PERFORMANCE OF NARITA BANANA HYBRIDS IN THE PRELIMINARY YIELD TRIAL FOR THREE CYCLES IN UGANDA

By

Tushemereirwe Wilberforce[1], Batte Michael[2], Nyine Moses[2], Tumuhimbise Robooni[1] *, Barekye Alex[1], Tendo Ssali[1], Talengera David[1], Kubiriba Jerome[1], Lorenzen Jim[4], Swennen Rony[3] * and Uwimana Brigitte[3]

[1] National Agricultural Research Organization (NARO)
P.O. Box 7065, Kampala, Uganda
[2] International Institute of Tropical Agriculture (IITA)
Sendusu, Uganda
[3] International Institute of Tropical Agriculture (IITA)
P.O. Box 10, Duluti, Arusha, Tanzania
[4] Bill & Melinda Gates Foundation, 500 5th Ave N. Seattle, WA 98102, USA

For correspondence: *rtumuhimbise@kari.go.ug and *r.swennen@cgiar.org

May 2015

Table of Contents

Executive Summary 2

1 Introduction 3

2 Materials and methods 4

3 Results 6

3.1 Performance of the NARITA hybrids for three cycles combined 6

3.2 Variation among traits for three cycles combined 7

3.3 Mean performance of NARITA hybrids averaged across three crop cycles 9

3.4 Estimates of better founder parent heterosis for hybrids and bunch yield for all the banana genotypes 11

3.5 Correlation among key agronomic and disease resistance traits across three cycles..13

3.6 Mean performance of NARITA hybrids in response to crop cycles 15

4 Discussion, conclusions and recommendations...23

5 Acknowledgements 24

6 References..24

Appendices 26

Appendix 1: Pedigree of NARITA hybrids evaluated for three crop cycles at IITA-Sendusu station, Uganda...26

Appendix 2a: Mean performance of NARITA hybrids for bunch weight, number of hands, number of fruit fingers, fruit finger circumference and fruit finger length across three crop cycles 28

Appendix 2b: Mean performance of NARITA hybrids for days to bunch maturity, plant height at flowering, plant girth at flowering, number of functional leaves at flowering (NFLF) and number of functional leaves at harvest across three crop cycles 29

Appendix 2c: Mean performance of NARITA hybrids for height of tallest sucker at flowering, height of tallest sucker at harvest, youngest leaf spotted at flowering and youngest leaf spotted at harvest across three crop cycles 30

Appendix 3: Pictures of NARITA banana hybrids and some of their progenitors 31

Executive Summary

Bananas (*Musa* spp.) are an indispensable part of life in Eastern Africa providing up to one fifth of total calorie consumption per capita. Unlike many staple crops, bananas deliver food throughout the year, making them an ideal crop for household incomes, food and nutrition security. However, banana yields are low due to several factors amongst others pests and diseases: weevils and nematodes, *Fusarium* wilt, bacterial wilt and black Sigatoka. There are many potential technology-based interventions for increasing banana yields but host plant resistance is the most appropriate and cost effective intervention given the current stage of development of banana systems in the region. Host-plant resistance also offers significant spill over benefits for human health and positive environmental impacts. Therefore, the Ugandan National Agricultural Research Organization (NARO) and the International Institute of Tropical Agriculture (IITA) jointly breed bananas largely for host-plant resistance to improve banana yields.

One of the most important current products of their joint banana breeding efforts is secondary triploid hybrids for food and juice herein referred to as NARITA hybrids. This name specifies the contribution of NARO and IITA.

An earlier report (NARITA report 1) presented the results of 25 NARITA hybrids for cycles 1 and 2 combined. The current report presents and discusses the results of the same 25 NARITA hybrids (18 for food and seven for juice) evaluated for three crop cycles at Sendusu in central Uganda and analyzed in combined and separate forms.

Results of individual NARITA hybrids within cycles showed high degree of variation for the traits assessed, implying a high potential for selection among the NARITA hybrids evaluated. For example, the bunch weight (BWT) of the individual NARITA hybrids ranged from as low as 5 kg for NARITA 19 to as high as 45 kg for NARITA 24 with a mean of 17.8 kg. Averaged across three cycles, BWT ranged from as low as 8.7 kg for NARITA 19 to as a high as 30.4 kg for NARITA 24. Ninety six per cent of the hybrids had a mean BWT greater than the mean of the local check (Mbwazirume) (11.0 kg). Similarly, NARITA hybrids were better than Mbwazirume for most of the other traits assessed. Eighty four per cent of the NARITA hybrids evaluated were better than the best founder parent (NFUUKA) for bunch yield (t ha^{-1}), indicative of the significant breeding progress made by NARO and IITA in this breeding program. This could be confirmed by the positive better founder parent heterosis for BWT recorded by all NARITA hybrids, with NARITA 17, NARITA 18, NARITA 7 (M9), NARITA 21 and NARITA 14 (all food type) exhibiting highest heterosis.

Results of combined analysis of variance (ANOVA) showed significant differences among the NARITA hybrids for all the 14 traits assessed including BWT. This indicated the potential for further selection and improvement of the NARITA hybrids for all the 14 traits. Additionally, results of combined ANOVA showed significant differences among three crop cycles for all the traits assessed except days to bunch maturity (DTM) and number of functional leaves at flowering (NFLF), indicating that the selection of banana hybrids could best be done at certain cycle numbers. The performance of NARITA hybrids for most traits was much higher at cycles 2 and 3 than at cycle 1 with the highest performance observed at cycle 3. However, the difference between cycle 2 and cycle 3 was not significantly different for most traits including BWT. The clear implication of this is that selection for banana hybrids should be done at cycle 2 to reduce costs involved in the management of trials since banana trials are always huge considering the size of bananas as well as spacing of 3 x 3 m or 2 x 3 m commonly used. Also, banana performance data analysis should not be based on a combined evaluation of cycle 1 and 2, as was previously done for NARITA report 1, but on an analysis of individual cycles, preferably cycle 2.

The limitation of single site and single line plots is acknowledged. Hence, NARITA hybrids will be evaluated in larger and replicated multi-location trials to ascertain their actual performance, adaptability and stability in comparison with the local EAHB cultivars. Nevertheless, based on these preliminary results, potential high yielding banana hybrids combining resistance to black Sigatoka and farmer-preferred quality traits exist within this NARITA population.

1 Introduction

The East and Central Africa (ECA) region has over 50% of its permanent crops' area under banana cultivation, which currently represents around half of the total area under banana cultivation across Africa (down from around 65% during the 1960s to 1990s). In recent years, ECA countries (Burundi, DR Congo, Kenya, Rwanda, Tanzania, and Uganda) annually produce 20.9 million tonnes (t) of bananas with a value of US$ 4.3 billion. Bananas are an indispensable part of life in this region providing up to one fifth of total calorie consumption per capita. The average daily per capita energy consumption from bananas in ECA is 147 kcal: 15-fold the global average and 6-fold the Africa average. Unlike many staple crops, bananas deliver food throughout the year. Cultivation of cooking bananas in Uganda and Tanzania is dominated by Matoke (AAA subgroup) and Mchare bananas (AA subgroup) that are cooked before consumption and represent a unique set of *Musa* germplasm only found in ECA. The perennial nature of banana coupled with an all-year-round fruiting character makes it an ideal crop for household food and income for the majority of smallholder farmers who grow the bulk of it.

Despite the benefits of banana, its production in the Great Lakes region has stagnated at 9.0 % of their yield potential. Pests (banana weevils and nematodes) and diseases (*Fusarium* wilt, bacterial wilt, and black Sigatoka) have been a substantial component of the problem and pose a particularly great threat to the future sustainability of banana production, with the potential of further destabilizing both food security and household incomes across this region. For example, the current banana yields in Uganda stand at 5-30 t ha^{-1} $year^{-1}$ and are further declining, compared to the potential yield of 70 t/ha/year (Asten et al., 2005; Barekye, 2009). Banana bunch weights at farm level have dropped from 60 kg to 10 kg, or even less (Barekye, 2009). The decline in banana yields has contributed to food shortages, thus putting consumers heavily dependent on banana at risk of food insecurity, particularly in areas where the crop is regarded as a staple food. Therefore, interventions focusing on producing higher yielding banana hybrids through development of host plant resistance to several pests and diseases are necessary.

In response to this thread, the National Agricultural Research Organization (NARO) and the International Institute of Tropical Agriculture (IITA) in Uganda jointly breed bananas. This involves several interploidy crosses to generate improved banana populations from which the best hybrids in terms of bunch yield, resistance to pests and diseases, and fruit quality traits are selected and evaluated for subsequent national release.

NARITA hybrids were developed by first crossing the triploid female fertile East African Highland Banana (EAHB-AAA) cultivars with a wild diploid (Calcutta 4, AA subgroup). The selected tetraploid hybrids were then crossed with improved diploids and the resulting secondary triploid hybrids were selected during the early evaluation trials and evaluated during the preliminary yield trials. Early evaluation consist of evaluating single plants among a large populations of hybrids, while a preliminary yield trial consist of evaluating a row of clonal hybrids. At each round of evaluation, selection was done focusing largely on yield, resistance to black Sigatoka, and orientation of bunches.

A recent report on NARITA performance dealt with data combining cycles 1 and 2 (Tushemereirwe et al., 2014). We report here the performance of the NARITAs for agronomic and disease resistance traits for each of the 3 cycles observed. This is to select the best hybrids for further breeding and multi-locational field testing in Uganda and Tanzania and identify the best cycle for selection.

2 Materials and methods

The 25 NARITA hybrids (Table 1) discussed in this report were developed by crossing cooking bananas of the East African highland banana (EAHB, AAA subgroup) and a wild diploid (Calcutta 4, AA subgroup). The full pedigree of the hybrids is provided (Appendix 1) and all are secondary triploids. Eighteen were selected for food and seven for juice.

Table 1: Twenty five secondary triploid NARITA hybrids planted in 2010 and evaluated for three cycles at IITA-Sendusu, Uganda

Serial Number	Hybrid† code	Usage	Mat units surviving till June 2014 (%)
1.	NARITA 23	Food	100
2.	NARITA 7 (M9)	Food	100
3.	NARITA 18	Food	90
4.	NARITA 8	Juice	100
5.	NARITA 4	Food	100
6.	NARITA 22	Food	100
7.	NARITA 14	Food	90
8.	NARITA 21	Juice	90
9.	NARITA 12	Food	90
10.	NARITA 10	Juice	80
11.	NARITA 11	Food	90
12.	NARITA 9	Juice	90
13.	NARITA 26	Food	90
14.	NARITA 15	Food	100
15.	NARITA 1	Food	100
16.	NARITA 13	Juice	80
17.	NARITA 24	Food	40
18.	NARITA 3	Juice	60
19.	NARITA 25	Food	60
20.	NARITA 20	Food	60
21.	NARITA 2	Food	70
22.	NARITA 17	Food	30
23.	NARITA 19	Food	80
24.	NARITA 16	Juice	40
25.	NARITA 5	Food	40

†NARITAs are ordered from the highest to the lowest bunch yield (t ha^{-1}) (see Table 5)

The trial was established at Sendusu, located in central Uganda at 32°36'E and 0°31'N, 1134 meters above sea level. Each hybrid was planted in the same field in one line represented by 10 plants. Hybrids were planted at different times in 2010 with subsequent gap fillings. The plots were given basic management practices (Tushemereirwe et al., 2003). At planting, 20 kg of well decomposed cow dung manure was applied in the planting hole of 0.5 m deep and 0.6 m wide. Plants were spaced 3 m between lines and 2 m between plants of the same line. Suckers were obtained from other trials at Sendusu-IITA station and subjected to hot water treatment before planting. Mulching was done every year and weeds were controlled by spraying agro-sate (Glyphosate). De-suckering was done at flowering of the mother plants to maintain the plant density and ensure that the number of bunch bearing plants was maintained at a level which reduces competition for water, light and nutrients; i.e. three plants (mother, daughter and granddaughter) were maintained. In cases where the number of suckers was more than what was required on a mat, they were uprooted for seed multiplication to establish other experiments and for indexing.

During the crop growth and at harvest, data were collected as described by Carlier et al. (2002), Orjeda (2000) and Barekye (2009) for three cycles on the following traits: bunch weight (BWT) (kg), number of hands (NH) and number of fruit fingers (NF) on a bunch, fruit finger length (FL) (cm), fruit finger circumference (FC) (cm), number of functional leaves at flowering (NFLF) and at harvest (NFLH), youngest leaf spotted at flowering (YLSF) and at harvest (YLSH), plant height at flowering (PH) (cm), plant girth at flowering (PG) (cm), height of tallest sucker at flowering (HTSF) (cm) and height of tallest sucker at harvest (HTSH) and days to bunch maturity (DTM). Flowering date was recorded as the date when the inflorescence was shooting. At the same date, PH was measured from the ground level to the point where the last leaf emerged from the pseudostem. Plant girth at flowering was determined as the circumference of the pseudostem of the flowering plant at 1 m above ground while NFLF was determined by direct counting. Youngest leaf spotted at flowering was determined by recording the leaf number with the first black Sigatoka symptoms counting from the youngest leaf towards to the oldest leaf. Height of tallest sucker at flowering was obtained by measuring the height of the tallest sucker from the ground level to a point where the last two leaves emerged from the pseudostem.

Harvesting was done when at least one fruit finger of the first hand on a bunch began to ripen and the date recorded. Days to bunch maturity were therefore recorded as the number of days between flowering and harvesting dates. Bunch weight was obtained by weighing the harvested bunch using a weighing scale. Number of hands on a bunch was obtained by counting the hands on a bunch, while the NF on a bunch was obtained by counting fruit fingers on a bunch. Finger length was obtained by measuring the length of one middle finger from each hand on a bunch and the average length calculated. Finger circumference was obtained by measuring the length around the middle finger of each hand on a bunch and the average circumference calculated. The NFLH was obtained by direct counting of the functional leaves. Youngest leaf spotted at harvest was determined by recording the leaf number of the first leaf showing black Sigatoka symptoms, counting from the youngest leaf moving towards to the oldest leaf. Height of tallest sucker at harvest was obtained by measuring the distance from the ground level to a point where the last two leaves emerged from the pseudostem. Bunch yield (kg ha^{-1}) was estimated from bunch weight (kg $plant^{-1}$) and percentage mat survival per genotype as:

$$\text{Bunch yield (t ha}^{-1}\text{)} = \frac{\text{Bunch weight (kg plant}^{-1}\text{)} \times \text{Number of plants ha}^{-1}\,[1] \times \text{\% Mat survival}}{1000}$$

Better founder parent heterosis (BFPH) for NARITA hybrids was calculated according to Chigeza et al. (2013) based on the EAHB genotypes that appeared in the pedigrees of NARITAs as follows:

$$\text{BFPH (\%)} = \frac{F_1 - \text{BFP}}{\text{BFP}} \times 100$$

BFP = mean of the better founder parent in the test cross (EAHBs).
F1 = NARITA hybrid performance

The data were collected for three cycles and subjected to analysis of variance using GenStat 14 (Payne et al., 2011). The means across three crop cycles were compared using the least significance differences (LSD) at 5% significance level.

Data analysis was performed using the following statistical model:

$$P_{ij} = \mu + G_i + C_j + GC_{ij} + e_{ij}$$

P_{ij} = phenotypic value of hybrid i harvested at crop cycle j; μ = population mean, G_i= effect of the i^{th} hybrid, C_j= effect of the j^{th} crop cycle; GC_{ij}= effect of the interaction between the i^{th} hybrid and the j^{th} crop cycle, e_{ij}= random error term associated with hybrid i at crop cycle j.

3 Results

3.1 Performance of the NARITA hybrids for three cycles combined

Of the 14 traits assessed during the three crop cycles, only one trait (HTSH) was negatively skewed (Table 2). There was high variation among the traits assessed. For example, BWT ranged from as low as 5.0 kg to as high as 45.0 kg with a mean of 18.5 kg. Number of hands ranged from 4.0 to 15.0 with a mean of 8.8 whereas NF ranged from 73.0 to 341.0 with a mean of 148.7. Days to bunch maturity, one of the key farmer-preferred traits, ranged from

[1] The number of plants ha^{-1} considering a spacing of 2 x 3 m is 1667.

as low as 84.0 to as high as 194.0 with a mean of 144.0. Youngest leaf spotted at flowering and at harvest ranged from 2.0 to 13.0 and 1.0 to 10.0 with means of 8.3 and 3.1, respectively. Fruit finger circumference ranged from 8.4 to 17.7 cm with a mean of 12.2 cm while FL ranged from 10 to 28 cm with a mean of 18.3 cm. The rest of the traits assessed similarly had high ranges. Coefficient of variation as a measure of the traits variation ranged from as low as 10.4 % for FC to as high as 60.1 for NFLH. Other traits with a relatively high CV compared to NFLH were YLSH and BWT.

