk that supports the inflorescence and attaches it to the rhizome.

Bunch

The bunch is the descriptive term for all the fruits along the rachis. The fruits are arranged into hands, the former clusters of flowers that were each subtended by a bract. By analogy, the fruits in a hand are often called fingers. The largest bunch, according to Guinness World Records, weighed in at 130 kg[6].

Rachis

The rachis is the stalk of the inflorescence from the first fruit to the male bud. It can be bare or covered with persistent bracts. The scars on the rachis indicate where the bracts were attached. They are called nodes.

Male bud

The male bud contains the male flowers enclosed in their bracts. It is sometimes called the bell. As the fruits mature, the rachis and male bud continue to grow. In some cultivars, the male bud ceases to grow after the fruits have set and can be more or less exhausted by the time the bunch reaches maturity. The presence or absence of the male bud is one of the traits used to distinguish cultivars.

REFERENCES

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2. Differences between roots and rhizomes, retrieved 16 March 2016

3. Robinson, J.C. and Galán Saúco, V. 2010. Bananas and plantains. Crop production science in horticulture. CABI, Wallingford (GBR). 297p.

4. What is a rhizome, retrieved 16 March 2016

5. Blog post Would the true peduncle please stand up? published 3 March 2016 in Under the peel, the blog of the ProMusa community.

6. http://www.guinnessworldrecords.com/records-10000/largest-bunch-of-bananas/

EXTERNAL LINKS

Musa ontology developed for the Generation Challenge Progam Crop Ontology

BANANA PLANT DEVELOPMENT

About banana lifecycle stages & states (off-type);

THE EAST AFRICAN HIGHLAND BANANAS (SOURCE MUSAPEDIA)

East African highland banana (EAHB) is the name of a subgroup of cooking and beer bananas domesticated in the Great Lakes region of East Africa. As the name indicates, EAHB cultivars grow best between 1,400 and 2,000 meters. They can be eaten ripe as dessert bananas, but their pulp is rather insipid. The subgroup accounts for the majority of the bananas grown in East Africa, especially in Uganda, where they are popularly known as matooke, after the traditional meal made from steamed bananas. Tooke is the Luganda word for banana and matooke its plural form[1].

MORPHOLOGICAL CHARACTERISTICS

The pseudostem is characteristically dark, its colour varying from brown to black. The male bud is a dull purple-brown. The male flowers have pink anthers and an orange stigma. The lobe of the compound petal is yellow.

CLONE SETS

The cultivars in the subgroup have been classified into five clone sets: Nfuuka, Musakala, Nakabulu, Nakitembe and Mbidde[2].

Nfuuka

Nfuuka means "changing". The cultivars in this clone set are morphologically unstable. It is the most heterogenous of the clones sets and also contains the greatest number of cultivars. The bunch is compact and hangs at an angle that varies from slight to 45 degrees. Fruit are medium in size fruit and point up at an angle. The tip of the male bud is not imbricated, i.e. the bracts meet at the tip. The rachis is generally bare.

Musakala

Musakala means "lax", which refers to the spacing between the fruit. The bunch points vertically down. The fruit are long (more than 20 cm) and point up. The tip is bottlenecked. The male bud is not imbricated. The rachis points vertically down. The Musakala clone set includes the high-yielding cultivars that are grown commercially to supply urban markets.

Nakabulu

Nakabulu means "short and plump". The bunch is compact and the fruit are short and jut out at a right angle. All the fruit ripen simultaneously. The bunch hangs at an angle. The tip of the male bud is more or less rounded. The rachis is bare and hangs at an angle.

Nakitembe

Nakitembe means 'like ekitembe', ekitembe being the local name in Uganda for enset. The cultivars in this clone set resemble enset in that the bracts and floral bracts of the male flowers persist on the rachis. The male bud is imbricated. Fruits have persitent style and stamins.

Mbidde

Mbidde means beer. The cultivars in this clone set can have characters of other clone sets but they all have in common that their pulp is bitter and astringent. The latex is plentiful and sticky, and the pseudostem is darker. Beer types are usually found at altitude.

REACTION TO PESTS AND DISEASES

EAHBs are generally susceptible to black leaf streak, nematodes, streak disease and banana weevils. Like all cultivars, they are susceptible to Xanthomonas wilt and bunchy top.

They are generally resistant to the race 1 and 2 strains that cause Fusarium wilt, whereas preliminary results suggest that they might be resistant to TR4.

BREEDING

In the 1990s, the National Agricultural Research Organization (NARO) of Uganda and the International Institute of Tropical Agriculture (IITA) started collaborating on the development of high-yielding and disease-resistant hybrids named after them: the NARITA hybrids.

REFERENCES

1. A basic grammar of Luganda

2. Shepherd, K. 1957. Banana cultivars in East Africa. Trop. Agric. 34:277-286.

3. Karamura D. A. 1999. Numerical taxonomic studies of the East African highland banana (Musa AAA-East Africa) in Uganda. PhD thesis from the University of Reading published by INIBAP, Montpellier, France. 192p.

4. Tanzania Musa: expedition 2001 by E. de Langhe, D. Karamura and A. Mbwana

5. Lejju, B.J., Taylor, D. and Robertshaw, P. 2005. Late-Holocene environmental variability at Munsa archaeological site, Uganda: a multicore, multiproxy approach. Holocene 15(7):1044-1061.

6. Lejju, B.J., Robertshaw, P. and Taylor, D. 2006. Africa's earliest bananas?. Journal of Archaeological Science 33(1):102-113.

7. Neumann, K. and Hildebrandt, E. 2009. Early bananas in Africa: the state of the art. Ethnobotany Research and Applications 7:353-362.

