

PROGRESS IN BREEDING DIPLOID GENETIC STOCKS OF BANANA WITH RESISTANCE TO BLACK SIGATOKA

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ABSTRACT

Selected genetically related diploid Musa materials of the base, first, and second generations of the breeding programme in the International Institute of Tropical Agriculture (IITA) high rainfall station, Onne were evaluated for black Sigatoka resistance and agronomic performance. This was done in order to assess the progress made over time in the breeding programme. The results obtained showed that progress has been made from the base generation to generation 1 and from generation 1 to generation 2 in the improvement of the yield attributes of the highly black Sigatoka resistant diploid Musa cultivars- Calcutta 4 and pisang lilin. The diploid hybrids selected in generations 1 and 2 were not as resistant to black Sigatoka disease as the parents. However, improvement at generation 2 has succeeded in bringing together, productivity and resistance traits which seemed to oppose each other in generation 1 as revealed by the biplots. The clones, 2625-5, 9007-4, 1518-4, and 2829-62 from the crosses between Bobby tannap and Calcutta 4 in generation 1 were strongly associated with index of non-spotted leaves in the biplot. The clones, 25291-S26, 25291-S32, 25291-S62, and 25291-1A from the double-cross (BT x C4) x (TL x PL) were associated with most of the yield, disease response and phenological traits. The clones, 25291-S89, 25291-S26, 25291-S32, 25291-S62, 25291-S58, 25233-S3, and 27398 had combination of positive and relatively high heterosis both for black Sigatoka resistance and productivity traits.

Key words: Genetic progress, black Sigatoka resistance, agronomic performance, diploid bananas

INTRODUCTION

Plantain and banana are important staples in the humid forest and mid altitude zones of sub-Saharan Africa. In some traditional production areas in West Africa, per capita consumption has been estimated as high as 150 kg while estimates are 220-460 kg for consumption in Burundi, Rwanda, and Uganda (Ortiz and Vuylsteke 1995). Small-scale farmers are the principal producers of plantain and banana in most places in Africa.

Black Sigatoka disease caused by the fungus, *Mycosphaerella fijiensis* Morelet has been a major threat to plantain and banana production. It causes yield losses of 30-50% (Stover 1983). Fungicidal control is effective but expensive and environmentally hazardous. Therefore, host plant resistance is the most practical option for its sustainable control,

especially for the poor resource farmers in sub-Saharan Africa.

Wild diploid bananas constitute important sources of resistance genes for the genetic improvement of the triploid landraces, but these diploids also contain many undesirable characteristics, notably poor bunch weight, very small fruit size, non-parthenocarpy (seeds in the fruits). Plant breeders therefore, seek to develop improved diploids with a balanced combination of resistance and good agronomic features. Such improved diploid could then be used for transfer of resistance genes to the landraces without the genetic drag of undesirable traits.

Inheritance studies in various crossbreeding schemes suggested that most traits of economic importance were more

predictably inherited from the diploid parents than from parents with a higher ploidy status (Tenkouano *et al.* 1998; Tenkouano *et al.* 1999). Diploids are used as recurrent parents in the crosses, 3x-2x, 4x-2x, 2x-4x, 2x-2x. They are equally used as genetic stocks for diplo-tetraploidization (2x->4x). Furthermore, genetic analysis is easier in a diploid background due to disomic inheritance to facilitate and accelerate breeding. This provided a justification for investment in the development of diploid breeding stocks as pursued by major programmes worldwide (Ortiz and Vuylsteke 1996), including those operated by the International Institute of Tropical Agriculture (IITA).

IITA has developed a relatively large number of diploid hybrids (Vuylsteke and Ortiz 1995). The enormous time and resources required in this breeding programme can only be justified if progress is being made. Also finding out the areas of progress if any, and areas where there is no progress, will help in re-strategizing in the breeding programme. However, there has been no systematic assessment of the progress made. Therefore, this research was initiated to evaluate and compare the agro-morphological and black Sigatoka resistance features of the diploid banana-derived hybrids selected over several generations in order to assess progress made over time.

MATERIALS AND METHODS

The research was conducted at the IITA High Rainfall Station, Onne, Nigeria (latitude 4° 43' N, longitude 7° 01' E and altitude of 10 m above sea level) between July 2006 to June 2007. The research materials were genetically related diploid bananas consisting of the base (2x⁰), the first (2x¹), and the second (2x¹¹) generations of the breeding programme in IITA, Onne station. The 2x⁰ cultivars are *Calcutta 4* and *Pisang Lilin*. The 2x¹ clones were developed by crossing some landraces (obino l'ewai, bobby tannap, tjau lagada and Wh-O-Gu) with the 2x⁰ cultivars, while the 2x¹¹ clones were obtained from crosses among the 2x¹ clones. These materials were established and maintained in the field at the spacing of 3 m between rows and 2 m within row. Data were collected on single row plots of three plants per clone on days to fruit filling, plant height at flowering (cm), plant girth at flowering (cm), number of standing leaves at flowering, number of youngest spotted leaves at flowering, number of standing leaves at harvest, weight of standing

leaves at harvest (kg), pseudostem weight at harvest (kg), height of tallest sucker at harvest (cm), bunch weight (kg), number of hands per bunch, number of fingers per bunch, fruit length (cm), and fruit circumference (cm).