Table 2: Summary statistics of 14 traits of 25 NARITA banana hybrids of three cycles combined

Traits	Minimum	Maximum	Mean	SD	CV (%)	Skew
BWT (kg)	5.0	45.0	18.5	7.1	40.2	1.0
NH	4.0	15.0	8.8	0.7	19.5	0.4
NF	73.0	341.0	148.7	41.9	28.9	0.7
FC (cm)	8.4	17.7	12.2	1.3	10.4	0.3
FL (cm)	10.0	28.0	18.3	2.8	15.5	0.1
DTM	84.0	194.0	144.0	30.9	21.5	5.4
PH (cm)	200.0	480.0	316.0	58.9	18.4	0.2
PG (cm)	30.0	86.0	51.7	9.4	18.7	0.5
NFLF	5.0	16.0	9.7	2.1	21.2	0.3
NFLH	0.0	10.0	4.2	2.4	60.1	0.1
HTSF (cm)	50.0	470.0	265.0	73.6	28.8	0.2
HTSH (cm)	70.0	480.0	305.5	63.9	21.2	-0.5
YLSF	2.0	13.0	8.3	2.0	24.9	0.1
YLSH	1.0	10.0	3.1	1.8	55.3	1.1

SD= standard deviation; CV (%)= coefficient of variation; BWT= bunch weight (kg); NH= number of hands; NF= number of fruit fingers; FC= fruit finger circumference (cm); FL= fruit finger length (cm); DTM= days to bunch maturity; PH= plant height at flowering (cm); PG= plant girth at flowering (cm); NFLF= number of functional leaves at flowering; NFLH= number of functional leaves at harvest; HTSF= height of tallest sucker at flowering (cm); HTSH= height of tallest sucker at harvest (cm); YLSF= youngest leaf spotted at flowering, YLSH= youngest leaf spotted at harvest.

3.2 Variation among traits for three cycles combined

Hybrids were significantly ($P<0.001$) different for all the traits assessed (Table 3). Crop cycles were significantly different for BWT, NH, NF, FC, FL, PH, PG, NFLH, HTSF, HTSH and YLSH ($P<0.001$); and YLSF($P<0.01$). Genotype by crop cycle interaction effect was significant for BWT, NF, FL, NFLF, YLSF and YLSH ($P<0.001$); FC, PG, NFLH ($P<0.01$); and NH, PH, HTSF and HTSH ($P<0.05$).

Table 3: Combined analysis of variance for 14 traits of 25 NARITA banana hybrids of three cycles combined

		Mean Squares						
Source of variation	**DF**	**BWT**	**NH**	**NF**	**FC**	**FL**	**DTM**	**PH**
Genotype (G)	24	297.9***	23.1***	10187.9***	11.2***	75.1***	3636.5***	15630.7***
Crop cycle (C)	2	1339.6***	48.6***	53184.4***	16.9***	64.7***	201.4	385146.4***
G x C	46	63.0***	2.2*	2312.2***	0.9**	6.2***	851.9	1325.3*
Residual	368	26.3	1.3	863.2	0.9	3.4	800.4	839.7
CV (%)		28.9	13.6	20.2	7.87	10.1	19.6	9.1
		Mean Squares						
Source of variation	**DF**	**PG**	**NFLF**	**NFLH**	**HTSF**	**HTSH**	**YLSF**	**YLSH**
Genotype (G)	24	478.0***	21.9***	37.4***	19571***	26773***	21.5***	15.6***
Crop cycle (C)	2	7403.9***	5.7	146.3***	367539***	37417***	15.9**	91.4***
G x C	46	44.8**	6.3***	4.9**	3859*	3662*	5.4***	3.5***
Residual	368	27.5	2.8	2.8	2696	2437	2.8	1.7
CV (%)		10.4	17.3	42.7	20.3	16.33	20.3	40.4

BWT= bunch weight (kg); NH= number of hands; NF= number of fruit fingers; FC= fruit finger circumference (cm); FL= fruit finger length (cm); DTM= days to bunch maturity; PH= plant height at flowering (cm); PG= plant girth at flowering (cm); NFLF= number of functional leaves at flowering; NFLH= number of functional leaves at harvest; HTSF= height of tallest sucker at flowering (cm); HTSH= height of tallest sucker at harvest (cm); YLSF= youngest leaf spotted at flowering, YLSH= youngest leaf spotted at harvest; CV (%)= coefficient of variation; *, **, *** significant at 0.05, 0.01, and 0.001 probability level, respectively.

3.3 Mean performance of NARITA hybrids averaged across three crop cycles

Bunch weight ranged from 8.7 kg for NARITA 19 to 30.4 kg for NARITA 24; with overall mean (18.5 kg) (Table 4). Ninety six per cent of the hybrids had a mean BWT greater than the local check, Mbwazirume (11.0 kg).

Number of hands on a bunch ranged from 5.9 for NARITA 19 to 11.6 for NARITA 24, with an overall mean (8.8). Ninety six per cent of the hybrids were better than Mbwazirume for this trait.

Number of fruit fingers ranged from 89.4 for NARITA 19 to 218.7 for NARITA 24, with an overall mean (148.7). Seventy six per cent of the hybrids were better than Mbwazirume for this trait.

Fruit finger circumference ranged from 10.9 cm for NARITA 2 and NARITA 16 to 13.5 cm for NARITA 7 and NARITA 23 with an overall mean of 12.2 cm. Twenty eight per cent of the hybrids were better than Mbwazirume for this trait.

Fruit finger length ranged from 14.1 cm for NARITA 19 to 22.9 cm for NARITA 16 with an overall mean of 18.3 cm. Ninety two per cent of the hybrids were better than Mbwazirume for this trait.

Days to bunch maturity mean ranged from as low as 119.2 days for NARITA 5 to as high as 182 days for NARITA 11, with an overall mean of 144.0 days. None of the hybrids was earlier than Mbwazirume in terms of maturity.

Plant height at flowering ranged from 263.1 cm for NARITA 19 to 372.5 cm for NARITA 26 with an overall mean of 330.0 cm. Sixty eight per cent of these hybrids had PH lower than for Mbwazirume (local check).

Plant girth at flowering ranged from 36.5 cm for NARITA 19 to 59.5 cm for NARITA 18, with an overall mean of 51.7 cm. Thirty six percent of the hybrids had PG greater than for the local check (Mbwazirume).

Number of functional leaves at flowering ranged from 7.9 for NARITA 13 to 12.5 for NARITA 5 with the overall mean of 9.7. Eighty eight per cent of the evaluated hybrids were better than the check cultivar (Mbwazirume) for NFLF.

Number of functional leaves at harvest ranged from 0.4 for NARITA 10 to 6.8 for NARITA 5 with the overall mean of 4.2. Sixty eight per cent of the evaluated hybrids were better than the check cultivar (Mbwazirume) for NFLH.

Height of tallest sucker at flowering ranged from 182.4 cm for NARITA 18 to 328.4 cm for NARITA 26 with the overall mean of 265.0 cm, whereas HTSH ranged from 136.0 cm similarly for NARITA 18 to 365.3 cm also for NARITA 26 with the overall mean of 305.5 cm.

Youngest leaf spotted at flowering was highest for NARITA 18 (10.4) and lowest for NARITA 10 (6.2). All the hybrids were better than Mbwazirume for the YLSF. Youngest leaf spotted at harvest was highest for NARITA 5 (5.1) and lowest for NARITA 13 (1.1).

Table 4: Mean performance of NARITA hybrids averaged across three crop cycles

HYBRIDS†	BWT	NH	NF	FC	FL	DTM	PH	PG	NFLF	NFLH	HTSF	HTSH	YLSF	YLSH
NARITA 23	22.7	11.2	178.9	13.5	16.0	131.3	341.2	57.9	10.5	5.5	255.8	310.7	9.2	4.4
NARITA 7 (M9)	21.3	8.7	143.2	13.5	18.6	123.9	355.6	56.8	10.2	4.4	270.9	318.2	8.4	3.1
NARITA 18	23.2	8.9	155.7	12.5	18.3	140.7	309.0	59.5	12.3	3.3	182.4	136.0	10.4	3.8
NARITA 8	20.8	8.5	143.8	12.8	19.1	136.6	362.4	58.2	9.6	3.8	298.4	346.3	8.3	3.4
NARITA 4	20.5	8.3	168.6	11.7	18.4	156.9	293.0	49.0	9.6	4.6	246.6	298.0	8.6	3.5
NARITA 22	19.7	7.9	134.5	12.5	20.7	144.6	319.3	51.2	10.8	5.6	266.3	321.2	9.1	4.0
NARITA 14	21.5	9.0	157.3	11.8	20.4	165.5	286.6	43.8	11.3	5.3	228.2	279.3	10.2	4.8
NARITA 21	20.7	9.6	154.7	13.1	18.3	158.1	311.1	50.7	10.9	4.7	276.4	349.0	9.1	3.5
NARITA 12	18.6	8.7	160.4	11.3	20.8	148.6	329.8	48.2	9.1	3.0	250.9	308.3	7.1	2.4
NARITA 10	19.8	9.2	181.9	11.9	17.7	157.5	302.7	53.3	8.1	0.4	250.2	298.3	6.2	1.2
NARITA 11	17.5	8.6	159.7	11.1	20.1	182.0	325.7	48.3	8.8	2.8	265.8	293.0	6.9	2.1
NARITA 9	16.8	7.6	118.9	13.0	20.6	167.1	286.6	49.5	9.5	1.9	228.0	265.5	7.4	2.0
NARITA 26	16.2	8.5	138.8	11.7	18.1	139.9	372.5	51.8	8.9	3.5	328.4	365.3	7.2	2.4
NARITA 15	13.6	7.8	118.4	12.1	17.0	134.9	301.8	46.3	9.2	2.9	231.4	290.5	7.4	2.3
NARITA 1	13.4	9.5	145.4	11.2	16.6	153.0	370.0	57.2	9.7	4.2	318.0	356.8	9.4	3.8
NARITA 13	15.7	8.6	133.4	11.9	18.5	145.3	295.6	44.8	7.9	1.4	240.1	242.8	6.4	1.1
NARITA 24	30.4	11.6	218.7	12.0	18.7	150.3	333.3	58.0	10.3	2.7	262.5	322.6	8.0	2.3
NARITA 3	19.4	7.8	129.9	12.4	21.7	147.4	304.8	47.4	9.5	6.1	229.3	275.2	8.7	4.9
NARITA 25	17.7	9.6	158.5	12.2	17.9	139.5	276.2	45.3	9.2	3.5	186.4	237.2	7.2	2.3
NARITA 20	15.9	9.5	159.7	11.6	16.1	150.6	300.9	51.8	10.5	4.1	246.5	330.3	8.6	2.8
NARITA 2	13.5	8.4	134.5	10.9	16.4	130.9	326.3	47.0	8.5	3.5	262.1	295.8	8.2	3.9
NARITA 17	25.0	10.9	189.0	13.0	18.2	150.8	312.1	53.0	10.0	4.8	187.5	298.0	8.1	3.2
NARITA 19	8.7	5.9	89.4	11.9	14.1	130.2	263.1	36.5	8.5	2.5	234.6	262.3	6.9	1.8
NARITA 16	16.1	6.6	113.5	10.9	22.9	133.1	282.9	48.9	8.0	2.8	219.1	277.1	6.8	2.3
NARITA 5	13.6	8.8	127.7	13.4	15.2	119.2	336.3	53.2	12.5	6.8	235.7	281.9	10.3	5.1
MEAN	**18.5**	**8.8**	**148.7**	**12.2**	**18.3**	**144.0**	**316.0**	**51.7**	**9.7**	**4.2**	**265.0**	**305.5**	**8.3**	**3.1**
$LSD_{0.05}$	**4.1**	**0.9**	**23.7**	**0.7**	**1.4**	**21.5**	**22.7**	**4.1**	**1.3**	**1.3**	**40.3**	**38**	**1.3**	**1.2**
MBWAZIRUME§	**11.0**	**6.5**	**130.2**	**12.5**	**15.2**	**115.0**	**273.9**	**52.8**	**8.4**	**2.9**	**-**	**-**	**4.0**	**-**

†NARITAs are ordered from the highest to the lowest based on bunch yield (t ha^{-1}) (see Table 5); BWT= bunch weight (kg); NH= number of hands; NF= number of fruit fingers; FC= fruit finger circumference (cm); FL= fruit finger length (cm); DTM= days to bunch maturity; PH= plant height at flowering (cm); PG= plant girth at flowering (cm); NFLF= number of functional leaves at flowering; NFLH= number of functional leaves at harvest; HTSF= height of tallest sucker at flowering (cm); HTSH= height of tallest sucker at harvest (cm); YLSF= youngest leaf spotted at flowering, YLSH= youngest leaf spotted at harvest; MBWAZIRUME§ = is a local check whose values were obtained from other experiments and were not included in any statistical analysis; $LSD_{0.05}$ = least significant difference at 5%.

3.4 Estimates of better founder parent heterosis for hybrids and bunch yield for all the banana genotypes

Estimates of better founder parent heterosis for the NARITA hybrids as well as bunch yield (t ha^{-1}) for all the test genotypes including the check cultivar (Mbwazirume) were performed (Table 5). The highest bunch yield (37.8 t ha^{-1}) among the hybrids was recorded by NARITA 23 and the lowest (9.1 t ha^{-1}) by NARITA 5. The highest heterosis (296.8%) was recorded by (NARITA 17) and the lowest (8.6%) by NARITA 19. For the founder parents, highest bunch yield (15.2 t ha^{-1}) was recorded by Nfuuka and the lowest (7.5 t ha^{-1}) by Entukura. Eighty four per cent of the NARITA hybrids were better than the best founder parent (Nfuuka) for bunch yield. The top five NARITA hybrids for heterosis (NARITA 17, NARITA 18, NARITA 7 (M9), NARITA 21 and NARITA 14) were all food type.

Table 5: Heterosis and bunch yield (t ha^{-1}) estimated from the bunch weight and percentage survival of banana mats evaluated across three crop cycles

HYBRIDS†	**Bunch weight (kg)**	**BFPH (%)**	**Mat units surviving till June 2014 (%)**	**Yield (t ha^{-1})**
NARITA 23	22.7	149.5	100	37.8
NARITA 7 (M9)	21.3	166.5	100	35.5
NARITA 18	23.2	169.8	90	34.8
NARITA 8	20.8	141.9	100	34.7
NARITA 4	20.5	138.4	100	34.2
NARITA 22	19.7	129.1	100	32.8
NARITA 14	21.5	150.0	90	32.3
NARITA 21	20.7	158.8	90	31.1
NARITA 12	18.6	132.5	90	27.9
NARITA 10	19.8	130.2	80	26.4
NARITA 11	17.5	118.8	90	26.3
NARITA 9	16.8	95.3	90	25.2
NARITA 26	16.2	-	90	24.3
NARITA 15	13.6	58.1	100	22.7
NARITA 1	13.4	55.8	100	22.3
NARITA 13	15.7	96.3	80	20.9
NARITA 24	30.4	-	40	20.3
NARITA 3	19.4	125.6	60	19.6
NARITA 25	17.7	-	60	17.7
NARITA 20	15.9	91.6	60	15.9
NARITA 2	13.5	114.3	70	15.8
NARITA 17	25.0	296.8	30	12.5
NARITA 19	8.7	8.6	80	11.6
NARITA 16	16.1	87.2	40	10.7
NARITA 5	13.6	58.1	40	9.1
PARENTS‡				
NFUUKA	11.3		80.8	15.2
KAZIRAKWE	9.1		92.7	14.1
ENYERU	8.7		97.9	12.7
ENZIRABAHIMA	8.6		87.9	11.6
KABUCURAGYE	8.3		56.2	7.8
ENTUKURA	6.3		71.4	7.5
NAKAWERE	8.0		-	-
CHECK (MBWAZIRUME§)	**11.0**		**60.2**	**11.0**

Hybrids† = NARITA hybrids are ordered based on their respective yield performance (t ha^{-1}; highest to lowest); ‡ = East African Highland banana parental genotypes that appeared in the pedigree of NARITA hybrids and whose data were obtained from other experiments; East African Highland banana parental genotypes that appeared in the pedigree of NARITA; BFPH= better founder parent heterosis calculated based on the East African Highland banana genotypes that appeared in the pedigrees of NARITAs; MBWAZIRUME§ = local check, data obtained from other experiments.