FURTHER READING

Banana cultivar names, synonyms and their usage in East Africa (PDF, 8MB)

Reconciling modernity and tradition to conserve diversity in the 2004 INIBAP Annual Report

THE NARITA HYBRIDS

NARITA hybrids are high-yielding and disease-resistant hybrids that are related to a group of cooking and juice bananas called East African highland bananas (EAHB). They are the result of over 20 years of joint breeding efforts between the institutes after which they are named: the National Agricultural Research Organization (NARO) of Uganda and the International Institute of Tropical Agriculture (IITA)[1]. IITA initiated the collaboration with NARO in the 1990s using some of the banana hybrids it had developed at its Onne field station in Nigeria[2]. The NARITAs

were developed in Uganda, at the National Agricultural Research Laboratories Kawanda[3] and the IITA Sendusu research station.

BREEDING STRATEGY

The NARITAs are secondary triploid (3x) hybrids[4]. They were generally obtained by crossing a female fertile EAHB cultivar (3x)[5] with a diploid (2x) source of resistance, more often than not Calcutta 4, a genebank accession of the wild species MUSA ACUMINATA ssp. BURMANNICA which provided resistance to black leaf streak. The selected tetraploid (4x) hybrids resulting from that cross were then crossed with improved diploids (2x) to produce secondary triploids from which individual NARITA hybrids were selected.

The genebank accessions used in the crosses came from the NARO field collection in Kawanda and the IITA field collection in Sendusu, Uganda. Some of the improved diploids are the products of previous breeding efforts by IITA at its Onne field station in Nigeria (the 7197-2, 8075-7, 9128-3 and 9719-7 hybrids, which used to be preceded by TMBx, for tropical MUSA bananas[2]) and by FHIA (the Honduran Agricultural Research Foundation) at its La Lima field station in Honduras (the SH2095, SH2766, SH3142, SH3217 and SH3362 hybrids, with SH standing for selected hybrids[6]).

REFERENCES

1. IITA press release on NARITA hybrids (25 October 2013).

2. Vuylsteke, D., Ortiz, R. and Ferris, S. 1993. Genetic and agronomic improvement for sustainable production of plantain and banana in sub-saharan Africa. African Crop Science Journal 1(1):1-8.

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4. Pillay, M.et al. 2004. Conventional breeding strategies to enhance the sustainability of Musa biodiversity conservation for endemic cultivars. African Crop Science Journal, 12(1):59-65.

5. Ssebuliba, R. et al. 2006. Reproductive efficiency and breeding potential of East African highland (Musa AAA-EA) bananas. Field Crops Research 95(2-3):250-255.

6. Rowe, P.R. and Richardson, D.L. 1975. Breeding bananas for disease resistance, fruit quality and yield. Bulletin No. 2. Tropical Agriculture Research Services (SIATSA), La Lima, Honduras. 41p.

7. Tushemereirwe, W. et al. 2015. Performance of NARITA banana hybrids in the preliminary yield trial for three cycles in Uganda.

8. IITA press release on project to boost banana production in Uganda and Tanzania (23 October 2014).

9. IITA press release on the launch of the project to boost banana production in East and Central Africa (20 May 2015)

ALSO ON THIS WEBSITE

Browse photos of NARITA hybrids in Musarama

Articles on NARITA hybrids in Musalit

EXTERNAL LINKS

Official website of Uganda's National Agricultural Research Organization, NARO and its banana research program

PART B – THE TRIALS

TRIAL GROUP SET-UP

The new NARITA hybrid bananas will be evaluated in multi-locational field trials at five sites across Tanzania and Uganda (Table XXX). These sites were chosen near to important banana production zones in these countries, and will be fully characterized for agro-ecological conditions and presence of pests and diseases.

Table XXX. Locations of the five trials within the [NARITA evaluation] trial group.

Country	Region	District	Site	Site manager	Location (coordinates)	Altitude (masl)
Tanzania	Kilimanjaro	Moshi	TaCRI	ARI Horti-Tengeru		
	Kagera	Bukoba	Maruku	ARI-Maruku		
	Mbeya	Rungwe	Mitalula	ARI-Uyole		
Uganda	Central	Wakiso	Kawanda	NARO		
	Western	Mbarara	Mbarara	NARO		

Show on a map?

The five sites will have a **similar experimental set-up** and f**ollow standardized data collection protocols**, to ensure that results can be compared across locations.

The trials will be managed on-station by researchers, but follow as much as possible local crop management practices. The trial sites will be fully characterized: soil analysis will be done, pests and diseases present in the field will be diagnosed, and climatic data will be collected during the course of the trials.

GENOTYPES INCLUDED

In total, 27 **NARITA hybrids** are available for testing, however, NARITA 1, NARITA 3, NARITA 5 and NARITA 17 did not multiply well in tissue culture and are thus not included in any of the trials. In addition, NARITA 15, NARITA 19, NARITA 20, NARITA 25, NARITA 26 and NARITA 27 are missing in the trial sites in Uganda; and NARITA 16 and NARITA 24 are missing in the trial sites in Tanzania (Table XXX).

The performance of the NARITAs will be compared with that of popular **local checks**. Mbwazirume is the universal local check, included in all five trial sites. Additionally, Nakitembe and Kisansa are included as local checks in Mbarara and Kawanda; Enyoya in Maruku; and Ndizi Uganda in TaCRI and Mitalula.

The trials also include a number of **reference accessions** for host reaction to a number of pests and diseases. For black leaf streak, Pisang Ceylan is included as the resistant reference, while Gros Michel and Williams are included as the susceptible references. For Fusarium wilt, Pisang Ceylan and Gros Michel are the susceptible references for race 1, Cachaco is the susceptible reference for race 2, and Williams is the resistant reference for race 1. Williams is also the susceptible reference for nematodes.

See Annex XXX for the Musapedia cultivar pages of the genotypes included in the trial group.

Table XXX. Genotypes included in the five trial sites.