From the data collected, index of non-spotted leaves, crop cycling index, leaf retention index, harvest index, total biomass, and number of fingers per hand were calculated. Inter-generation changes were estimated using a relative performance differential (RPD) analogous to single parent heterosis (SPH). Thus, progress in generation 1 relative to generation 0 (RPD_{1,0}), in generation 2 relative to generation 0 (RPD_{2,0}), and in generation 2 relative to generation 1 (RPD_{2,1}) were calculated as outlined below:

$$RPD_{1,0} = 100 \times ((G_1 - G_0) / G_0)$$

$$RPD_{2,0} = 100 \times ((G_2 - G_0) / G_0)$$

$$RPD_{2,1} = 100 \times ((G_2 - G_1) / G_1)$$

Where G₀, G₁, and G₂ indicate the performance of individuals in generation 0, 1, and 2, respectively. Heterosis of individual clones of generation 1 hybrids relative to generation 0 were calculated. The heterosis of individual clones of generation 2 hybrids relative to generation 0 and relative to their mid-parent values were equally calculated. These were done to assess intra-generation differences. Principal component analysis (PCA) was performed on the data collected, using GENSTAT Discovery Edition 1 Release 4.23 (GENSTAT 2003).

RESULTS

The results of the genetic progress made from generation to generation for 15 traits in the 3 generations are presented in Table 1. All the yield parameters except harvest index, recorded progress from generation 0 to generation 1. There were retrogressions from generation 0 to generation 1 for all the disease response traits except leaf retention index, while growth/phenological traits showed increase in plant height and plant girth and decrease in days to fruit filling and cycling index. From generation 0 to generation 2, progress was made in all the yield traits, all the disease response traits retrogressed, while the growth/phenological traits showed increase in plant height and plant girth and decrease in days to fruit filling and cycling index. All the traits except leaf retention index and index of non-spotted leaves recorded increase from generation 1 to generation 2. The bunch weight made an outstanding high progress from generation to generation, followed by number of fingers. Though harvest index retrogressed

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from generation 0 to generation 1, it recorded appreciable progress in generation 2. Generally, all the yield parameters recorded genetic gain from generation to generation.

Table 2 shows the heterosis of 19 clones of generation 1 hybrids relative to generation 0 for 10 traits. All the clones showed negative heterotic values for the disease response traits (INSL and YLSF). The clones, 1518-4, 9007-4, 1199-6, 2625-5, and 1586-2 had relatively higher values. However, it is observed that

they generally had negative heterotic values for the productivity traits (BWT, HND, FNG, FLT, FCR, and HI). The clones, 1448-1, 1549-5, and 1549-7 had positive and relatively high heterotic values for the productivity traits. All the clones except 9722-1 had positive values for plant girth. The heterotic values for plant height were positive in all the clones except for 2625-5, 9722-1, and 9007-4. The clones, 1518-4 and 5306-1 had average values for both plant height and girth.