3.5 Correlation among key agronomic and disease resistance traits across three cycles

Banana crop cycle was positively and significantly correlated with BWT, NH, NF, FC, FL, PH, PG, NFLH, HTSF, HTSH and YLSH (P<0.001); and YLSF (P<0.01) (Table 6). Bunch weight was positively and significantly (P<0.001) correlated with all the banana traits assessed. Of all these traits that were significantly correlated with BWT, NF followed by PG, NH and FL showed highest correlation. Days to bunch maturity was negatively and non-significantly correlated with most of the other traits, except NFLH and YLSH where the correlation was significant (P<0.01), as well as BWT and FL where the correlation was positive and significant (P<0.001). Days to bunch maturity was also positively and significantly (P<0.01) correlated with NF. Youngest leaf spotted at flowering was positively and significantly correlated BWT, FC, FL, PH, PG, NFLF and NFLH (P<0.001), and NH and crop cycle (P<0.01). Youngest leaf spotted at harvest on the other hand was positively and significantly correlated with crop cycle, BWT, FC, PH, PG, NFLF, NFLH, HTSF and YLSF (P<0.001); NH, NF and FL (P<0.01); and HTSH (P<0.05). Youngest leaf spotted at harvest also was negatively and significantly correlated with DTM (P<0.01).

Table 6: Correlation among 14 banana traits across three crop cycles

Traits	CCL	BWT	NH	NF	FC	FL	DTM	PH	PG	NFLF	NFLH	HTSF	HTSH	YLSF	YLSH
CCL	1.00														
BWT	0.27***	1.00													
NH	0.22***	0.54***	1.00												
NF	0.31***	0.64***	0.83***	1.00											
FC	0.19***	0.42***	0.09*	0.01	1.00										
FL	0.18***	0.52**	- 0.02	0.14***	0.32***	1.00									
DTM	- 0.04	0.15***	0.07	0.14**	- 0.03	0.19***	1.00								
PH	0.68***	0.36***	0.38***	0.39***	0.23***	0.23***	- 0.03	1.00							
PG	0.57***	0.56***	0.53***	0.53***	0.34***	0.27***	- 0.01	0.84***	1.00						
NFLF	0.03	0.31***	0.12***	0.08	0.35***	0.20***	- 0.01	0.09*	0.28***	1.00					
NFLH	0.34***	0.17***	0.17**	0.14**	0.24***	0.09*	- 0.13**	0.36***	0.34***	0.19***	1.00				
HTSF	0.52***	0.20***	0.19**	0.22**	0.14***	0.16***	- 0.01	0.73***	0.59***	- 0.02	0.25***	1.00			
HTSH	0.21***	0.21***	0.26***	0.26***	0.06	0.08	0.03	0.39***	0.39***	0.02	0.19***	0.41***	1.00		
YLSF	0.11**	0.27***	0.13**	0.07	0.29***	0.15***	- 0.01	0.17***	0.31***	0.86***	0.28***	0.07	0.07	1.00	
YLSH	0.32***	0.17***	0.15**	0.14**	0.18***	0.14**	- 0.13**	0.36***	0.37***	0.23***	0.88***	0.20***	0.12**	0.34***	1.00

CCL= crop cycle; BWT= bunch weight (kg); NH= number of hands; NF= number of fruit fingers; FC= fruit finger circumference (cm); FL= fruit finger length (cm); DTM= days to bunch maturity; PH= plant height at flowering (cm); PG= plant girth at flowering (cm); NFLF= number of functional leaves at flowering; NFLH= number of functional leaves at harvest; HTSF= height of tallest sucker at flowering (cm); HTSH= height of tallest sucker at harvest (cm); YLSF= youngest leaf spotted at flowering, YLSH= youngest leaf spotted at harvest; *, **, *** significant at 0.05, 0.01, and 0.001 probability level, respectively.

3.6 Mean performance of NARITA hybrids in response to crop cycles

Mean performance of NARITA hybrids for BWT, NH, NF, FC, FL, PH, PG, HTSF, HTSH, NFLH, YLSF and YLSH was significantly higher at cycle 2 and 3 than at cycle 1 (Table 7). There were no significant differences in mean performance of NARITA hybrids for DTM and NFLF across the crop cycles. It was interesting to note that for all the traits assessed cycle 1 was far much worse than cycle 2 and 3 and that there was not much to be gained to evaluate bananas up to cycle 3 as non-significant difference between cycle 2 and 3 were observed for most traits.

Table 7: Mean performance of NARITA hybrids per cycle

Traits	Cycle 1	Cycle 2	Cycle 3	Mean	$LSD_{0.05}$
BWT (kg)	15.7	19.8	20.1	18.5	1.3
NH	8.1	9.0	9.2	8.8	0.3
NF	127.3	156.6	162.1	148.7	7.7
FC (cm)	11.8	12.3	12.5	12.2	0.2
FL (cm)	17.5	18.4	18.9	18.3	0.5
DTM	144.9	144.7	142.5	144.0	6.8
PH (cm)	231.1	345.3	372.5	316.0	7.2
PG (cm)	43.7	53.7	57.8	51.7	1.3
NFLF (cm)	9.5	9.9	9.7	9.7	0.4
NFLH (cm)	3.1	4.2	5.2	4.2	0.4
HTSF	208.6	288.4	298.0	265.0	12.9
HTSH	287.3	310.9	318.4	305.5	12.4
YLSF	7.9	8.4	8.5	8.3	0.4
YLSH	2.5	3.5	4.2	3.1	0.4

BWT= bunch weight (kg); NH= number of hands; NF= number of fruit fingers; FC= fruit finger circumference (cm); FL= fruit finger length (cm); DTM= days to bunch maturity; PH= plant height at flowering (cm); PG= plant girth at flowering (cm); NFLF= number of functional leaves at flowering; NFLH= number of functional leaves at harvest; HTSF= height of tallest sucker at flowering (cm); HTSH= height of tallest sucker at harvest (cm); YLSF= youngest leaf spotted at flowering, YLSH= youngest leaf spotted at harvest; $LSD_{0.05}$ = least significant difference at 5%.

In order to visually examine the performance of each NARITA hybrid for each trait at each crop cycle, histograms were drawn for each trait. The variation of individual traits for each NARITA for different crop cycle numbers, were presented (Figures 1-14). Generally, the performance of NARITA hybrids for almost all the traits was much higher at cycle 2 and 3 than at cycle 1. The difference between the results of crop cycles 2 and 3 for most traits including BWT was non-significantly different (Appendices 2a, 2b and 2c).

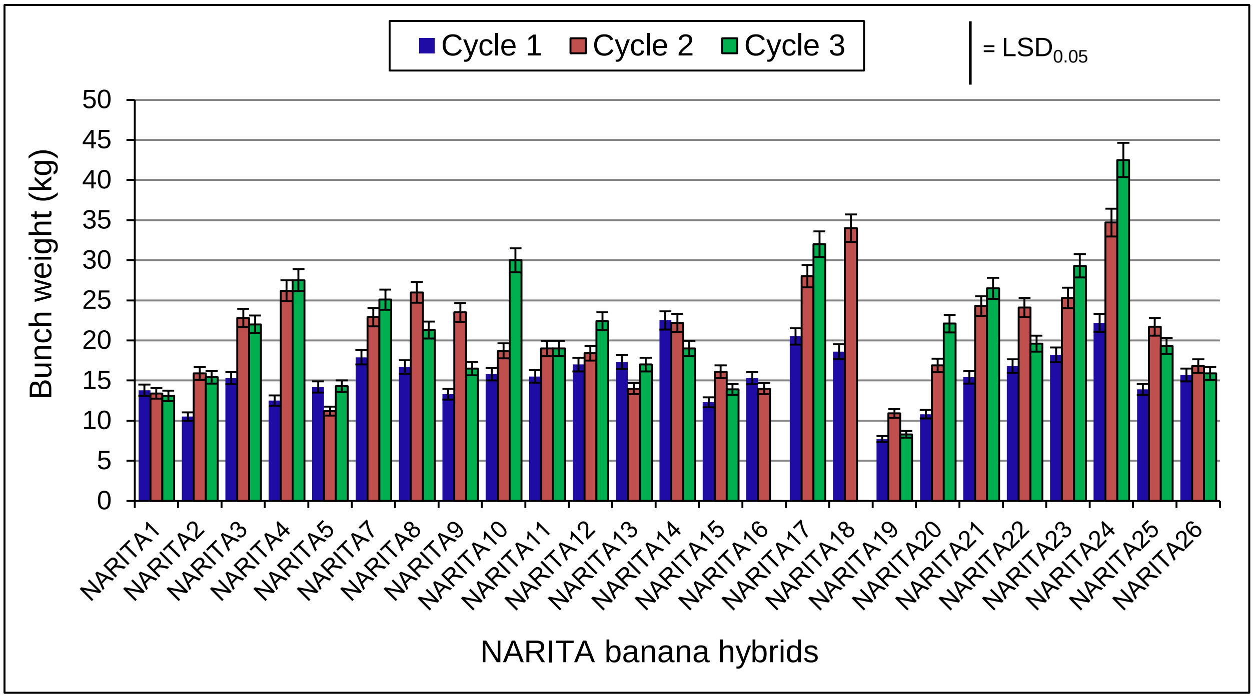


Figure 1: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycles for banana bunch weight (kg).

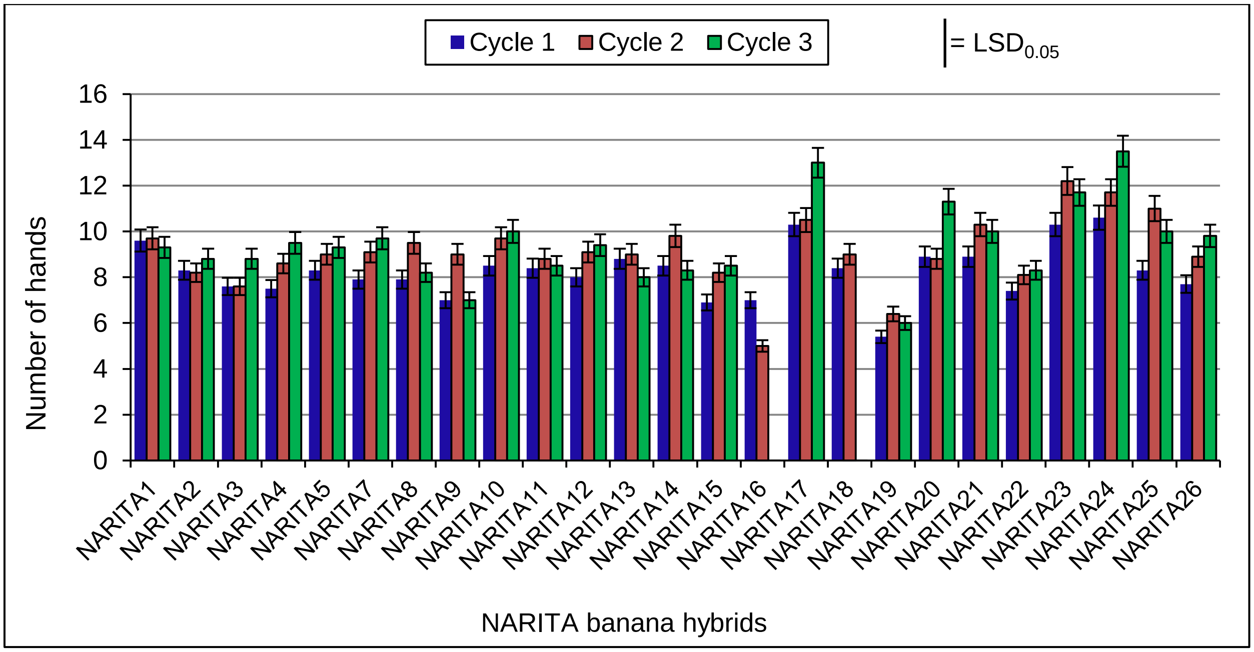


Figure 2: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycles for the number of hands on a bunch.

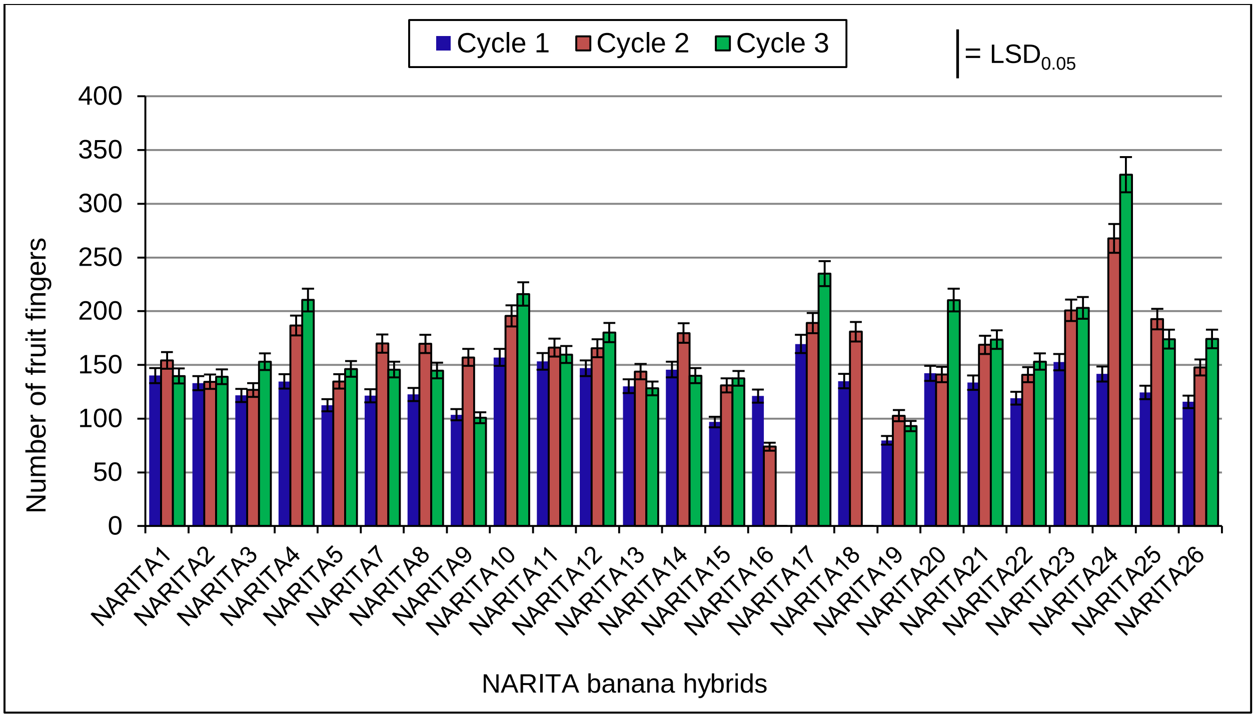


Figure 3: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for the number of fruit fingers per bunch.