Genotype name	Genome group	Subgroup	Accession ID	Genotype ID	Genotype purpose	TaCRI	Maruku	Mitalula	Kawanda	Mbarara
NARITA 1	3x	EAHB		1	Test accession	X	X	X	X	X
NARITA 2	3x	EAHB		2	Test accession	✓	✓	✓	✓	✓
NARITA 3	3x	EAHB		3	Test accession	X	X	X	X	X
NARITA 4	3x	EAHB		4	Test accession	✓	✓	✓	✓	✓
NARITA 5	3x	EAHB		5	Test accession	X	X	X	X	X
NARITA 6	3x	EAHB		6	Test accession	✓	✓	✓	✓	✓
NARITA 7	3x	EAHB		7	Test accession	✓	✓	✓	✓	✓
NARITA 8	3x	EAHB		8	Test accession	✓	✓	✓	✓	✓
NARITA 9	3x	EAHB		9	Test accession	✓	✓	✓	✓	✓
NARITA 10	3x	EAHB		10	Test accession	✓	✓	✓	✓	✓
NARITA 11	3x	EAHB		11	Test accession	✓	✓	✓	✓	✓
NARITA 12	3x	EAHB		12	Test accession	✓	✓	✓	✓	✓
NARITA 13	3x	EAHB		13	Test accession	✓	✓	✓	✓	✓
NARITA 14	3x	EAHB		14	Test accession	✓	✓	✓	✓	✓
NARITA 15	3x	EAHB		15	Test accession	✓	✓	✓	X	X
NARITA 16	3x	EAHB		16	Test accession	X	X	X	✓	✓
NARITA 17	3x	EAHB		17	Test accession	X	X	X	X	X
NARITA 18	3x	EAHB		18	Test accession	✓	✓	✓	✓	✓
NARITA 19	3x	EAHB		19	Test accession	✓	✓	✓	X	X
NARITA 20	3x			20	Test accession	✓	✓	✓	X	X
NARITA 21	3x			21	Test accession	✓	✓	✓	✓	✓
NARITA 22	3x			22	Test accession	✓	✓	✓	✓	✓

NARITA 23	3x			23	Test accession	✓	✓	✓	✓	✓
NARITA 24	3x			24	Test accession	X	X	X	✓	✓
NARITA 25	3x			25	Test accession	✓	✓	✓	X	X
NARITA 26	3x			26	Test accession	✓	✓	✓	X	X
NARITA 27	3x			27	Test accession	✓	✓	✓	X	X
Mbwazirume	AAA			29	Universal local check	✓	✓	✓	✓	✓
Kisansa	AAA			30	Local check	X	X	X	✓	✓
Enyoya	AAA			30	Local check	X	✓	X	X	X
Ndizi Uganda	AAA			30	Local check	✓	X	✓	X	X
Nakitembe	AAA	EAHB		35	Local check	X	X	X	✓	✓
Pisang Ceylan	AAB	Mysore		31	Reference accession resistant to BLS; susceptible to Foc R1	X	X	X	✓	✓
Cachaco	ABB	Bluggoe		32	Reference accession susceptible to Foc R2	✓	✓	✓	✓	✓
Gros Michel	AAA	Gros Michel		33	Reference accession susceptible to BLS; susceptible to Foc R1	✓	✓	✓	✓	✓
Williams	AAA	Cavendish		34	Reference accession susceptible to BLS; resistant to Foc R1; susceptible to nematodes	✓	✓	✓	✓	✓
Williams	AAA	Cavendish		34b	Border row	✓	✓	✓	✓	✓

TRIAL DESIGN AND PLANT LABELLING

The trials follow a **randomized complete block design**, with 4 blocks, and 12 mats per genotype per block.

Each mat in the trial will receive a **unique code**, that allows to unambiguously identify the mat in the trial and follow its development over time. The unique code consists of:

- the trial site name: i.e. TaCRI, Maruku, Mitalula, Kawanda or Mbarara;

followed by:

- the spatial position ID: this is made up of the block ID, the row ID and the column ID (Fig. XXX and XXX);

followed by:

- the genotype ID: see Table XXX for the genotype IDs;

followed by:

- the mat ID: this will always be 1, even across the different crop cycles, unless the whole mat needs to be uprooted, in which case the replanted mat receives mat ID 2.

For example, the unique code "Kawanda_1C11_25_1" refers to the first mat of the genotype NARITA 25 that can be found in block 1, row C, column 11 of the Kawanda trial site.