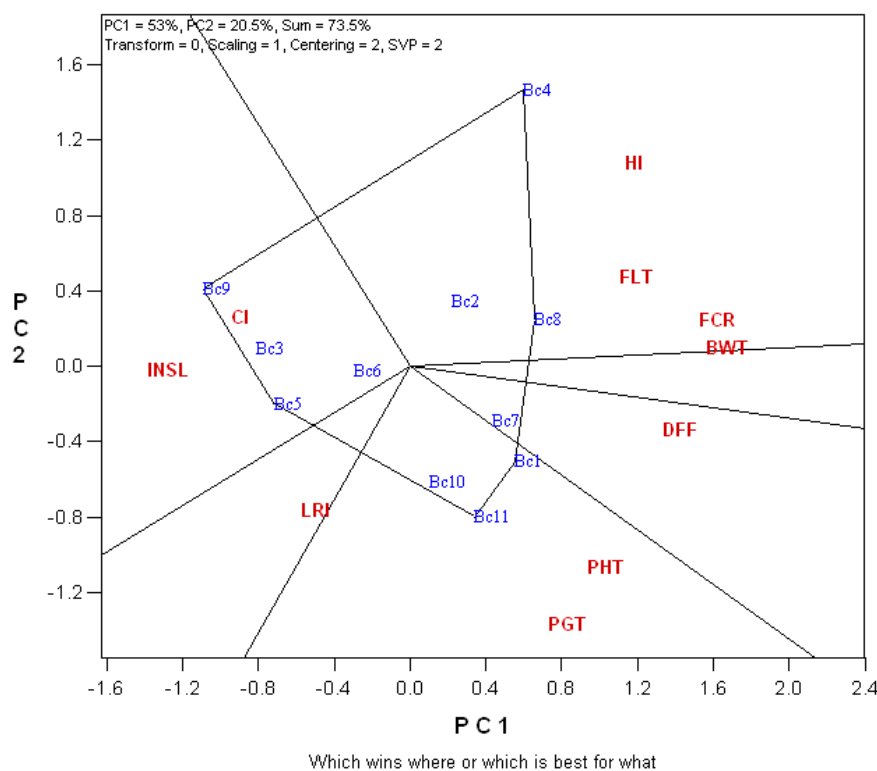
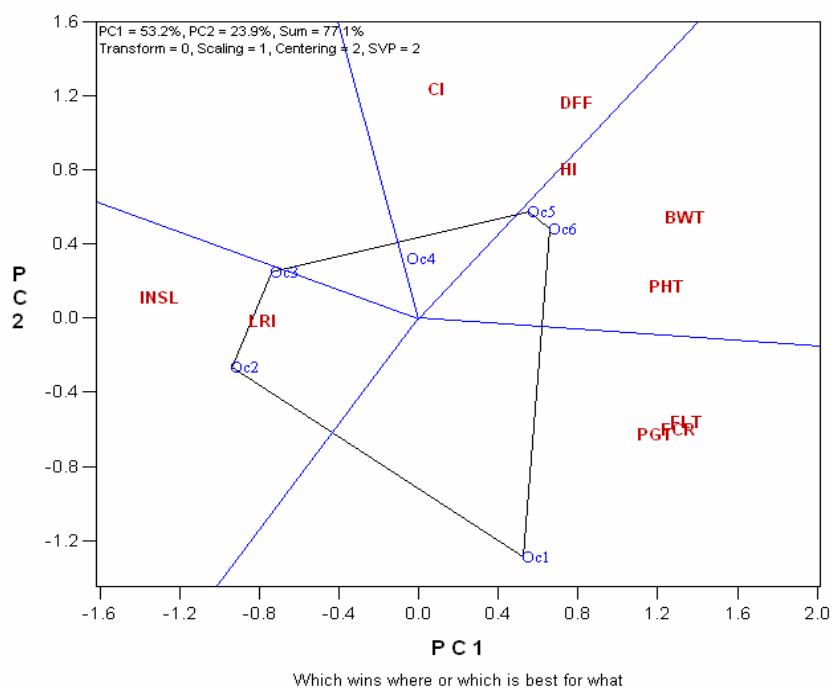


Figure 1: Biplot of the primary hybrids (BT x C4) showing the association of the clones with different traits

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Oc1 = 7356-1
Oc2 = 1199-6
Oc3 = 1586-2
Oc4 = 1448-1

Oc5 = 1549-5
Oc6 = 1549-7
OL = Obino L'ewai
C4 = Calcutta 4

Figure 2: Biplot of the primary hybrids (OL x C4) showing the association of the clones with different traits.

Table 1: Genetic progress (from generation to generation), for 15 traits in 3 generations of *Musa*

	Traits	RPD _{1,0}	RPD _{2,0}	RPD _{2,1}
Growth/Phenology	PHT	27.0	39.2	9.7
	PGT	40.7	45.2	3.2
	DFF	-7.7	-2.9	5.2
	CI	-15.9	-10.9	5.9
Disease Response	NSLF	-12.0	-3.3	9.9
	LRI	12.2	-34.0	-41.0
	YLSF	-34.4	-33.3	1.7
	INSL	-29.4	-35.7	8.9
Yield	BWT	90.9	245	81.0
	HI	-11.5	37.7	55.6
	HND	23.8	42.9	15.4
	FNGS	40.1	85.4	32.4
	NFH	14.0	28.7	12.9
	FLT	18.8	51.8	27.7
	FCR	4.4	17.6	12.7

PHT= plant height, PGT= plant girth, DFF= days to fruit filling, CI= cycling index, NSLF=Number of standing leaves at flowering, LRI= leaf retention index, YLSF=youngest leaf Spotted at flowering, INSL= index of non-spotted leaves, BWT=bunch weight, HI=harvest Index, HND= number of hands, FNGS= number of fingers, NFH= number of fingers per hand, FLT= fruit length, FCR= fruit circumference, RPD_{1,0}= progress from generation 0-1, RPD_{2,0}= Progress from generation 0-2, RPD_{2,1}= progress from generation 1-2

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Table 2: Heterosis of 19 clones of generation 1 hybrids relative to generation 0 for 10 traits.