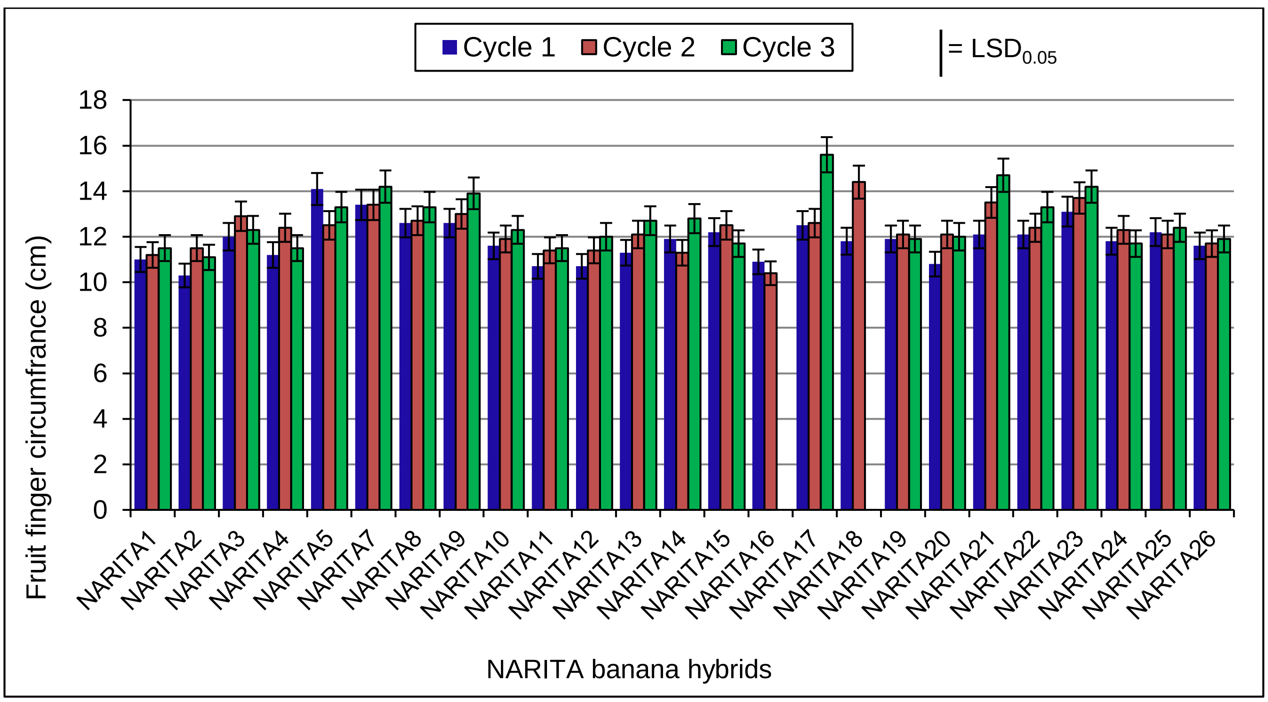


Figure 4: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for fruit finger circumference (cm).

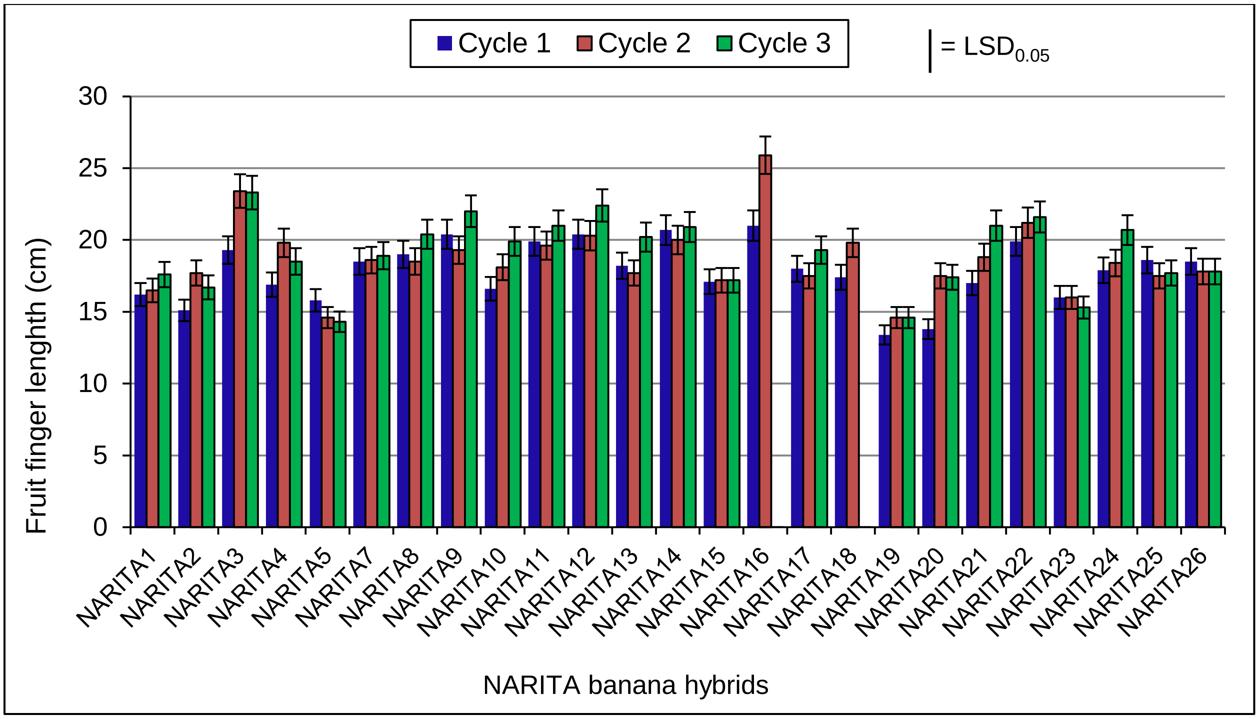


Figure 5: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for fruit finger length (cm).

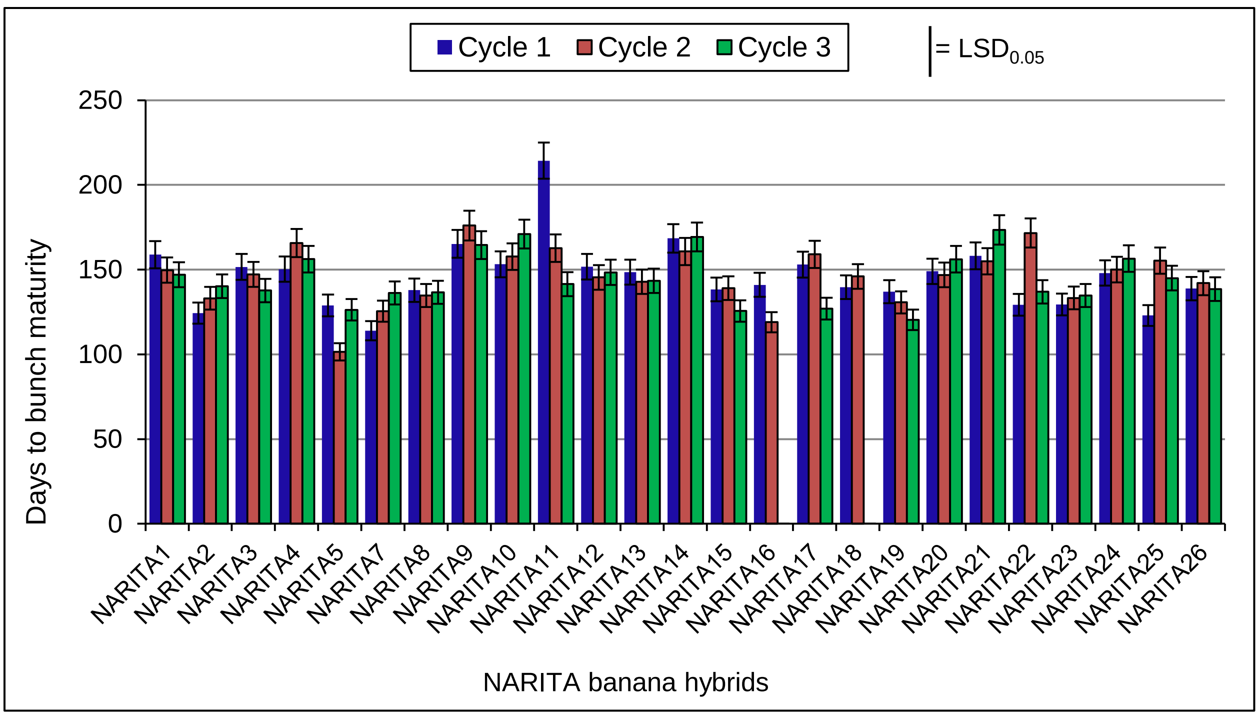


Figure 6: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycles for days to bunch maturity.

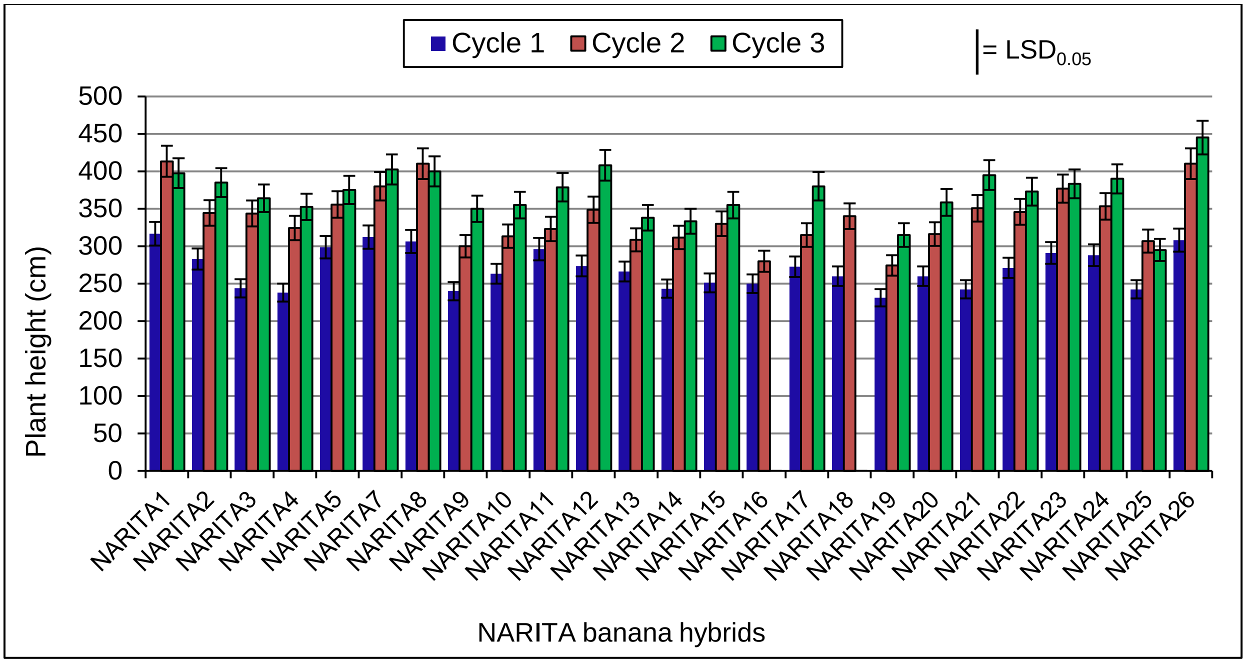


Figure 7: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for plant height (cm).

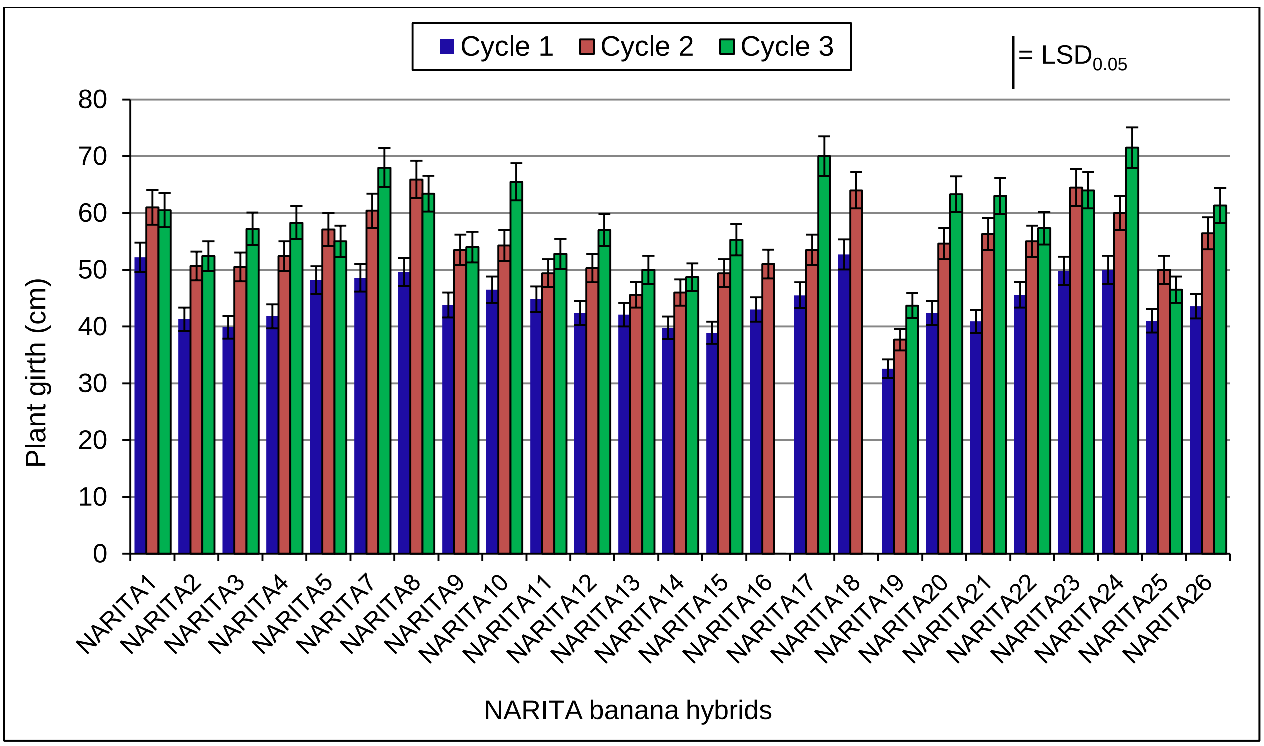


Figure 8: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for plant girth (cm).

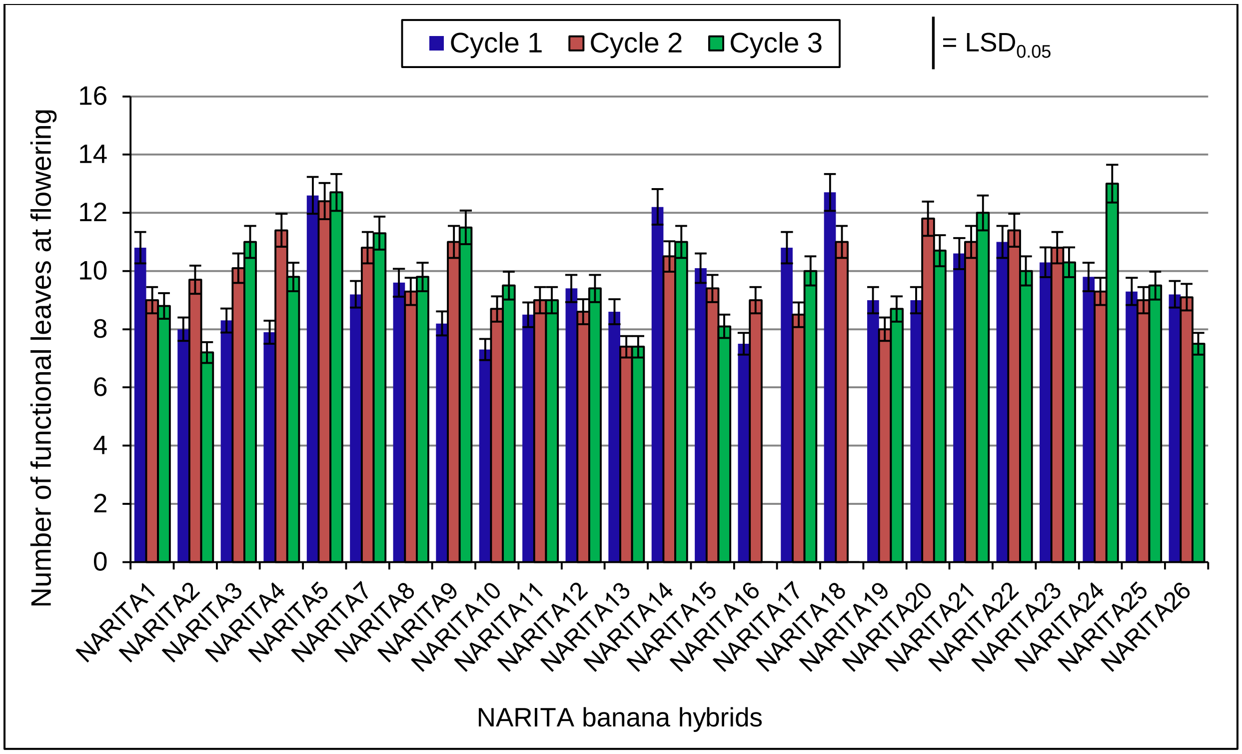


Figure 9: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for number of functional leaves at flowering.