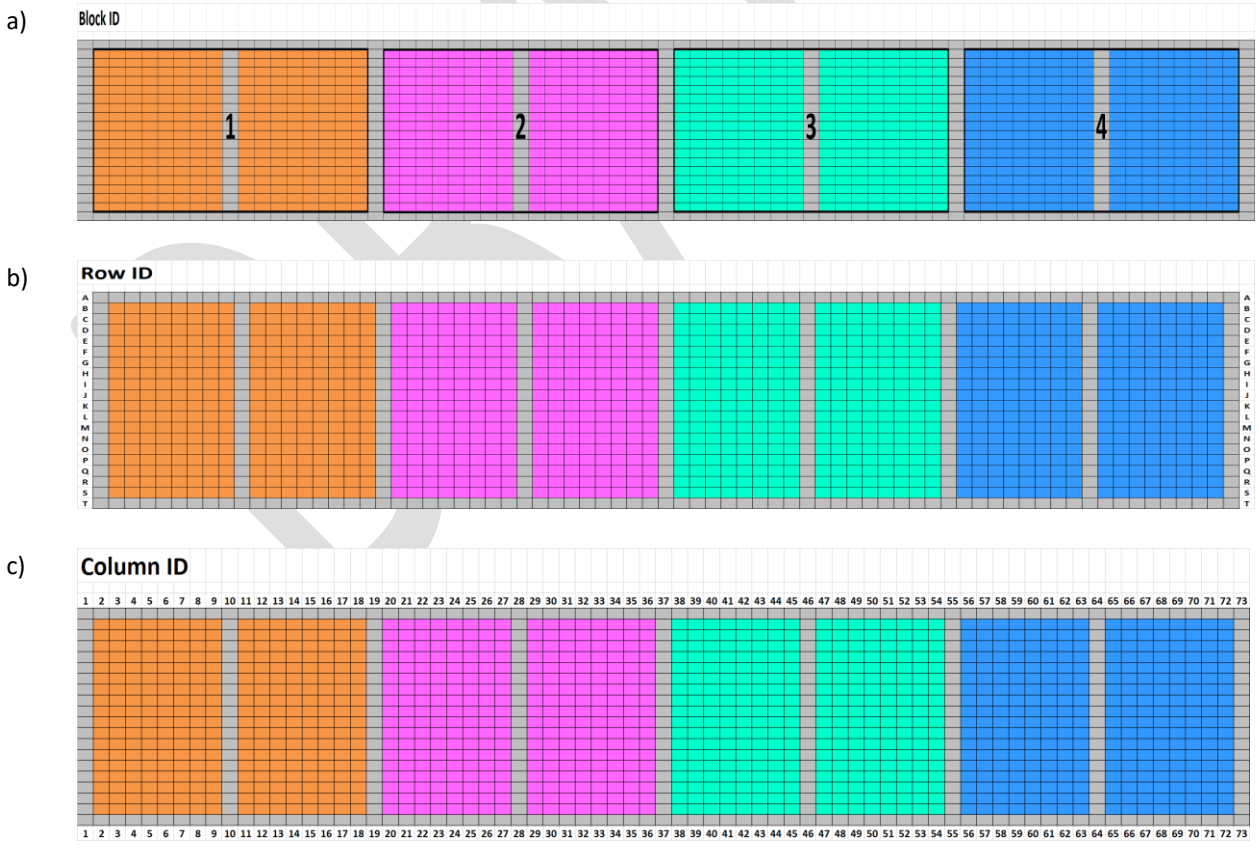
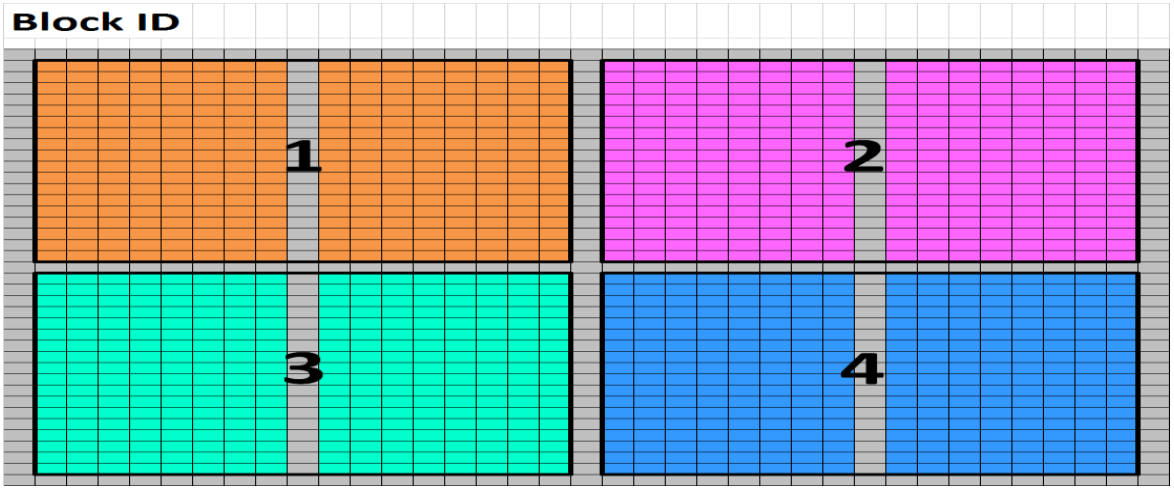
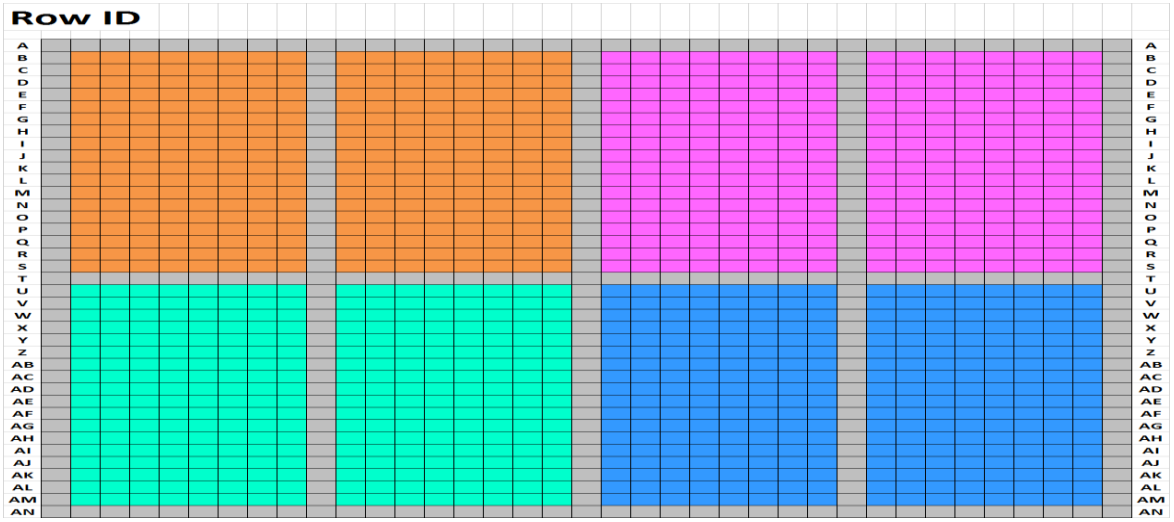


Fig. XXX. a) Block ID, b) row ID, and c) column ID, for the two sites in Uganda.

a)



b)



c)