Clone ID	PGT	PHT	YLSF	INSL	BWT	HND	FNG	FLT	FCR	HI
7356-1	85.4	44.3	-35.7	-44.0	144.4	-14.3	-17.6	88.9	62.1	-32.9
1199-6	10.0	7.6	-35.7	-13.2	30.6	-14.3	-3.7	17.6	8.6	6.8
1586-2	37.5	28.3	-35.7	-18.3	-36.1	-35.7	-36.4	-7.5	-17.3	-56.2
1448-1	50.8	48.1	-28.6	-24.5	214.8	19.1	42.1	30.8	24.8	17.2
1549-5	49.2	35.1	-46.4	-44.0	327.8	0.0	27.2	62.5	37.8	71.9
1549-7	50.8	53.4	-25.0	-44.0	327.8	42.9	23.6	61.2	37.8	36.2
15035-2	53.2	46.6	-46.4	-46.3	155.6	28.6	27.2	27.5	7.8	-10.7
2625-20	15.5	13.4	-25.0	-25.3	80.6	0.0	-5.5	17.6	23.2	24.4
2625-5	1.3	-2.7	-35.7	-13.3	-47.2	-14.3	-17.6	-30.7	-22.2	-47.7
9722-1	-4.2	-6.1	-41.1	-40.9	150.0	14.3	3.4	79.7	27.2	109.8
1518-4	24.1	0.8	-35.7	-6.6	-27.8	-14.3	-28.4	32.1	-15.7	-45.5
2829-62	29.3	14.5	-53.6	-35.6	-11.1	-4.8	2.1	21.1	-10.9	-44.3
4600-12	43.0	21.4	-25.0	-35.8	105.6	-7.1	3.9	44.7	18.3	-9.9
4600-15	31.2	11.1	-46.4	-43.1	119.4	0.0	20.0	42.0	24.0	25.0
9007-4	5.3	-10.7	-46.4	-10.4	-77.8	-28.6	-36.4	-15.5	-35.2	-70.3
5306-1	50.8	9.9	-35.7	-37.8	44.4	28.6	19.6	-16.8	5.4	-31.0
4281-2	56.3	37.4	-25.0	-25.3	91.7	0.0	20.9	47.3	110	-35.4
1968-2	10.7	4.2	-19.6	-29.7	283.3	-50.0	-60.6	118.0	91.3	-8.5
9128-3	109.8	68.6	-46.2	-38.8	306.0	211.6	315.7	14.0	-0.5	-8.5

PGT= Plant girth, PHT= Plant height, YLSF= Youngest leaf spotted at flowering, INSL= Index of non-spotted leaves, BWT= Bunch weight, HND= Number of hands, FNG= Number of fingers, FLT= Fruit length, FCR= Fruit circumference, HI= Harvest index.

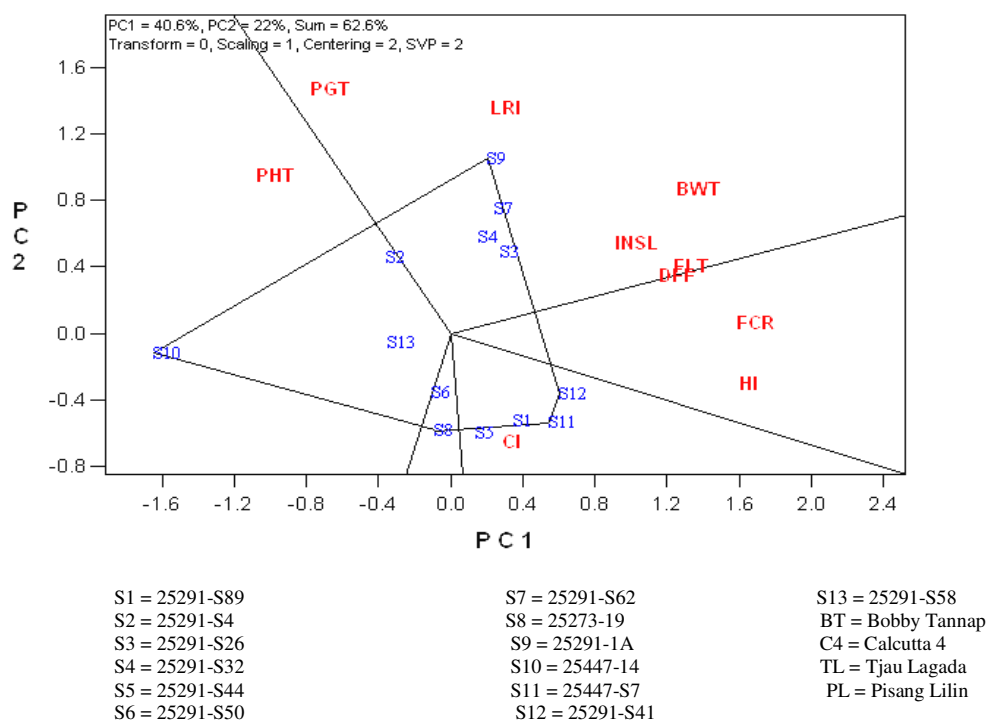


Figure 3: Biplot of the secondary hybrids ((BT x C4) x (TL x PL)) showing the association of the clones with different traits