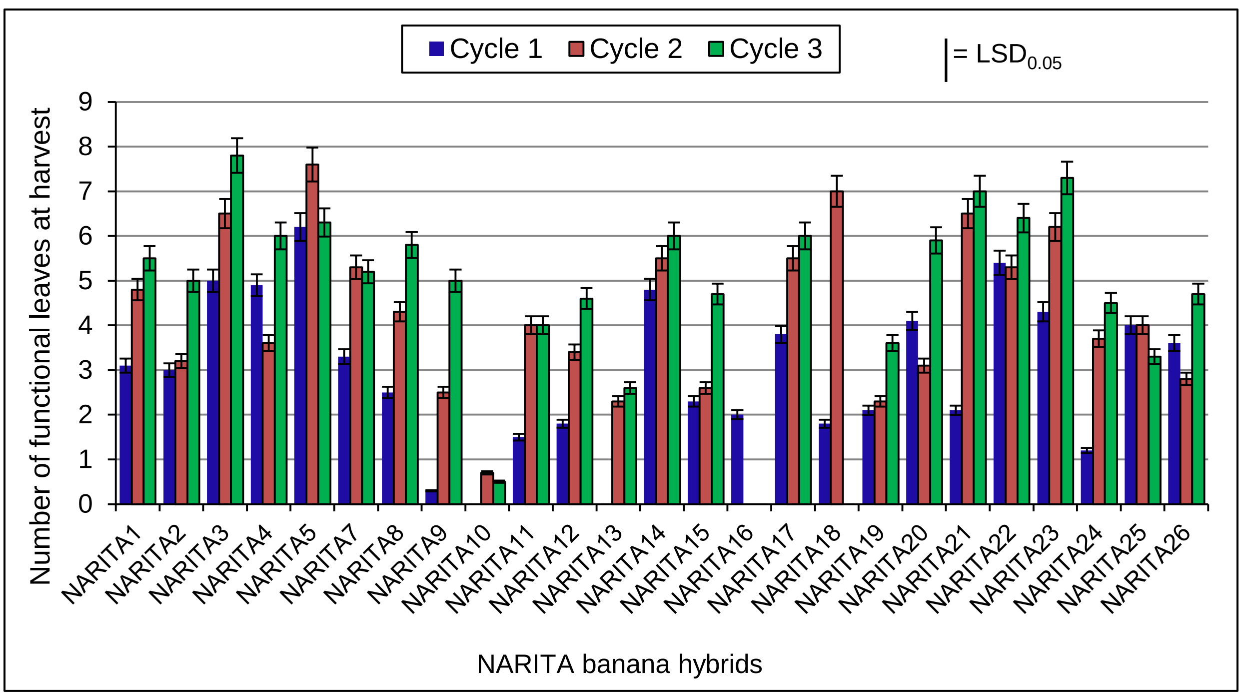


Figure 10: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for number of functional leaves at harvest.

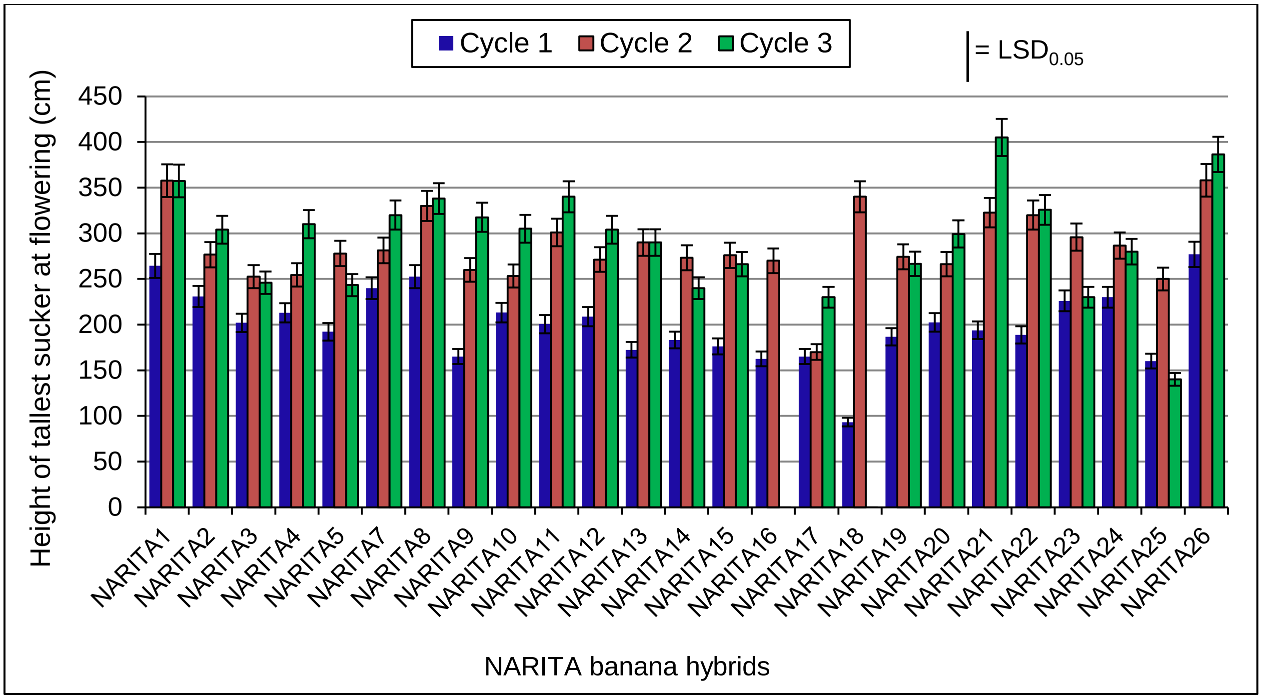


Figure 11: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for the height of tallest sucker at flowering.

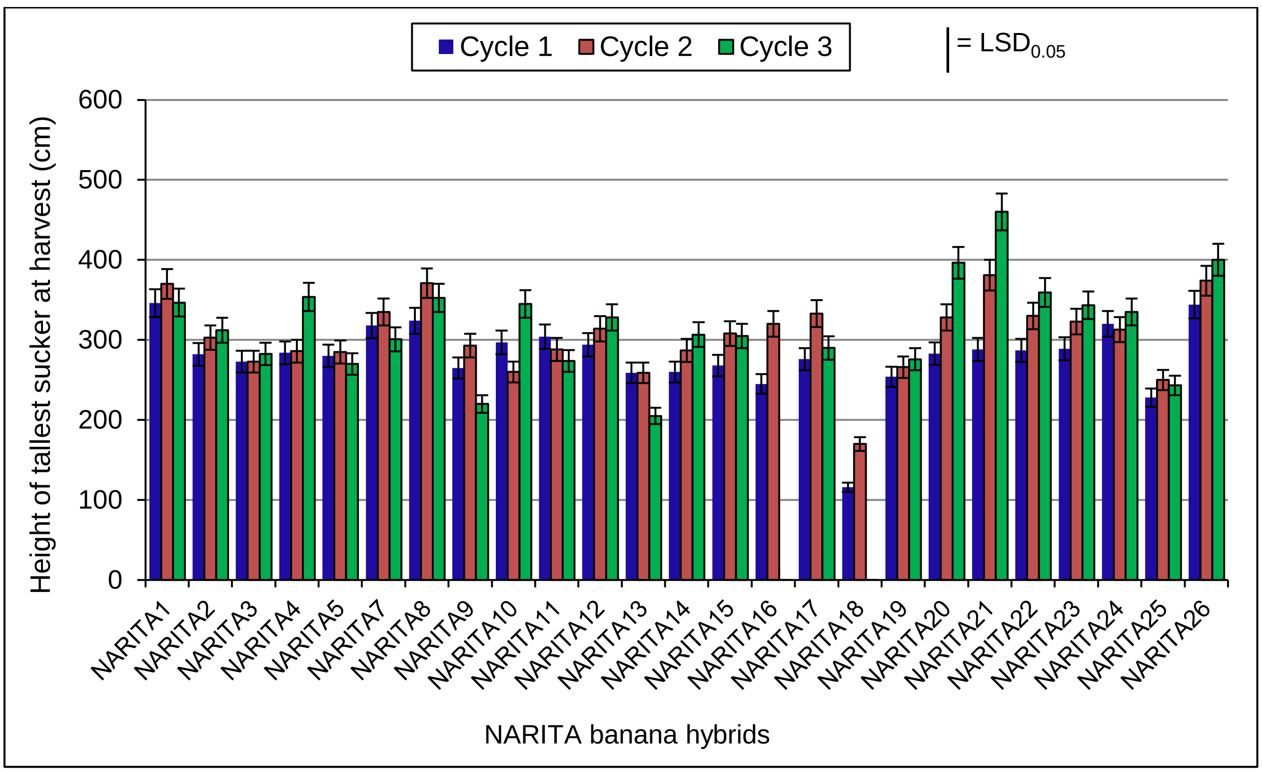


Figure 12: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for the height of tallest sucker at harvest.

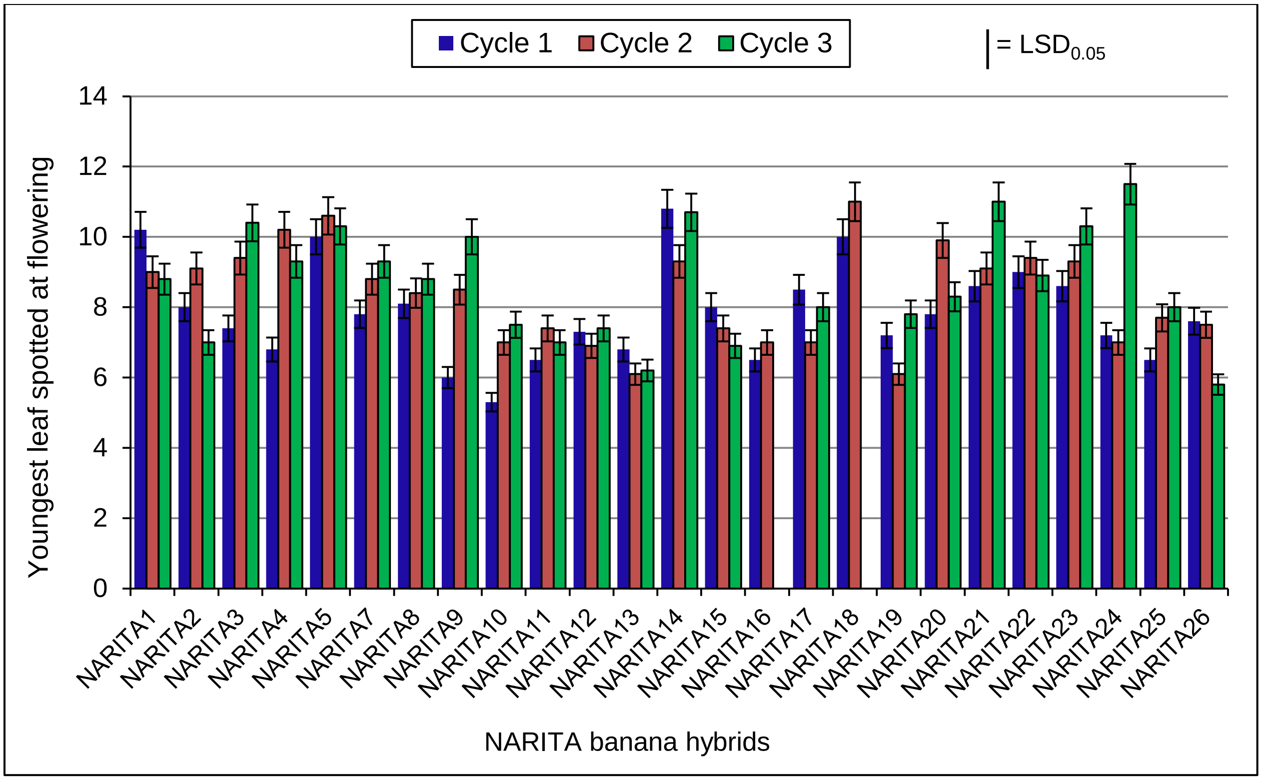


Figure 13: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for the youngest leaf spotted at flowering.

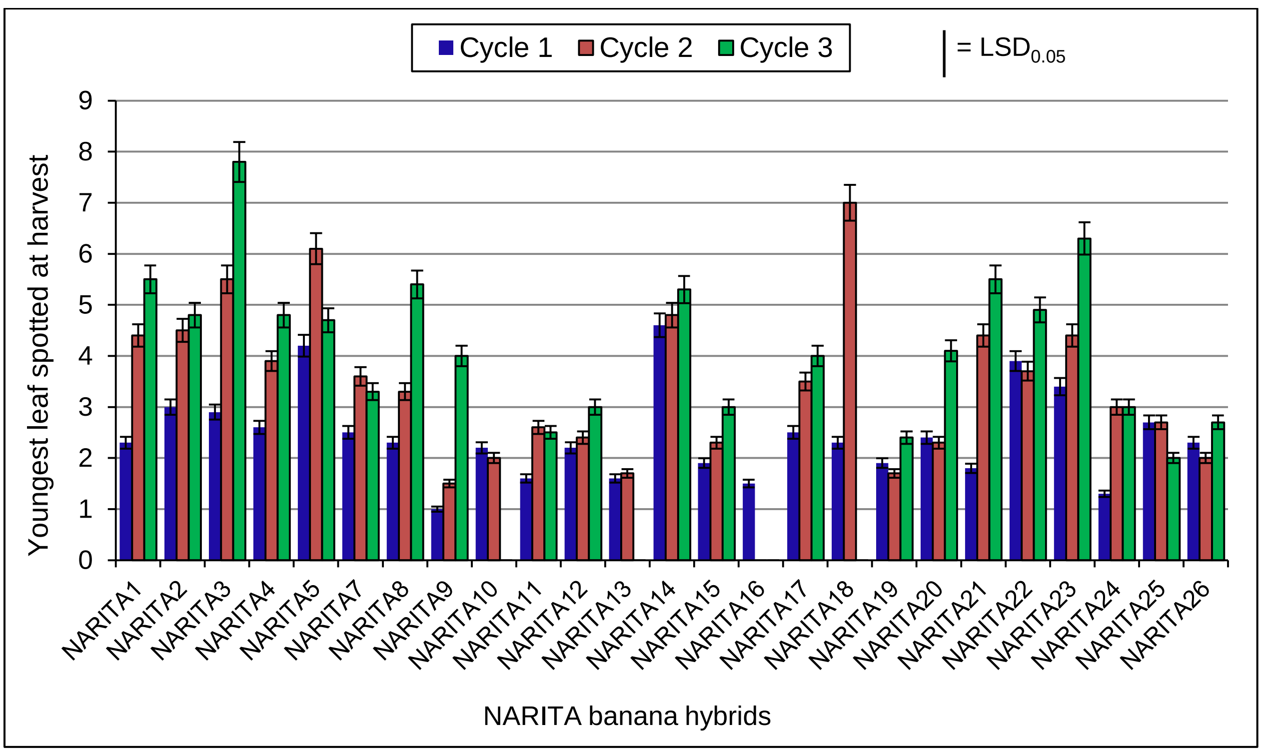


Figure 14: Mean performance of 25 NARITA hybrids evaluated at Sendusu-IITA station for three crop cycle for the youngest leaf spotted at harvest.

4 Discussion, conclusions and recommendations

The current report presents and discusses field performance of 25 of 27 NARITA banana hybrids evaluated over three cropping cycles at IITA-Sendusu station, Uganda. In the first section of this report, NARITA results were presented as averages of three cycles, while in the second section; results of NARITA hybrids were presented per cycle (Figure 1-14).

Results of individual NARITA hybrids within cycles showed high degree of variation for the traits assessed, implying a high potential for selection among the NARITA hybrids evaluated. The positive skewness for all the traits assessed (except HTSH) revealed that all the traits assessed (except HTSH) could be improved by conventional breeding.

Significant differences among the 25 NARITA hybrids for all the 14 traits assessed indicate the potential for selection and improvement of the test hybrids for all the traits, whereas significant differences among three crop cycles for most traits was a clear indication that selection for NARITA hybrids could best be done at a specific crop cycle.