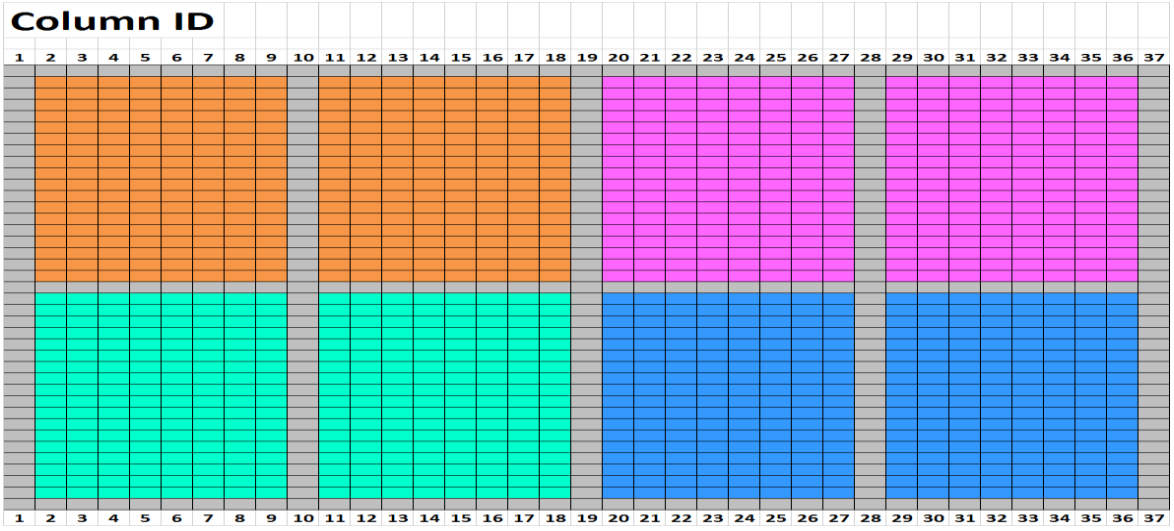


Fig. XXX. a) Block ID, b) row ID, and c) column ID, for the three sites in Tanzania.

The unique code, both in alpha-numerical and in QR code format, will be printed on a label that will be attached to a PVC stake and placed next to the respective plant (Picture XXX).

Picture XXX. Labels.

Each trial is surrounded by a row of border plants, and the four blocks are also separated from each other by a row of border plants. These border plants are not part of the trial, and no data are collected on them.

See Annex XXX for actual planting designs in the five trial sites.

PART C - DATA COLLECTION

Data on plant growth, host reaction to black leaf streak, Fusarium wilt, weevils, nematodes, Xanthomonas wilt and bunchy top, and yield will be collected for each plant in the trial (except the border plants and the gap-filled plants), using standardized methods which are explained in this manual.

Some data will be collected on a monthly basis, starting 3 months after planting. Other data will be collected at shooting or at harvest. A detailed description of the variables to be measured at different stages is given below.

PRE-PLANTING AND PLANTING INFORMATION

- Planting material ordered from where
- Date of receipt of planting material
- Date of starting of plantlet hardening
- Date of field planting
- Other notes and observations on pre-planting and planting

MANAGEMENT PRACTICES

- Previous land use
- Irrigation (frequency, amount)
- Inorganic fertilizer (type, frequency, amount)
- Organic fertilizer (type, frequency, amount)
- Mulching (frequency, amount)
- Deleafing (frequency, method)
- Sucker management (frequency, method)
- Weeding (frequency, method)
- Disease control (pathogen, frequency, method)
- Pest control (pathogen, frequency, method)
- Other notes and observations on management practices

SOIL

- Soil type conditions during trial file (a file with data and information on measurements of soil characteristics related to the trial)

WEATHER

- Weather during trial file (a file with data on weather conditions during the trial)

VARIABLES TO BE MEASURED IN THE FIELD

Every session always starts with scanning the QR code of the plant you collect data from, and a description of the lifecycle stage or state of the plant.

The lifecycle stages are:

- monthly data collection
- at shooting
- at harvest
- after harvest

INSERT IMAGES OF SHOOTING AND HARVEST?

The state of the plant can be:

- off-type
- damaged
- toppled
- snapped
- broken
- dead

INSERT DRAWINGS/IMAGES OF TOPPLING, SNAPPING, BREAKING?

The variables to be measured are organized in modules.

AGRONOMIC MODULE

Number of functional leaves

On a monthly basis, at shooting and at harvest, count the number of functional leaves. A functional leaf has 50% or more of the leaf surface area as green, healthy, photosynthetic tissue. Consider all leaves between, and inclusive of, the newest leaf and the oldest standing leaf.

INSERT DRAWING FUNCTIONAL LEAF

Date of shooting

At shooting, record the approximate date that the inflorescence emerges from the pseudostem and is still in an erect position, and take a photo of the inflorescence at shooting

INSERT PHOTO OF INFLORESCENCE AT SHOOTING

Plant height

At shooting, measure the distance from the pseudostem base at the ground to the intersection of the petioles of the two youngest leaves (leaf ranks "1" and "2"), using a measuring pole or sliding ruler (cm).

INSERT DRAWING

Plant circumference

At shooting, measure the circumference of the pseudostem of the plant at 1 m from the ground and at 20 cm from the ground, using a tape measure (cm).

INSERT

Tallest sucker height

At shooting and at harvest, on the tallest sucker, measure the distance from the pseudostem base at the ground to the intersection of the petioles of the two youngest leaves (leaf ranks "1" and "2"), using a measuring pole or sliding ruler (cm).

Tallest sucker number of functional leaves

At shooting and at harvest, count the number of functional leaves of the tallest sucker. A functional leaf has 50% or more of the leaf surface area as green, healthy, photosynthetic tissue. Consider all leaves between, and inclusive of, the newest leaf and the oldest standing leaf.

Finger age grade

At harvest, measure the lateral diameter of a finger, from the left to the right side (not from the ventral to the dorsal side), at the widest point, using calipers (mm).

Bunch weight

Before harvest, take a photo of the mature bunch. Harvest the mature bunch by cutting the peduncle above the proximal hand and weigh the bunch, including the rachis, using scales (kg).

LEAF SPOTS MODULE

FUSARIUM WILT MODULE

XANTHOMONAS WILT MODULE

BUNCHY TOP MODULE

WEEVILS MODULE

NEMATODES MODULE

At shooting, collect all roots from a standard-size excavation of 20 x 20 x 20 cm extending outwards from the corm of the plant. Take only roots from the selected plant.