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Table 3: Heterosis of 19 clones of generation 2 hybrids relative to generations 0 and 1 for 10 traits.

Clone ID	PGT		PHT		YLSF		INSL		BWT		HND		FNG		FLT		FCR		HI	
	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1	Gn 0	Gn 1
25291-S89	38.0	-18.2	22.9	-12.6	-44.4	11.1	-23.8	21.3	239.5	22.9	26.4	-34.3	40.5	-37.6	50.3	28.3	23.9	30.6	57.7	110.7
25291-S4	70.0	0.8	60.8	14.3	-27.8	44.4	-37.1	0.1	269.3	33.7	97.5	2.7	147.7	10.1	24.3	6.1	3.2	8.9	3.7	38.6
25291-S26	67.6	-0.6	51.3	7.6	-27.8	44.4	-35.9	2.0	370.2	70.3	26.4	-34.3	92.8	-14.4	104.1	74.2	20.2	26.8	48.8	98.8
25291-S32	61.5	-4.3	62.3	15.4	-18.5	63.0	-28.6	13.6	464.2	104.3	137.0	23.3	216.5	40.6	65.7	41.4	15.0	21.3	47.2	96.6
25291-S44	20.3	-28.7	32.4	-5.9	-44.4	11.1	-51.7	-23.2	202.8	9.6	-5.2	-50.7	29.0	-42.7	74.6	49.0	22.4	29.1	58.8	112.1
25291-S50	42.8	-15.4	39.5	-0.8	-55.6	-11.1	-42.8	-9.0	166.1	-3.7	26.4	-34.3	12.2	-50.2	65.7	41.4	10.6	16.6	24.1	65.8
25291-S62	74.9	3.7	51.3	7.6	-18.5	63.0	-27.5	15.5	407.7	83.8	89.6	-1.4	149.4	10.8	109.1	78.5	17.5	23.9	33.8	78.8
25273-19	39.6	-17.3	46.6	4.2	-55.6	-11.1	-61.9	-39.3	319.7	52.0	105.4	6.8	193.5	30.4	17.2	0.0	18.0	24.4	51.2	102.0
25291-1A	73.2	2.7	48.9	5.9	-44.4	11.1	-48.5	-18.1	512.4	121.8	65.9	-13.7	227.2	45.4	54.4	31.8	30.5	37.6	59.2	112.7
25447-14	78.1	5.6	70.2	21.0	-66.7	-33.3	-61.9	-39.3	46.8	-46.8	58.0	-17.8	141.8	7.4	1.8	-13.1	-26.3	-22.2	-54.8	-39.6
25447-S7	29.9	-23.0	18.2	-16.0	-22.2	55.6	-42.8	-9.0	354.1	64.5	73.8	-9.6	52.5	-32.3	74.0	48.5	20.9	27.5	91.5	155.9
25291-S41	38.0	-18.2	50.1	6.7	-27.8	44.4	-37.1	0.1	480.3	110.1	34.3	-30.2	80.2	-19.9	84.6	57.6	26.8	33.8	111.7	182.7
25291-S58	46.8	-13.0	59.6	13.5	-38.9	22.2	-35.7	2.4	136.2	-14.5	34.3	-30.2	24.1	-44.8	62.7	38.9	19.5	26.0	-3.5	28.9
26535	33.0	-5.0	29.8	-1.2	-46.4	-9.1	-29.1	1.4	135.2	16.6	9.5	2.2	46.3	19.8	19.8	-4.9	8.6	1.5	16.5	34.7
25233-S3	-1.0	-29.3	-6.9	-29.1	-21.4	33.3	-18.6	16.4	168.5	33.2	9.5	2.2	-4.5	-21.8	49.7	18.9	22.6	14.7	114.3	147.9
25287-S28	37.5	-8.9	7.6	-27.3	-41.1	-17.5	-28.0	-4.6	219.4	1.4	-14.3	-28.0	-26.1	-48.0	61.2	23.2	37.8	10.4	20.4	2.7
25386-S18	50.3	30.2	29.8	14.5	-25.0	0.0	-40.6	-20.5	222.2	78.5	0.0	0.0	8.1	14.4	55.4	32.2	41.0	14.5	45.2	16.8
27398	25.7	-0.8	19.1	10.6	-78.7	-75.1	-25.3	5.3	172.2	237.9	0.0	10.6	100.6	130.9	98.2	56.6	16.7	34.6	76.5	220.5
19890-2	28.3	-2.8	33.2	12.7	-40.7	23.2	-38.0	-2.7	52.9	108.3	-26.3	-30.0	-35.8	-48.3	30.2	19.0	31.3	61.6	-26.8	41.6