Estimated yield of the 25 NARITA hybrids ranged from 9.1 to 37.8 t ha^{-1} while the yield of their EAHB parental genotypes ranged from 7.5 - 15.2 t ha^{-1}. Eighty per cent of the NARITA hybrids evaluated had mean BWT greater than 14.7 kg[2] and were also better than Mbwazirume (a local check), implying that significant breeding progress was made by NARO and IITA in developing NARITAs and that a majority of the hybrids qualified for selection for an advanced yield trial. The breeding progress made in this breeding program was also confirmed by the positive better founder parent heterosis recorded by all NARITAs for BWT. Similarly, for each of the 14 traits assessed a majority of the hybrids scored highly and were better than Mbwazirume and could be selected for advanced yield trials. Nevertheless, these NARITA hybrids need to be ranked based on consumer acceptability in combination with yield and growth behaviour.

Bunch weight, one of the most important traits breeders and farmers normally select for, was highly and positively correlated with all banana traits assessed. Hence all the non- bunch related traits assessed could be used to estimate yields when bunches are lost due to wind damage and theft. It was also observed that BWT, NH, NF, FC, FL, PH, PG, HTSF, HTSH, NFLH, YLSF and YLSH were significantly influenced by harvest cycle number. Indeed, cycle number results revealed that the performance of NARITA hybrids for most traits was much higher at cycles 2 and 3 than at cycle 1 with the highest performance observed at cycle 3. However, the difference between cycle 2 and cycle 3 results was non-significantly different for most traits including BWT, implying selection of hybrids for most traits could be done already at

[2] The cut-off bunch weight in this report is 14.7 kg. This is derived from 11.3 kg (maximum bunch weight for the EAHB cultivar (Nfuuka; Table 5) + (11.3 kg x 30%). Thirty per cent is the current desired NARO-IITA yield increase.

cycle 2. This also implied that banana performance data analysis should not be based on a combined evaluation of cycle 1 and 2, as was previously done for NARITA report 1, but on an analysis of individual cycle, preferably cycle 2. It is therefore recommended that selection for banana hybrids should always be done at cycle 2 to reduce costs involved in management of trials since banana trials are always huge considering the size of bananas as well as spacing of 3 x 3 m or 2 x 3 m commonly used.

The limitation of evaluating NARITA hybrids in non-replicated single line plots in one location is acknowledged. However these NARITAs will be further tested in replicated multi-environment trials to ascertain their actual performance, adaptability and stability in comparison with the local EAHB cultivars as checks. In the first report we presented results of two cycles, moreover averaged. In contrast this report provides results of three cycle numbers (both averaged and separated).

5 Acknowledgements

The authors of this report are grateful to the former NARO and IITA breeders, technicians and field assistants for their involvement in the development, evaluation and selection of NARITAs. They also greatly acknowledge the funding agencies whose funds were fundamental in the development of NARITA hybrids. Finally, thanks go to the Bill & Melinda Gates Foundation for the financial support to the banana breeding activities at IITA and NARO as part of the project 'Improvement of banana for smallholder farmers in the Great Lakes Region of Africa' (OPP1093845).

6 References

Asten, P.J., Gold, A.V.,Wendt, C.S., Waele, J., Okech, D.D., Ssali, S.H.O., and Tushemereirwe, W.K. 2005. The contribution of soil quality to yield and its relation with other banana yield loss factors in Uganda, Seeta, Uganda: International Plant Genetic Resources Institute, Montpellier. pp. 100-115.

Barekye, A. 2009. Breeding investigations for black Sigatoka resistance and associated traits in diploids, tetraploids and the triploid progenies of bananas in Uganda. PhD.Thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Carlier J., De Waele, D., and Escalant, J.V. 2002. Global evaluation of Musa germplasm for resistance to *Fusarium* wilt, *Mycosphaerella* leaf spot diseases and nematodes. (A.Vézina and C. Picq, eds). INIBAP Technical Guidelines 6. The International Network for the Improvement of Banana and Plantain, Montpellier, France.

Chigeza, G., Mashingaidze, K., and Shanahan, P. 2013. Advanced cycle pedigree breeding in sunflower. I: Genetic variability and testcross hybrid performance for seed yield and other agronomic traits. Euphytica 190:3-25.

Food and Agriculture Organisation (FAO). 2012. FAO food balance sheet. FAO, Rome. http://www.faostat.fao.org/ (accessed, 13/12/2014).

Heslop-Harrison, J.S. and Schwarzacher, T. 2007. Domestication, genomics and the future for banana. Annals of Botany 100:1073-1084.

IITA. 1998. Plantain and banana Improvement Program-Annual Report for 1997. International Institute of Tropical Agriculture, Onne, Nigeria.

Karamura, E., Frison, E., Karamura, D. and Sharrock, S. 1999. Banana Production Systems in Eastern and Southern Africa. In: Bananas and Food Security. International Symposium 10-14 November 1998 Cameroon in: Picq, C., Foure, E. and E.A. Frison (eds.). 401-412.

Lorenzen, J., Tenkouano, A., Bandyopadhyay, R., Vroh, B., Coyne, D. and Tripathi, L. 2010. Overview of Banana and Plantain (Musa spp.) Improvement in Africa: Past and Future. In, 2010. Acta Hort.

Orjeda, G. 2000. Evaluating bananas: a global partnership. Results of IMTP Phase II. International Network for the Improvement of Banana and Plantain. Montpellier, France.

Payne, R.W., Harding, S.A., Murray, D.A , Soutar, D.M., Baird, D.B., Glaser, A.I., Welham, S.J., Gilmour, A.R., Thompson, R., and Webster. R. 2011. The guide to genstat release 14, part 2: statistics. VSN International, Hemel Hempstead, UK.

Smale, M. 2006. Assessing the impact of crop genetic improvement in sub-Saharan Africa: Research context and highlights. In: Melinda, S., Edmeades, S., and De Groote (Eds.). Promising Crop biotechnologies for smallholder farmers in East Africa: Bananas and Maize. Genetic Resources Policies Briefs 19-2006.

Tripathi, L., Tripathi, J.N. and Tushemereirwe, W. K. 2010. Control of banana xanthomonas wilt disease using genetic engineering on banana andplantain in Africa. In, 2010. Acta Hort. 879.

Tushemerweirwe, W., Nankinga, C., Kasheija, I., and Tinzaara, W. 2003. Banana Production Mannual. Second Edition. NARO, Kawanda.

Tushemereirwe, W., M. Batte, M. Nyine, R. Tumuhimbise, A. Barekye, S. Tendo, J. Kubiriba, J. Lorenzen, and R. Swennen (2014). Performance of NARITA banana hybrids in the preliminary yield trial, Uganda. http://www.iita.org/2014-press-releases/-/asset_publisher/CxA7/content/preliminary-results-of-narita-hybrids-trials-show-high-yield-potential-to-increase-banana-production?redirect=%2FHome

Appendices

Appendix 1: Pedigree of NARITA hybrids evaluated for three crop cycles at IITA-Sendusu station, Uganda

Name	Hybrid code	Female parent	Male parent	Pedigrees for the female parents	Pedigrees for the male parents
NARITA 23	21086S-1	Kazirakwe	7197-2	Unknown	(SH3362 X Long Tavoy), SH3362 (SH3217 X SH3142), SH3217(SH2095 X SH2766), SH2095 [(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang JariBuaya)
NARITA 18	14539S-4	365K-1	660K-1	(Kabucuragye X Calcutta 4)	(Enzirabahima X Calcutta 4)
NARITA 7 (M9)	12419S-13	1201K-1	SH3217	(Nakawere X Calcutta 4)	(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)]
NARITA 22	19798S-2	917K-2	9128-3	(Enzirabahima X Calcutta 4)	(Tjau lagada X Pisang lilin)
NARITA 8	12468S-18	917K-2	SH3217	(Enzirabahima X Calcutta 4)	(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)]
NARITA 14	12949S-2	917K-2	7197-2	(Enzirabahima X Calcutta 4)	(SH3362 X Long Tavoy), SH3362 (SH3217 X SH3142), SH3217(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang JariBuaya)
NARITA 4	9187S-8	660K-1	9128-3	(Enzirabahima X Calcutta 4)	(Tjau Lagada X Pisang Lilin)
NARITA 21	17503S-3	1201K-1	7197-2	(Nakawere X Calcutta 4)	(SH3362 X Long Tavoy), SH3362 (SH3217 X SH3142), SH3217(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang JariBuaya)
NARITA 9	12468S-6	917K-2	SH3217	(Enzirabahima X Calcutta 4)	(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)]
NARITA 12	12479S-13	1201K-1	9128-3	(Nakawere X Calcutta 4)	(Tjau lagada X Pisang lilin)
NARITA 11	12479S-1	1201K-1	9128-3	(Nakawere X Calcutta 4)	(Tjau lagada X Pisang lilin)
NARITA 26	HJ	Unknown	Unknown	Unknown	Unknown
NARITA 15	13284S-1	660K-1	9128-3	(Enzirabahima X Calcutta 4)	(Tjau lagada X Pisang lilin)
NARITA 10	12477S-13	917K-2	SH3217	(Enzirabahima X Calcutta 4)	(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)]
NARITA 1	7798S-2	917K-2	9128-3	(Enzirabahima X Calcutta 4)	(Tjau Lagada X Pisang Lilin)
NARITA 13	12618S-1	1201K-1	SH3362	(Nakawere X Calcutta 4)	(SH3217 X SH3142), SH3217(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang JariBuaya)

NARITA 3	9494S-10	917K-2	SH3362	(Enzirabahima X Calcutta 4)	(SH3217 X SH3142), SH3217(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau Lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau Lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang Jari Buaya)
NARITA 25	HX	Unknown	Unknown	Unknown	Unknown
NARITA 24	HB	Unknown	Unknown	Unknown	Unknown
NARITA 2	9750S-13	401k-1	9128-3	(Entukura X Calcutta 4)	(Tjau Lagada X Pisang Lilin)
NARITA 20	16457S-2	Entukura	365K-1	Unknown	(Kabucuragye X Calcutta 4)
NARITA 19	16242S-1	1201K-1	8075-7	(Nakawere X Calcutta 4)	(SH3362 X Calcutta 4), SH3362 (SH3217 X SH3142), SH3217 (SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang JariBuaya).
NARITA 17	13573S-1	1438K-1	9719-7	(Entukura X Calcutta 4)	(madang X Calcutta 4)
NARITA 16	135225S-5	917K-2	SH3362	(Enzirabahima X Calcutta 4)	(SH3217 X SH3142), SH3217(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang JariBuaya)
NARITA 5	8386S-19	917K-2	SH3217	(Enzirabahima X Calcutta 4)	(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau Lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau Lagada X (wild malaccensis X Guyod)]
NARITA 6	11274S-3	222K-1	9128-3	(Nfuuka X Calcutta 4)	(Tjau Lagada X Pisang Lilin)
NARITA 27	9518S-12	222K-1	SH 3362	(Nfuuka X Calcutta 4)	(SH3217 X SH3142), SH3217(SH2095 X SH2766), SH2095[(Sinwobogi X Tjau Lagada) X (wild malaccensis X Guyod)], SH2766 [Tjau Lagada X (wild malaccensis X Guyod)], SH3142 (Intermating Pisang Jari Buaya)

Appendix 2a: Mean performance of NARITA hybrids for bunch weight, number of hands, number of fruit fingers, fruit finger circumference and fruit finger length across three crop cycles

	BWT			NH			NF			FC			FL		
NARITA	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**
NARITA1	13.8	13.4	13.1	9.6	9.7	9.3	140.1	154.2	139.7	11.0	11.2	11.5	16.2	16.5	17.6
NARITA10	15.8	18.7	30.0	8.5	9.7	10.0	157	195.7	216	11.6	11.9	12.3	16.6	18.1	19.9
NARITA11	15.5	19.0	19.0	8.4	8.8	8.5	153.4	166.2	159.7	10.7	11.4	11.5	19.9	19.6	21.0
NARITA12	17.0	18.4	22.4	8.0	9.1	9.4	147	165.5	180.2	10.7	11.4	12.0	20.4	20.3	22.4
NARITA13	17.3	14.0	17.0	8.8	9.0	8.0	130.2	143.9	128.2	11.3	12.1	12.7	18.2	17.7	20.2
NARITA14	22.5	22.2	19.0	8.5	9.8	8.3	145.7	179.7	140	11.9	11.3	12.8	20.7	20.0	20.9
NARITA15	12.3	16.1	13.9	6.9	8.2	8.5	96.9	130.9	137.5	12.2	12.5	11.7	17.1	17.2	17.2
NARITA16	15.3	14.0	-	7.0	5.0	-	121	74	-	10.9	10.4	-	21.0	25.9	-
NARITA17	20.5	28.0	32.0	10.3	10.5	13.0	169.5	189	235	12.5	12.6	15.6	18.0	17.5	19.3
NARITA18	18.6	34.0	-	8.4	9.0	-	135	181	-	11.8	14.4	-	17.4	19.8	-
NARITA19	7.7	10.9	8.3	5.4	6.4	6.0	79.8	102.8	93.1	11.9	12.1	11.9	13.4	14.6	14.6
NARITA2	10.5	15.9	15.4	8.3	8.2	8.8	133.1	134.4	139	10.3	11.5	11.1	15.1	17.7	16.7
NARITA20	10.8	16.9	22.1	8.9	8.8	11.3	142.2	141.1	210.4	10.8	12.1	12.0	13.8	17.5	17.4
NARITA21	15.4	24.3	26.5	8.9	10.3	10.0	133.6	168.7	173.5	12.1	13.5	14.7	17.0	18.8	21.0
NARITA22	16.8	24.1	19.6	7.4	8.1	8.3	119.1	140.9	153.1	12.1	12.4	13.3	19.9	21.2	21.6
NARITA23	18.2	25.3	29.3	10.3	12.2	11.7	152.6	200.8	203	13.1	13.7	14.2	16.0	16.0	15.3
NARITA24	22.2	34.7	42.5	10.6	11.7	13.5	141.6	267.7	327	11.8	12.3	11.7	17.9	18.4	20.7
NARITA25	13.9	21.7	19.3	8.3	11.0	10.0	124.5	192.7	174	12.2	12.1	12.4	18.6	17.5	17.7
NARITA26	15.7	16.8	15.9	7.7	8.9	9.8	115.7	147.7	174.2	11.6	11.7	11.9	18.5	17.8	17.8
NARITA3	15.3	22.8	22.0	7.6	7.6	8.8	121.6	126.7	153	12.0	12.9	12.3	19.3	23.4	23.3
NARITA4	12.5	26.2	27.5	7.5	8.6	9.5	134.6	186.7	210.5	11.2	12.4	11.5	16.9	19.8	18.5
NARITA5	14.2	11.2	14.3	8.3	9.0	9.3	112.6	134.7	146.3	14.1	12.5	13.3	15.8	14.6	14.3
NARITA7 (M9)	17.9	22.9	25.1	7.9	9.1	9.7	121.4	169.9	145.7	13.4	13.4	14.2	18.5	18.6	18.9
NARITA8	16.7	26.0	21.3	7.9	9.5	8.2	122.5	169.7	144.8	12.6	12.7	13.3	19.0	18.5	20.4
NARITA9	13.3	23.5	16.5	7.0	9.0	7.0	103.7	157	101	12.6	13.0	13.9	20.4	19.3	22.0
MEAN	**15.6**	**20.8**	**21.4**	**8.2**	**9.1**	**9.4**	**130.2**	**160.9**	**168.9**	**11.9**	**12.3**	**12.7**	**17.8**	**18.7**	**19.1**
$LSD_{0.05}$	**4.4**	**8.1**	**8.7**	**1.1**	**1.8**	**1.7**	**29.6**	**42.1**	**45.8**	**1.0**	**1.2**	**1.8**	**1.9**	**2.6**	**2.8**

C1 =cycle 1, C2= cycle 2, C3 =cycle 3; BWT= bunch weight (kg); FC= fruit finger circumference (cm); FL= fruit finger length (cm); NF= number of fruit fingers; NH= number of hands; $LSD_{0.05}$ = least significant difference at 5%.