INSERT DRAWING

Dead and functional roots

Divide the collected roots into two categories: dead roots, functional roots. Dead roots are completely rotten or shriveled whereas functional roots show at least some healthy tissue. Count the number of roots in each category.

Select at random five functional primary roots, at least 10 cm long. Reduce the length of the five selected roots to 10 cm.

Root knot nematodes

Determine the presence/absence of root knot nematodes, observed externally as galls on the roots.

INSERT DRAWING ROOT GALLS

Slice through the roots length-wise.

Egg-laying females

Evaluate one half of each of the five roots for the presence/absence of egg-laying females of root knot nematodes.

INSERT DRAWING/PHOTO

Root necrosis

Evaluate one half of each of the five roots for the percentage of root cortex showing necrosis. The maximum root necrosis per root half can be 20%, giving a maximum root necrosis of 100% for the five halves together. Record the total root necrosis of the five roots.

INSERT DRAWING FOR ROOT NECROSIS

Sample collection

Place the five scored roots, plus some extra roots and a handful of soil, in a plastic bag. Close the bag and label it with the unique mat code. Store the sample in a cool box and transport it within 5 days to a laboratory for extraction of nematodes and determination of nematode species, stages and density.

SCHEDULE OF MEASUREMENTS

An overview of the different variables to be measured, the schedule of measurement and the equipment required is given in Table XXX.

NEEDS TO BE UPDATED WITH LATEST CHANGES

Table XXX. Schedule of data collection and equipment required.

Data module	Variable	Schedule of data collection					Equipment required
		Monthly from 3 months after planting	**At shooting**	**At harvest**	**After harvest**	**As required**	
Universal	Plant ID	✓	✓	✓	✓	✓	Camera of the tablet or a barcode scanner
Universal	What is the lifecycle stage or state of the plant	✓	✓	✓	✓	✓	None
Agronomic	Number of functional leaves	✓	✓	✓			None
[BLS]	Youngest leaf spotted	✓	✓	✓			None
BLS	Rank of oldest standing leaf	✓	✓	✓			None
BLS	Black Sigatoka disease severity	✓	✓	✓			None
Fusarium	Rating of external symptoms of Fusarium wilt	✓	✓	✓			None
Agronomic	Plant height		✓				Measuring stick
Agronomic	Plant circumference		✓				Tape measure
Agronomic	Tallest sucker height		✓	✓			Measuring stick
Agronomic	Finger age grade			✓			Calipers
Agronomic	Bunch weight			✓			Weighing scales
Agronomic	Number of hands in bunch			✓			None
Agronomic	Hand weight				✓		Weighing scales and basket
Agronomic	Number of fingers in hand				✓		None
Agronomic	Finger weight				✓		Weighing scales and basket
Agronomic	Finger external length				✓		Tape measure

Agronomic	Finger circumference				✓		Tape measure
Agronomic	Finger diameter				✓		Calipers
Agronomic	Pulp diameter				✓		Calipers
Agronomic	Peel thickness				✓		Calipers
Agronomic	Describe the plant and how it was recognised as off-type					✓	None
Agronomic	Describe the damage to the plant					✓	None
Agronomic	Cause of damage					✓	None
Agronomic	Describe the apparent cause of death to the plant [cause of death]					✓	None

PART D - MOBILE DATA SYSTEM

A mobile application will be used for data collection, to ensure uniform data collection and allow easy data compilation into a common database.

THE SECTION BELOW NEEDS TO BE CHECKED AGAINST THE LATEST UPDATES in the online tool.

Q1) PLANT ID

Scan the QR code of the plant you collect data from.

Q2) WHAT IS THE LIFECYCLE STAGE OR STATE OF THE PLANT?

Select one of the following options to describe the lifecycle stage or state of the plant.

Response

Select one option:

- monthly data collection
- at shooting
- at harvest
- after harvest
- off-type
- damaged
- dead

→ Q3) MONTHLY DATA COLLECTION VARIABLES

Q3.1) NUMBER OF FUNCTIONAL LEAVES

Count the number of functional leaves. A functional leaf has 50% or more of the leaf surface area as green, healthy, photosynthetic tissue. Consider all leaves between, and inclusive of, the newest leaf and the oldest standing leaf.

Response

Between 0-20 leaves.

Q3.2) YOUNGEST LEAF SPOTTED

Record the rank (order) of the youngest leaf spotted (the first fully unfurled leaf with at least 10 discrete, mature, necrotic lesions or one large necrotic area with 10 light-coloured dry centres), counting the rank by starting with the youngest completely unrolled leaf as "1" and moving downwards.

Response

Between leaf rank 1-20.

Q3.3) RANK OF OLDEST STANDING LEAF

Record the rank (order) of the oldest standing leaf (with an erect petiole), counting the rank by starting with the youngest completely unrolled leaf as "1" and moving downwards.

Response

Between leaf rank 1-20.

Q3.4) BLACK LEAF STREAK DISEASE SEVERITY

Visually observe and record the amount of the surface area of each standing leaf that is affected by black Sigatoka, using the categories.

Response

For each standing leaf, starting with the oldest and moving upwards to the youngest, select one option:

1. no symptoms
2. less than 1% of leaf with symptoms
3. 1-5% of leaf with symptoms
4. 6-15% of leaf with symptoms
5. 16-33% of leaf with symptoms
6. 34-50% of leaf with symptoms
7. 51-100% of leaf with symptoms
8. no leaf to score, or not a standing leaf

Q3.5) RATING OF EXTERNAL SYMPTOMS OF FUSARIUM WILT

Visually observe and record the extent of leaf yellowing and wilting caused by Fusarium wilt, using the categories.

Response

Select one option:

1. no visual leaf symptoms
2. 0-33% of older banana leaves turning yellow
3. 34-66% of older leaves turning yellow, with some hanging down the pseudostem
4. 67-100% of leaves turning yellow and necrotic, with leaves hanging down the pseudostem
5. plant dead, with brown leaves hanging down the pseudostem

Q3.6) TAKE A PHOTO OF THE EXTERNAL SYMPTOMS OF FUSARIUM WILT

Response

Take a photo.