PGT= Plant girth, PHT= Plant height, YLSF= Youngest leaf spotted at flowering, INSL= Index of non-spotted leaves, BWT= Bunch weight, HND= Number of hands, FNG= Number of fingers, FLT= Fruit length, FCR= Fruit circumference, HI= Harvest index, Gn= Generation

The heterosis of 19 clones of generation 2 hybrids relative to generations 0 and 1 for 10 traits are presented in Table 3. Relative to generation 0, all the clones had negative heterosis with respect to the disease response traits (INSL and YLSF). However, relative to generation 1, the clones, 25291-S89, 25291-S26, 25291-S32, 25291-S62, 25291-S58, 25233-S3, and 27398 recorded positive and relatively high heterosis with respect to INSL and YLSF. Interestingly, relative to generation 0, these clones had generally positive and relatively high values for the productivity traits.

Table 4 shows the result of the Principal Component Analysis (PCA) of the primary hybrid clones which were obtained from crosses between *bobby tannap* and *Calcutta 4* (BT x C4). The PCA reduced the original ten variables into 4 major components, which accounted for 94.16% of the total variability. The first and most important component, PRIN 1 accounted for 52.97% of the original variation. The subsequent 3 components accounted for 20.47%, 13.53%, and 7.19%, respectively. Examination of the Eigenvector values, which are relative weights accounted for by each individual variable showed that the bunch weight, days to fruit filling, fruit circumference, and index of non-spotted leaves were the major contributors to PRIN 1. Plant girth, plant height, and harvest index affected PRIN 2. PRIN 3 had high loading for leaf retention index and cycling index, while high loading for PRIN 4 were observed in fruit length and days to fruit filling. The genetic relationships among the 11 clones were revealed by the pattern shown by the biplot (Figure 1). The clones 2625-20, 9722-1, and 4600-15 had good performance for yield parameters (harvest index, fruit length, fruit circumference, and bunch weight), while the growth parameters (plant height and plant girth) were found to be associated with the clones 15035-2, 5306-1, and 4281-2. The clones 2625-5, 1518-4, 2829-62, and 9007-4 showed good performance for index of non-spotted leaves and cycling index, while days to fruit filling was associated to 4600-12. It should be noted however, that the clone 2829-62 was the closest to the central point for all the groups and therefore, had average performance for every trait.

The result of the PCA for the primary hybrid clones, which were obtained from crosses between *obino l'ewai* and *Calcutta 4* (OL x C4) is presented in Table 5. The first four components accounted for

98.18% of the total variation (i.e. 53.17%, 23.91%, 14.74%, and 6.36% respectively). PRIN 1 recorded high loading for index of non-spotted leaves, bunch weight, and fruit length, while PRIN 2 loaded highly for cycling index and days to fruit filling. The characters that affected PRIN 3 were harvest index and leaf retention index, while PRIN 4 was affected by leaf retention index and plant height. Figure 2 shows the association of the traits with the different clones. Good performance for harvest index and bunch weight and poor plant height performance were associated with the clones, 1549-5 and 1549-7. The disease response traits were associated with 1586-2 and 1199-6 clones as they had good performance for index of non-spotted leaves and leaf retention index. The fruit characteristics (fruit length and fruit circumference) and plant girth were associated with 7356-1. The clone, 1448-1 being closest to the central point, had average performance for every trait.

In the secondary hybrid of the double-cross between ((*bobby tannap* and *Calcutta 4* (BT x C4)) and ((*tjau lagada* and *pisang lilin* (TL x PL))- ((BT x C4) x (TL x PL))) (Table 6), the result of the PCA revealed that the first four components accounted for 84.19% of the total variance (i.e. 40.64%, 22.03%, 12.05%, and 9.47% respectively). PRIN 1, being the most important, was able to classify the clones basically on yield parameters (bunch weight, fruit circumference, fruit length and harvest index). With PRIN 2, the clones were majorly classified based on plant girth and leaf retention index. PRIN 3 loaded high for cycling index and plant height, while PRIN 4 had high loading for index of non-spotted leaves. The biplot of the secondary hybrids (Figure 3) revealed that the resistance and productivity traits, which seem to oppose each other in generation 1 (Figures 1 and 2), have been brought together in generation 2. The clones, 25291-S26, 25291-S32, 25291-S62, and 25291-1A had good performance for most of the traits (plant girth, leaf retention index, bunch weight, index of non-spotted leaves, and fruit length). The clones, 25291-S89, 25291-S44, 25447-S7, and 25291-S41 had good cycling index only, while 25447-14 and 25291-S4 were associated with plant height. It was observed that 25291-S50 and 25273-19 were not associated with any specific trait, while no specific clone was associated with fruit circumference and harvest index. The clone, 25291-S58 had average performance for every trait, being closest to the central point.