Appendix 2b: Mean performance of NARITA hybrids for days to bunch maturity, plant height at flowering, plant girth at flowering, number of functional leaves at flowering (NFLF) and number of functional leaves at harvest across three crop cycles

	DMT			PH			PG			NFLF			NFLH		
NARITA	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**
NARITA1	158.8	149.7	147.0	316.7	413.3	397.5	52.2	61.0	60.5	10.8	9.0	8.8	3.1	4.8	5.5
NARITA10	153.2	157.7	171.0	263.3	313.3	355.0	46.5	54.3	65.5	7.3	8.7	9.5	0.0	0.7	0.5
NARITA11	214.3	162.6	141.5	296.2	323.0	378.7	44.8	49.4	52.8	8.5	9.0	9.0	1.5	4.0	4.0
NARITA12	151.7	145.4	148.4	273.7	348.7	408.0	42.4	50.3	57.0	9.4	8.6	9.4	1.8	3.4	4.6
NARITA13	148.5	142.9	143.4	266.2	308.6	338.0	42.1	45.6	50.0	8.6	7.4	7.4	0.0	2.3	2.6
NARITA14	168.5	160.7	169.3	243.3	311.7	333.3	39.8	46.0	48.7	12.2	10.5	11.0	4.8	5.5	6.0
NARITA15	138.3	139.1	125.6	251.2	330.0	355.0	38.9	49.4	55.3	10.1	9.4	8.1	2.3	2.6	4.7
NARITA16	141.0	119.0	-	250.0	280.0	-	43.0	51.0	-	7.5	9.0	-	2.0	-	-
NARITA17	153.0	159.0	127.0	272.5	315.0	380.0	45.5	53.5	70.0	10.8	8.5	10.0	3.8	5.5	6.0
NARITA18	139.7	146.0	-	260.0	340.0	-	52.7	64.0	-	12.7	11.0	-	1.8	7.0	-
NARITA19	137.0	130.7	120.4	231.1	274.4	315.0	32.6	37.7	43.7	9.0	8.0	8.7	2.1	2.3	3.6
NARITA2	124.4	133.1	140.2	283.0	344.4	385.0	41.3	50.7	52.4	8.0	9.7	7.2	3.0	3.2	5.0
NARITA20	149.0	146.9	156.1	260.0	316.2	358.6	42.4	54.6	63.3	9.0	11.8	10.7	4.1	3.1	5.9
NARITA21	158.1	154.9	173.5	242.5	350.6	395.0	40.9	56.3	63.0	10.6	11.0	12.0	2.1	6.5	7.0
NARITA22	129.2	171.6	136.9	271.1	345.7	372.9	45.6	55.0	57.3	11.0	11.4	10.0	5.4	5.3	6.4
NARITA23	129.4	133.3	134.7	291.1	376.7	383.3	49.8	64.5	64.0	10.3	10.8	10.3	4.3	6.2	7.3
NARITA24	148.0	150.0	156.5	288.0	353.3	390.0	50.0	60.0	71.5	9.8	9.3	13.0	1.2	3.7	4.5
NARITA25	123.0	155.3	145.0	242.5	306.7	295.0	41.0	50.0	46.5	9.3	9.0	9.5	4.0	4.0	3.3
NARITA26	138.8	142.0	138.5	308.0	410.0	445.0	43.6	56.4	61.3	9.2	9.1	7.5	3.6	2.8	4.7
NARITA3	151.6	147.2	137.7	244.0	343.7	364.0	39.9	50.5	57.2	8.3	10.1	11.0	5.0	6.5	7.8
NARITA4	150.3	165.7	156.2	238.0	324.4	352.5	41.8	52.4	58.3	7.9	11.4	9.8	4.9	3.6	6.0
NARITA5	128.8	101.5	126.3	298.9	355.7	375.0	48.2	57.1	55.0	12.6	12.4	12.7	6.2	7.6	6.3
NARITA7 (M9)	113.9	125.5	136.3	312.2	380.0	402.5	48.6	60.4	68.0	9.2	10.8	11.3	3.3	5.3	5.2
NARITA8	137.9	134.7	136.6	306.4	410.0	400.0	49.6	65.9	63.4	9.6	9.3	9.8	2.5	4.3	5.8
NARITA9	165.2	176.0	164.5	240.0	300.0	350.0	43.8	53.5	54.0	8.2	11.0	11.5	0.3	2.5	5.0
MEAN	**146.1**	**146.0**	**144.9**	**270.0**	**339.0**	**370.8**	**44.3**	**54.0**	**58.2**	**9.6**	**9.9**	**9.9**	**2.9**	**4.3**	**5.1**
$LSD_{0.05}$	**34.8**	**38.7**	**24.8**	**28.2**	**44.4**	**43.8**	**4.3**	**7.1**	**11.5**	**1.7**	**2.4**	**2.6**	**1.8**	**2.3**	**2.4**

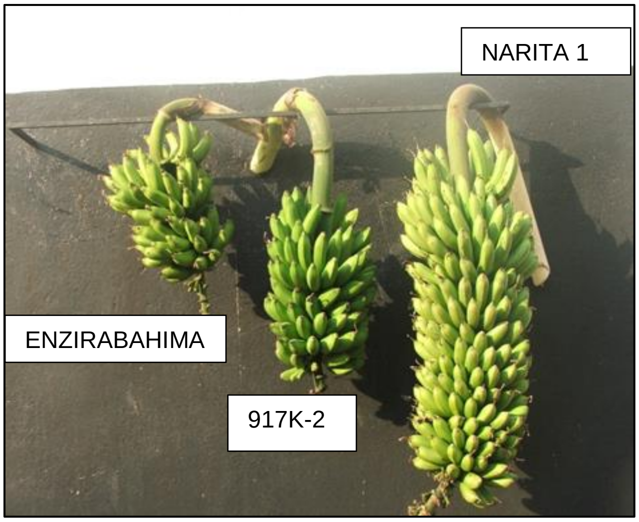
C1 =cycle 1, C2= cycle 2, C3 =cycle 3; DTM= days to bunch maturity; NFLF= number of standing leaves at flowering; NFLH= number of standing leaves at harvest; PG= plant girth at flowering (cm); PHF=plant height at flowering (cm); $LSD_{0.05}$ = least significant difference at 5%.

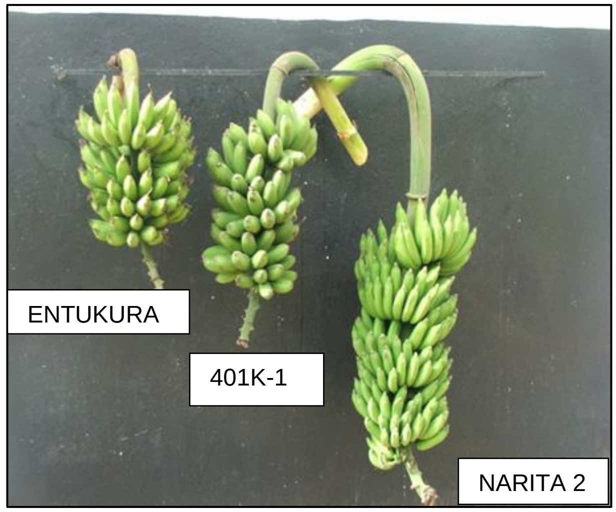
Appendix 2c: Mean performance of NARITA hybrids for height of tallest sucker at flowering, height of tallest sucker at harvest, youngest leaf spotted at flowering and youngest leaf spotted at harvest across three crop cycles

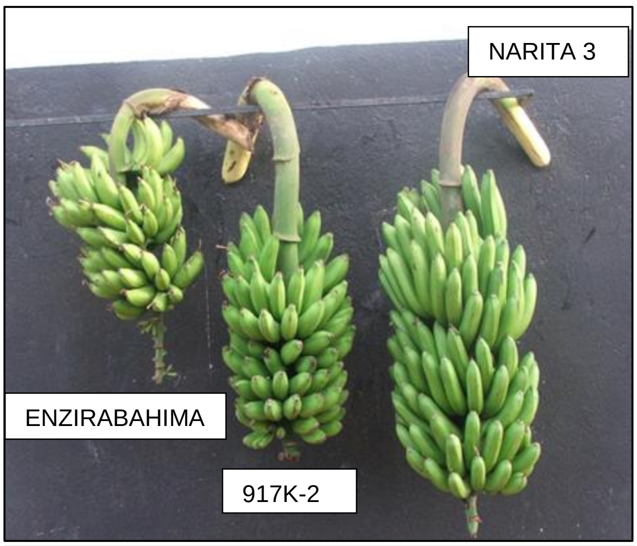
	HTSF			HTSH			YLSF			YLSF		
NARITA	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**
NARITA1	264.4	357.8	357.5	346	370	346.7	10.2	9.0	8.8	2.3	4.4	5.5
NARITA10	213.3	253.3	305.0	297	260	345.0	5.3	7.0	7.5	2.2	2.0	-
NARITA11	200.6	301.0	340.0	304	288	273.8	6.5	7.4	7.0	1.6	2.6	2.5
NARITA12	208.8	271.3	304.0	294	314	328.0	7.3	6.9	7.4	2.2	2.4	3.0
NARITA13	172.5	290.0	290.0	259	259	205.0	6.8	6.1	6.2	1.6	1.7	-
NARITA14	183.3	273.3	240.0	260	287	306.7	10.8	9.3	10.7	4.6	4.8	5.3
NARITA15	176.3	276.0	266.2	268	308	305.0	8.0	7.4	6.9	1.9	2.3	3.0
NARITA16	162.5	270.0	-	245	320	-	6.5	7.0	-	1.5	-	-
NARITA17	165.0	170.0	230.0	276	333	290.0	8.5	7.0	8.0	2.5	3.5	4.0
NARITA18	93.3	340.0	-	116	170	-	10.0	11.0	-	2.3	7.0	-
NARITA19	186.7	274.4	266.7	254	266	275.8	7.2	6.1	7.8	1.9	1.7	2.4
NARITA2	231.0	276.7	304.0	282	303	312.0	8.0	9.1	7.0	3.0	4.5	4.8
NARITA20	202.5	266.3	299.3	283	328	396.4	7.8	9.9	8.3	2.4	2.3	4.1
NARITA21	193.8	322.5	405.0	288	381	460.0	8.6	9.1	11.0	1.8	4.4	5.5
NARITA22	188.9	320.0	325.7	287	330	359.3	9.0	9.4	8.9	3.9	3.7	4.9
NARITA23	226.1	295.8	230.0	289	323	343.3	8.6	9.3	10.3	3.4	4.4	6.3
NARITA24	230.0	286.7	280.0	320	313	335.0	7.2	7.0	11.5	1.3	3.0	3.0
NARITA25	160.0	250.0	140.0	228	250	243.3	6.5	7.7	8.0	2.7	2.7	2.0
NARITA26	277.0	358.1	386.3	344	374	400.0	7.6	7.5	5.8	2.3	2.0	2.7
NARITA3	202.0	252.5	246.0	273	273	282.5	7.4	9.4	10.4	2.9	5.5	7.8
NARITA4	213.0	254.4	310.0	284	286	353.8	6.8	10.2	9.3	2.6	3.9	4.8
NARITA5	192.2	277.9	243.3	280	285	270.0	10.0	10.6	10.3	4.2	6.1	4.7
NARITA7 (M9)	240.0	281.3	320.0	318	335	300.8	7.8	8.8	9.3	2.5	3.6	3.3
NARITA8	252.7	330.0	338.0	324	371	352.5	8.1	8.4	8.8	2.3	3.3	5.4
NARITA9	165.0	260.0	317.5	265	293	220.0	6.0	8.5	10.0	1.0	1.5	4.0
MEAN	**200.0**	**284.4**	**293.2**	**279.0**	**304.7**	**317.6**	**7.9**	**8.4**	**8.7**	**2.4**	**3.5**	**4.2**
$LSD_{0.05}$	**42.3**	**80.5**	**97.2**	**37.8**	**71.8**	**106.9**	**1.7**	**2.3**	**2.7**	**1.4**	**1.8**	**2.4**

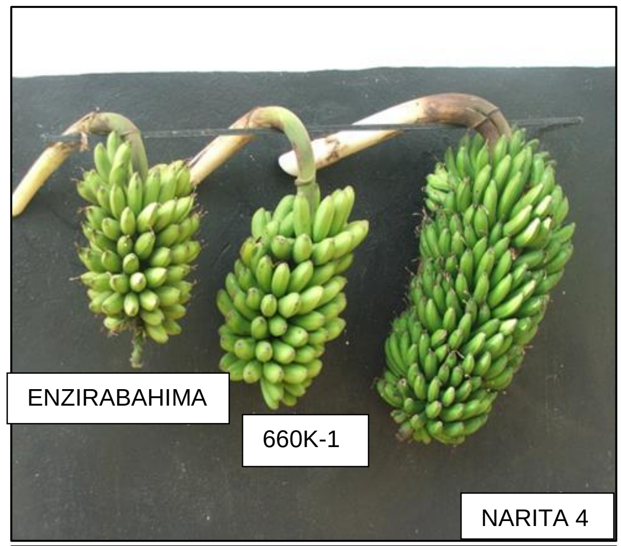
C1 =cycle 1, C2= cycle 2, C3 =cycle 3; HTSF= height of tallest sucker at flowering (cm); HTSH= height of tallest sucker at harvest (cm); YLSF= youngest leaf spotted at flowering, YLSH= youngest leaf spotted at harvest; $LSD_{0.05}$ = least significant difference at 5%.

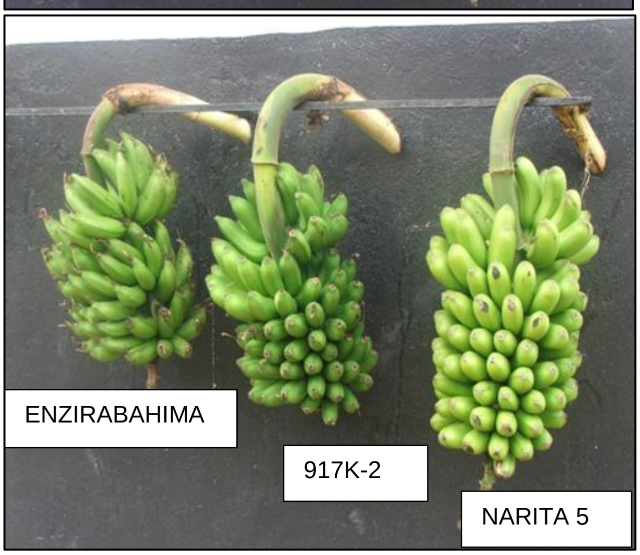
Appendix 3: Pictures of NARITA banana hybrids and some of their progenitors