→ Q4) AT SHOOTING DATA COLLECTION VARIABLES

Q4.1) DATE OF SHOOTING

Record the approximate date that the inflorescence emerges from the pseudostem and is still in an erect position.

Response

Record the approximate date.

Q4.2) TAKE A PHOTO OF THE INFLORESCENCE AT SHOOTING

Optional.

Response

Take a photo.

Q4.3) PLANT HEIGHT

Measure the distance from the pseudostem base at the ground to the intersection of the petioles of the two youngest leaves (leaf ranks "1" and "2"), using a measuring pole or sliding ruler (cm).

Response

Between 50-999 cm.

Q4.4) PLANT CIRCUMFERENCE

Measure the circumference of the pseudostem of the plant at 1 m from the ground, using a tape measure (cm).

Response

Between 20-300 cm.

Q4.5) TALLEST SUCKER HEIGHT

On the tallest sucker, measure the distance from the pseudostem base at the ground to the intersection of the petioles of the two youngest leaves (leaf ranks "1" and "2"), using a measuring pole or sliding ruler (cm).

Response

Between 50 - 999 cm.

Q4.6) NUMBER OF FUNCTIONAL LEAVES

Count the number of functional leaves. A functional leaf has 50% or more of the leaf surface area as green, healthy, photosynthetic tissue. Consider all leaves between, and inclusive of, the newest leaf and the oldest standing leaf.

Response

Between 0 (no functional leaves on the plant) – 20 leaves.

Q4.7) YOUNGEST LEAF SPOTTED

Record the rank (order) of the youngest leaf spotted (the first fully unfurled leaf with at least 10 discrete, mature, necrotic lesions or one large necrotic area with 10 light-coloured dry centres), counting the rank by starting with the youngest completely unrolled leaf as "1" and moving downwards.

Response

Between leaf rank 0 (no spotted leaves on the plant) – 20.

Q4.8) RANK OF OLDEST STANDING LEAF

Record the rank (order) of the oldest standing leaf (with an erect petiole), counting the rank by starting with the youngest completely unrolled leaf as "1" and moving downwards.

Response

Between leaf rank 0 (no standing leaves on the plant) – 20.

Q4.9) BLACK SIGATOKA DISEASE SEVERITY

Visually observe and record the amount of the surface area of each standing leaf that is affected by black Sigatoka, using the categories.

Response

For each standing leaf, starting with the oldest and moving upwards to the youngest, select one option:

1. no symptoms

2. less than 1% of leaf with symptoms
3. 1-5% of leaf with symptoms
4. 6-15% of leaf with symptoms
5. 16-33% of leaf with symptoms
6. 34-50% of leaf with symptoms
7. 51-100% of leaf with symptoms
8. no leaf to score, or not a standing leaf

Q4.10) RATING OF EXTERNAL SYMPTOMS OF FUSARIUM WILT

Visually observe and record the extent of leaf yellowing and wilting caused by Fusarium wilt, using the categories.

Response

Select one option:

1. no visual leaf symptoms
2. 0-33% of older banana leaves turning yellow
3. 34-66% of older leaves turning yellow, with some hanging down the pseudostem
4. 67-100% of leaves turning yellow and necrotic, with leaves hanging down the pseudostem
5. plant dead, with brown leaves hanging down the pseudostem

Q4.11) TAKE A PHOTO OF THE EXTERNAL SYMPTOMS OF FUSARIUM WILT

Response

Take a photo.

→ Q5) AT HARVEST DATA COLLECTION VARIABLES

Q5.1) TALLEST SUCKER HEIGHT

On the tallest sucker, measure the distance from the pseudostem base at the ground to the intersection of the petioles of the two youngest leaves (leaf ranks "1" and "2"), using a measuring pole or sliding ruler (cm).

Response

Between 50 - 999 cm.

Q5.2) NUMBER OF FUNCTIONAL LEAVES

Count the number of functional leaves - 50% or more of the leaf surface area as green, healthy, photosynthetic tissue. Consider all leaves between, and inclusive of, the newest leaf and the oldest standing leaf.

Response

Between 0 (no functional leaves on the plant) – 20 leaves.

Q5.3) YOUNGEST LEAF SPOTTED

Record the rank (order) of the youngest leaf spotted (the first fully unfurled leaf with at least 10 discrete, mature, necrotic lesions or one large necrotic area with 10 light-coloured dry centres), counting the rank by starting with the youngest completely unrolled leaf as "1" and moving downwards.

Response

Between leaf rank 0 (no spotted leaves on the plant) – 20.

Q5.4) RANK OF OLDEST STANDING LEAF

Record the rank (order) of the oldest standing leaf (with an erect petiole), counting the rank by starting with the youngest completely unrolled leaf as "1" and moving downwards.

Response

Between leaf rank 1-20.

Q5.5) BLACK LEAF STREAK DISEASE SEVERITY

Visually observe and record the amount of the surface area of each standing leaf that is affected by black Sigatoka, using the categories.

Response

For each standing leaf, starting with the oldest and moving upwards to the youngest, select one option:

1. no symptoms
2. less than 1% of leaf with symptoms
3. 1-5% of leaf with symptoms
4. 6-15% of leaf with symptoms
5. 16-33% of leaf with symptoms
6. 34-50% of leaf with symptoms
7. 51-100% of leaf with symptoms
8. no leaf to score, or not a standing leaf

Q5.6) RATING OF EXTERNAL SYMPTOMS OF FUSARIUM WILT

Visually observe and record the extent of leaf yellowing and wilting caused by Fusarium wilt, using the categories.

Response

Select one option:

1. no visual leaf symptoms
2. 0-33% of older banana leaves turning yellow
3. 34-66% of older leaves turning yellow, with some hanging down the pseudostem
4. 67-100% of leaves turning yellow and necrotic, with leaves hanging down the pseudostem
5. plant dead, with brown leaves hanging down the pseudostem

PHOTOS

Q5.7) TAKE A PHOTO OF THE EXTERNAL SYMPTOMS OF FUSARIUM WILT

Response

Take a photo.