Table 4: Eigenvector values for principal components of the primary hybrid clones obtained from crosses between bobby tannap and Calcutta 4.

Trait	PC1	PC2	PC3	PC4
BWT	-0.42432	0.04035	-0.02586	-0.11620
CI	0.25624	0.11074	-0.58365	-0.36809
DFP	-0.36215	-0.15095	-0.09166	0.46168
FCR	-0.41304	0.10077	0.19034	0.07936
FLT	-0.29893	0.20359	0.18848	-0.69934
HI	-0.30837	0.46578	0.14669	-0.01297
INSL	0.37478	-0.01339	0.31604	-0.12354
LRI	0.15589	-0.33709	0.64163	-0.13613
PGT	-0.19806	-0.60069	-0.09466	-0.10151
PHT	-0.25318	-0.46918	-0.19101	-0.31340

PC1: principal component 1, PC2: principal component 2, PC3: principal component 3, PC4: principal component 4, BWT: bunch weight, CI: cycling index, DFF: days to fruit filling, FCR: fruit circumference, FLT: fruit length, HI: harvest index, INSL: index of non-spotted leaves, LRI: leaf retention index, PGT: plant girth, PHT: plant height.

Table 5: Eigenvector values for principal components of the primary hybrid clones obtained from crosses between obino l'ewai and Calcutta 4.

Trait	PC1	PC2	PC3	PC4
BWT	-0.37618	-0.24234	0.26086	-0.10183
CI	-0.01290	-0.55476	-0.29736	-0.35168
DFP	-0.21572	-0.52216	-0.08084	0.27743
FCR	-0.36922	0.27457	0.24312	-0.10787
FLT	-0.38407	0.25869	0.18619	0.07900
HI	-0.21579	-0.35864	0.53597	0.08197
INSL	0.42420	-0.04784	0.03505	-0.23414
LRI	0.25979	0.01030	0.52870	-0.59286
PGT	-0.33327	0.28674	-0.31554	-0.27908
PHT	-0.35053	-0.07292	-0.27504	-0.52933

PC1: principal component 1, PC2: principal component 2, PC3: principal component 3, PC4: principal component 4, BWT: bunch weight, CI: cycling index, DFF: days to fruit filling, FCR: fruit circumference, FLT: fruit length, HI: harvest index, INSL: index of non-spotted leaves, LRI: leaf retention index, PGT: plant girth, PHT: plant height.

Table 6: Eigenvector values for principal components of the secondary hybrid clones obtained from the double-cross- (BT x C4) x (TL x PL).

Trait	PC1	PC2	PC3	PC4
BWT	0.35775	0.33277	-0.12842	-0.35653
CI	0.08280	-0.25752	-0.78809	-0.22511
DFP	0.33095	0.13202	0.09547	0.09000
FCR	0.45299	0.02267	0.06932	-0.15747
FLT	0.35339	0.15185	-0.08649	0.36958
HI	0.45834	-0.12354	-0.02034	-0.26096
INSL	0.26130	0.20780	-0.29830	0.66244
LRI	0.06369	0.52256	0.18628	-0.33442
PGT	-0.22111	0.56432	-0.05512	0.10114
PHT	-0.30699	0.36329	-0.46249	-0.15409

PC1: principal component 1, PC2: principal component 2, PC3: principal component 3, PC4: principal component 4, BWT: bunch weight, CI: cycling index, DFF: days to fruit filling, FCR: fruit circumference, FLT: fruit length, HI: harvest index, INSL: index of non-spotted leaves, LRI: leaf retention index, PGT: plant girth, PHT: plant height, BT: bobby tannap, C4: Calcutta 4, TL: tjau lagada, PL: pisang lilin

DISCUSSION

The outstanding progress made over the bunch weight from generation to generation shows that there was tremendous improvement over the poor yield of the base generation cultivars (*Calcutta 4* and *pisang lilin*). Progress that was recorded from generation to generation over the fruit length and fruit circumference indicates that the poor fruit sizes of *Calcutta 4* and *pisang lilin* have

been improved upon over the generations. Vuylsteke and Swennen (1993) reported that the poor bunch characters of *Calcutta 4* were generally not transmitted to the tetraploid progenies. The drop in harvest index from generation 0 to generation 1 is likely due to the small plant stature of *Calcutta 4* and *pisang lilin* compared to the plant sizes in generation 1. However, progress made over the harvest index from generation 1 to generation 2 shows

improvement in conversion efficiency of generation 2 over generation 1.