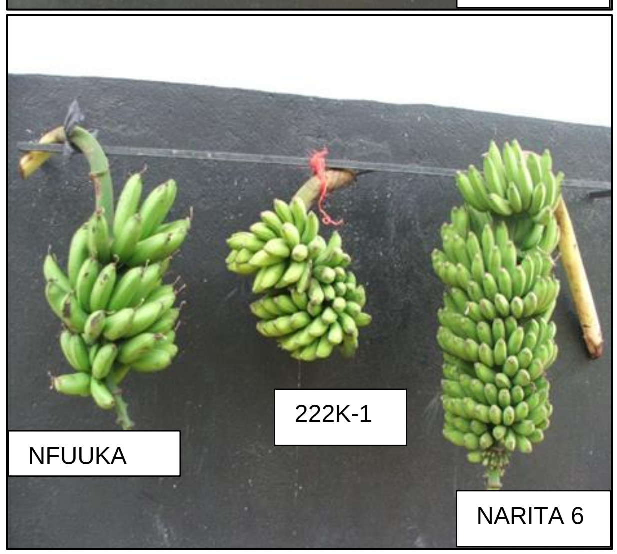


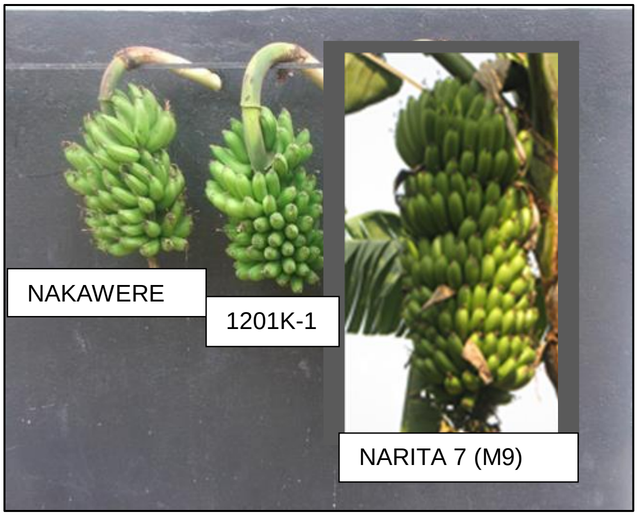


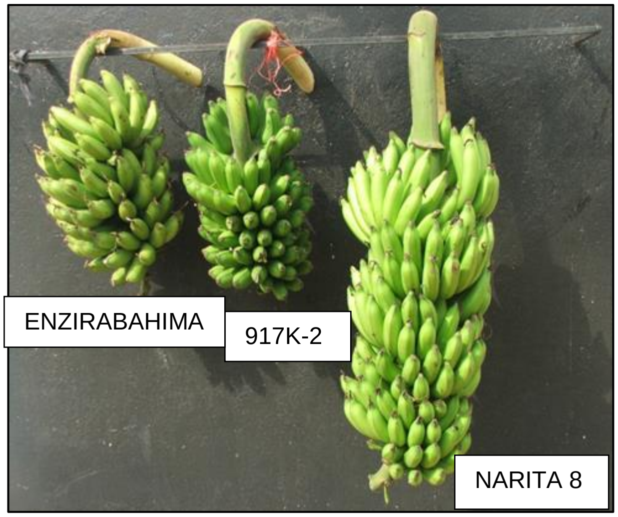


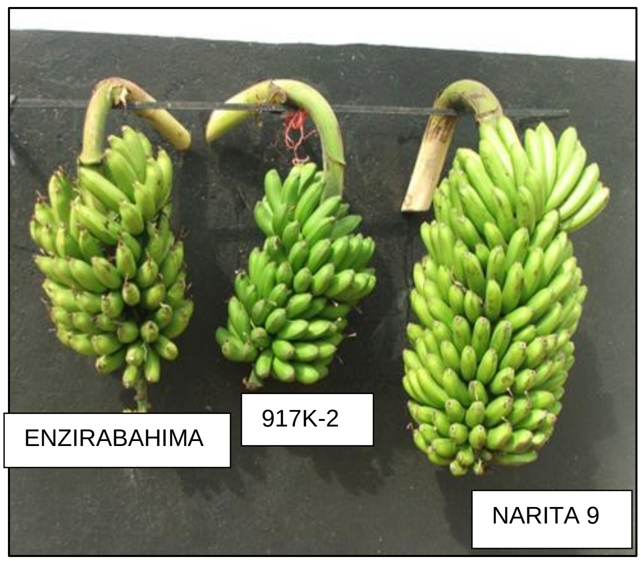


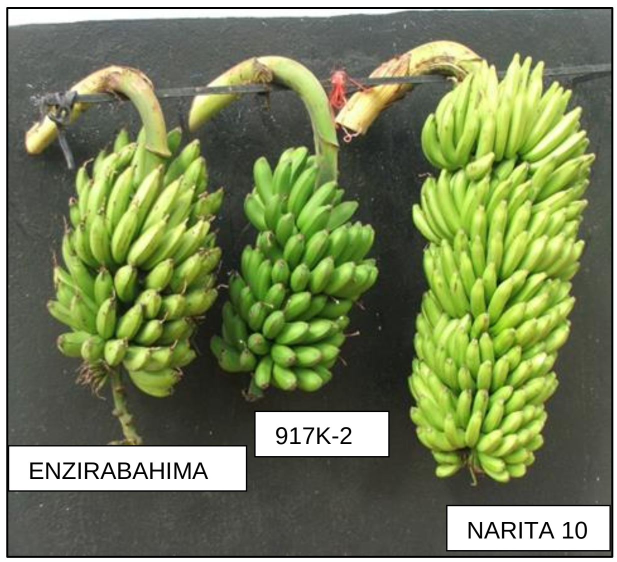


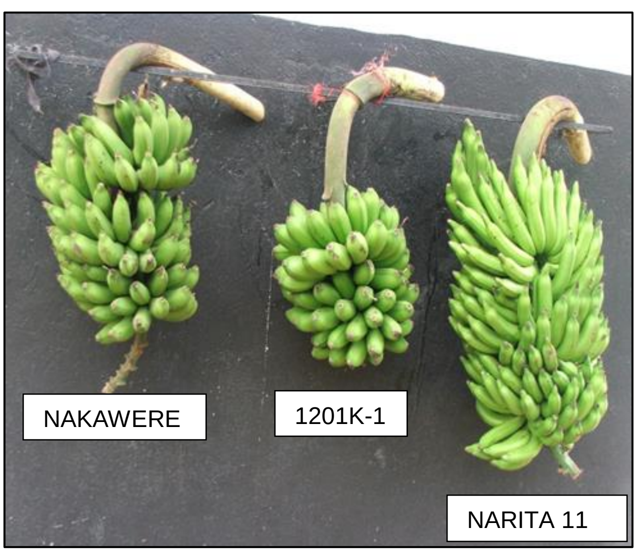


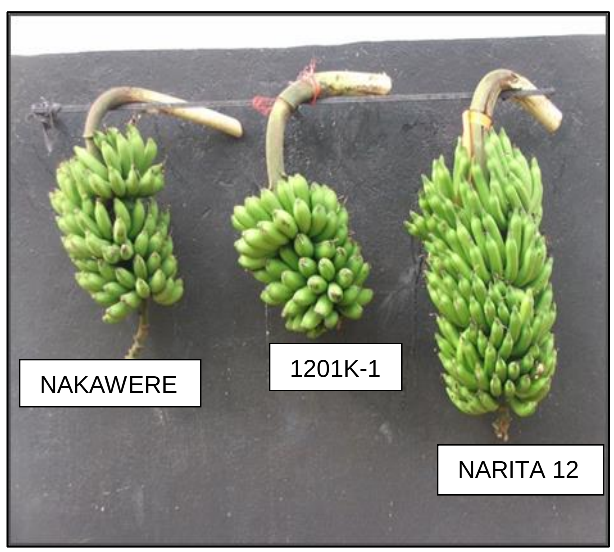

NAKAWERE
1201K-1
NARITA 7 (M9)

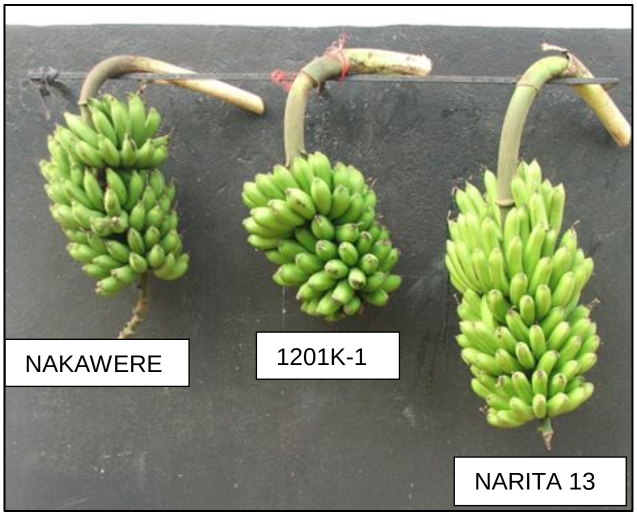

ENZIRABAHIMA
917K-2
NARITA 8

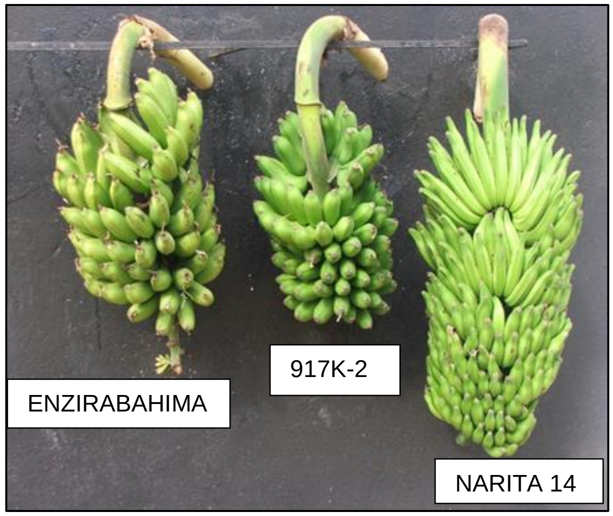

ENZIRABAHIMA
917K-2
NARITA 9

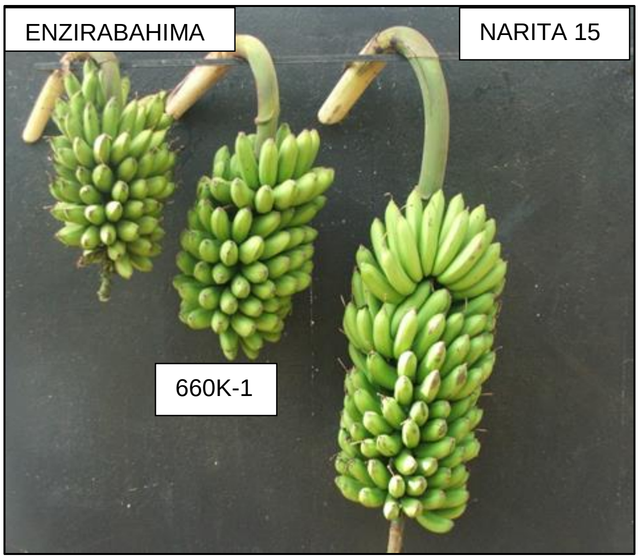

ENZIRABAHIMA
917K-2
NARITA 10


NAKAWERE
1201K-1
NARITA 11

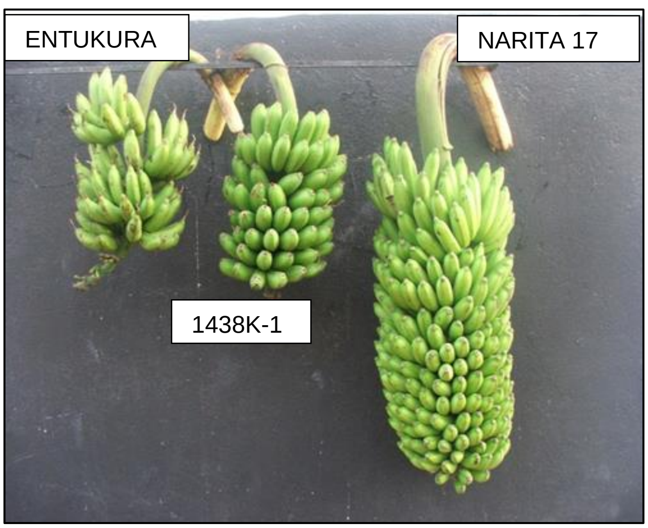

NAKAWERE
1201K-1
NARITA 12


NAKAWERE
1201K-1
NARITA 13

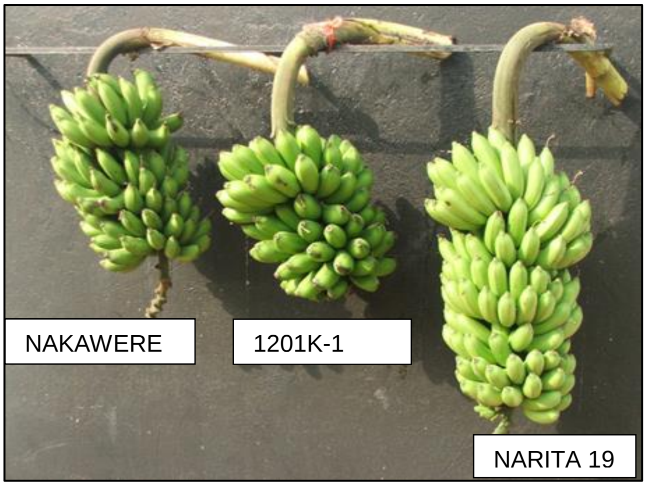

ENZIRABAHIMA
917K-2
NARITA 14

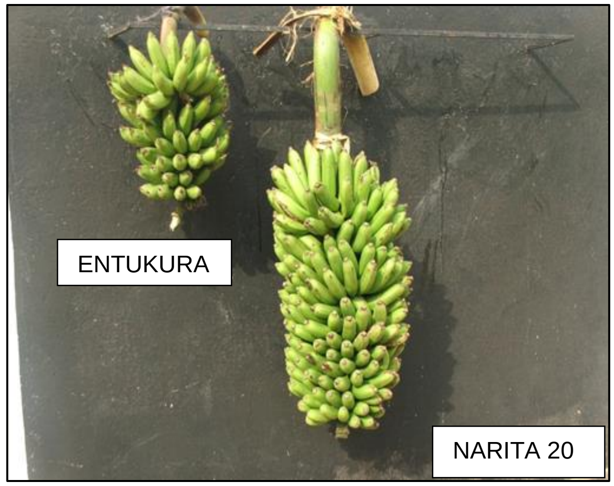

ENZIRABAHIMA
NARITA 15
660K-1

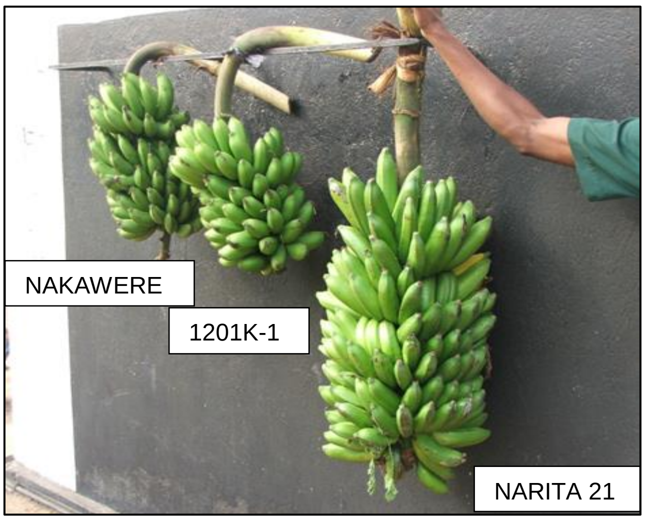

NARITA 16

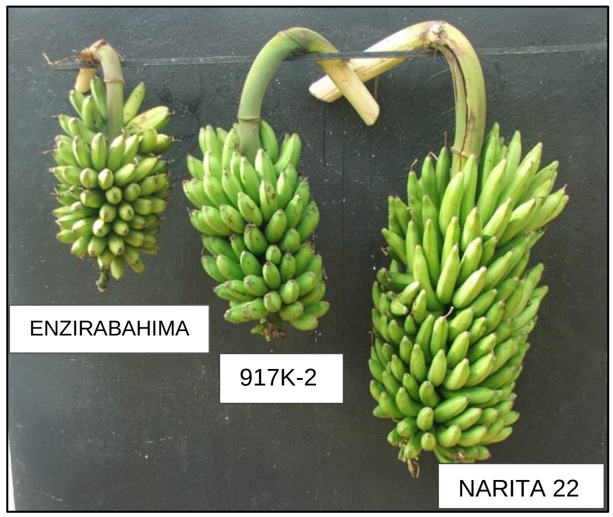

ENTUKURA
NARITA 17
1438K-1

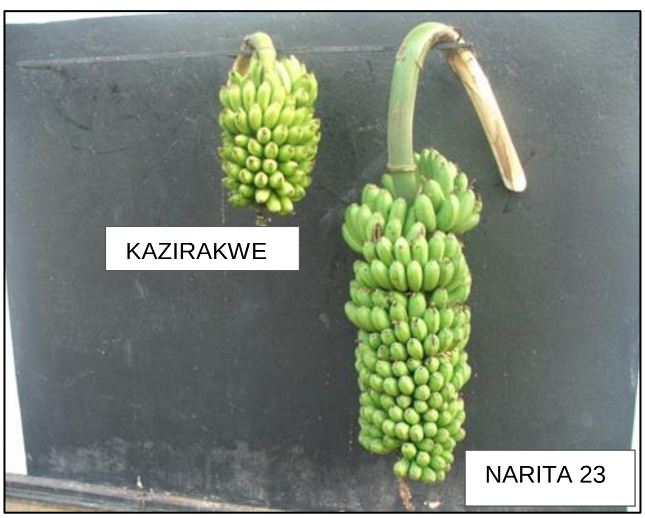

NARITA 18


NAKAWERE
1201K-1
NARITA 19


ENTUKURA
NARITA 20


NAKAWERE
1201K-1
NARITA 21


ENZIRABAHIMA
917K-2
NARITA 22


KAZIRAKWE
NARITA 23


NARITA 24


NARITA 25


NARITA 26