Q5.8) FINGER AGE GRADE

Measure the lateral diameter of a finger, from the left to the right side (not from the ventral to the dorsal side), at the widest point, using calipers (mm).

Response

XXX

Q5.9) TAKE A PHOTO OF THE BUNCH BEFORE HARVEST

Response

Take a photo.

→ Q6) AFTER HARVEST DATA COLLECTION VARIABLES

Q6.1) BUNCH WEIGHT

Harvest the mature bunch by cutting the peduncle above the proximal hand and weigh the bunch, including the rachis, using scales (kg).

Response

XXX

Q6.2) NUMBER OF HANDS IN BUNCH

Count how many hands are in the bunch.

Response

XXX

Each hand data collection

Collect the following data for each hand in the bunch. Associate the data with the rank (order) of the hand in the bunch, starting with the hand at the proximal end (closest to the pseudostem) of the bunch as "1" and continuing to the hand at the most distal end (closest to the male bud).

For: **Each hand in the bunch, beginning with hand rank "1" and moving downwards.**

Q6.3) Hand weight

Cut the hand from the rachis and weight the hand using scales (kg).

Response

Q6.4) Number of fingers in hand

Count how many fingers are in the hand.

Response

Finger measurements from two hands data collection

Recommended to collect data from hand rank 2 or 3; and 7 or second-most distal hand.

Collect the data from three fingers in the middle section of the outer whorl of the hand.

Hand rank

Associate the data with the rank (order) of the hand in the bunch, starting with the hand at the proximal end (closest to the pseudostem) of the bunch as "1" and continuing to the hand at the most distal end (closest to the male bud).

For: **Finger measurements (1 of 3) from hand (1 of 2)**

Finger measurements (2 of 3) from hand (1 of 2)

Finger measurements (3 of 3) from hand (1 of 2)

Finger measurements (1 of 3) from hand (2 of 2)

Finger measurements (2 of 3) from hand (2 of 2)

Finger measurements (3 of 3) from hand (2 of 2)

Q6.5) Finger weight (g)

Weigh finger, using scales (g).

Response

Q6.6) Finger external length (mm)

Measure the length of the finger, along the external (dorsal) arc, excluding the pedicel and the fruit tip, using a tape measure (mm).

Response

Q6.7) Finger circumference (mm)

Measure the circumference of the finger at its widest point, using a tape measure (mm).

Response

Q6.8) Finger diameter (mm)

Measure the lateral diameter of the finger, from the left to the right side (not from the ventral to the dorsal side), at the widest point, using calipers (mm).

Response

Q6.9) Pulp diameter (mm)

Remove the peel of the finger and measure the lateral diameter of the fruit pulp, from the left to the right side (not from the ventral to the dorsal side), at the widest point, using calipers (mm).

Response

Q6.10) Peel thickness (mm)

Remove the peel of the finger and measure the thickness of the peel, using calipers (mm).

Response

→ Q7) OFF-TYPE DATA COLLECTION VARIABLES

Q7.1) DESCRIBE THE PLANT AND HOW IT WAS RECOGNISED AS ON OFF-TYPE

Response

Q7.2) TAKE A PHOTO OF THE PLANT AND THE PARTS THAT MADE IT RECOGNIZABLE AS AN OFF-TYPE

Optional.

Response

Q7.3) CONTINUE TO COLLECT DATA FROM THE PLANT?

Select 'yes' if the plant is shooting, flowering or ready to be harvested like a true-to-type plant. Select 'no' if the plant is not at one of these lifecycle stages like a true-to-type plant.

Response

select one option:

- yes
- no

Q7.4) AS WELL AS BEING AN OFF-TYPE, IS THE PLANT…

Select one of the following options to describe the lifecycle stage or state of the plant.

Response

Select one option:

- monthly data collection
- at shooting
- at harvest

→ Q8) DAMAGED DATA COLLECTION VARIABLES

Q8.1) DESCRIBE THE DAMAGE TO THE PLANT

Record which part(s) of the plant is damaged and describe how it is damaged.

Response

Q8.2) APPARENT CAUSE OF DAMAGE TO THE PLANT

Record the apparent cause(s) of the damage.

Response

Q8.3) TAKE A PHOTOGRAPH OF THE DAMAGE TO THE PLANT

Q8.4) CONTINUE TO COLLECT DATA FROM THE PLANT?

Select 'yes' if the plant is shooting, flowering or ready to be harvested like a true-to-type plant. Select 'no' if the plant is not at one of these lifecycle stages like a true-to-type plant.

Response

Select one option:

- yes
- no

Q8.5) AS WELL AS BEING DAMAGED, IS THE PLANT…

Select one of the following options to describe the lifecycle stage or state of the plant.

Response

Select one option:

- monthly data collection
- at shooting
- at harvest

→ Q9) DEAD DATA COLLECTION VARIABLES

Q9.1) APPARENT CAUSE OF DEATH TO THE PLANT

Record the apparent cause(s) of the death.

Response

Q9.2) TAKE A PHOTO OF THE DEAD PLANT

Response

Take a photo.

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REFERENCE DOCUMENTS AND BACKGROUND READING

For more information on the NARITA hybrids:

- Tushemereirwe, W., Batte, M., Nyine, M., Tumuhimbise, R., Barekye, A., Tendo, S., Talengera, D., Kubiriba, J., Lorenzen, J., Swennen, R. and Uwimana, B. 2015. Performance of NARITA banana hybrids in the preliminary yield trial for three cycles in Uganda. IITA, NARO, Uganda. 35p.
- Musapedia page on NARITA hybrids

ANNEXES

ANNEX 1 – XXXX

ANNEX 2 – XXXX

ACTUAL PLANTING DESIGNS

Paste planting design of 5 sites here

PNG files folder

Genotype info from ProMusa pages