Progress in cycling index from generation 1 to generation 2 shows reduction in time interval from harvest to harvest, which increases the frequency of harvest and subsequent increase in farmers' income. Progress in plant girth helps in resistance to lodging. The general retrogression in disease response traits indicates that the hybrids were not as resistant to black Sigatoka as *Calcutta 4* and *pisang lilin*, which are highly resistant to the disease. Vuylsteke *et al.* (1997) reported that most of the hybrids obtained from the crosses of *obino l'ewai* and *bobby tannap* with *Calcutta 4* showed partial resistance to black Sigatoka disease; and that none of the hybrids expressed the high level of resistance (immunity) of *Calcutta 4*. High values of genetic advance are indicative of additive gene action, whereas low values are indicative of non-additive gene action (Singh and Narayanan 1993). Therefore high genetic advance recorded by bunch weight from generation to generation indicates that bunch weight was under the influence of additive gene action in this research. This does not agree with the report of Peloquin and Ortiz (1992) which stated that non-additive gene action controls yield in vegetatively propagated polyploids. Most other traits with low genetic gain however, were under the control of non-additive gene action. However, number of fingers with moderate genetic gain from generation to generation was likely under the influence of both additive and non additive gene effect.

In the primary hybrids, the traits contributing to the first principal component for the crosses between *bobby tannap* and *Calcutta 4* were bunch weight, days to fruit filling, fruit circumference, and index of non-spotted leaves. For the crosses between *obino l'ewai* and *Calcutta 4*, the first principal component was determined by bunch weight, fruit length and index of non-spotted leaves. With PRIN 1 accounting for most of the variation in the data collected, the primary hybrid clones were majorly separated on the basis of yield and disease response.

The assessment of the performances of individual clones within a family over the different traits was done using the biplot of the families- BT x C4, OL x C4 and (BT x C4) x (TL x PL). The resistance and productivity traits seem to oppose each other in generation 1. Both traits however, have been brought together in generation 2. This is further substantiated by the fact that the clones,

25291-S89, 25291-S26, 25291-S32, 25291-S62, 25291-S58, 25233-S3, and 27398 in generation 2 had combination of positive and relatively high heterosis both for disease response and productivity traits. This progress indicates prospect for concurrent improvement of both traits in higher generations. The *bobby tannap* and *Calcutta 4* crosses having 4600-15, 2625-20 and 9722-1 clones associated with bunch weight, fruit circumference, fruit length and harvest index indicates that these clones can be selected for further yield improvement. In the same vein, the clones, 2625-5, 9007-4, 1518-4, and 2829-62 being associated with index of non-spotted leaves and cycling index are likely to be very useful materials to be selected for further improvement in black Sigatoka resistance. The clone, 4600-12 can be useful for improvement of days to fruit filling, while plant girth can likely be improved using 4281-2, 5306-1 and 15035-2 clones. Worthy of notice however, is the clone, 2829-62, which had average performance for every trait, and therefore, can be a good selection material for further improvement of all the traits concurrently.

For the *obino l'ewai* and *Calcutta 4* crosses, the clones, 1549-5 and 1549-7 having good performance for harvest index and bunch weight, and 7356-1 being associated with fruit length and fruit circumference, indicate that these clones can be useful in yield improvement. The clones, 1199-6 and 1586-2 being associated with index of non-spotted leaves and leaf retention index, suggests that these clones can contribute in black Sigatoka resistance improvement. The clone, 1448-1, which had average performance for all the traits, can be useful in concurrent improvement of all the traits.

Since the first principal component accounts for most of the variations in the data collected, the secondary hybrid clones were majorly separated based on yield attributes as PRIN 1 was determined by bunch weight, fruit circumference, fruit length, and harvest index. The clones, 25291-S26, 25291-S32, 25291-S62, and 25291-1A being associated with bunch weight, fruit length, index of non-spotted leaves, leaf retention index, days to fruit filling, and plant girth suggests that they can serve as good selections for improvement of yield, disease resistance and phenological traits. The clones, 25291-S89, 25291-S44, 25447-S7, and 25291-S41 can serve as good selections for cycling index improvement, while the clone, 25447-14 is not good for any trait. It should be however, noted that the clone, 25291-S58 is closest to the central point

and that concurrent improvement of all the traits can be done by its selection.

Since this research was aimed at balanced combination of resistance and good agronomic features, the clones, 25291-S89, 25291-S26, 25291-S32, 25291-S62, 25291-S58, 25233-S3, and 27398 which met this requirement are good selection materials for advancement to higher generations.

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