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IMPROVED POLYPLOID *MUSA* GERMPLASM DEVELOPED THROUGH PLOIDY MANIPULATIONS

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ABSTRACT

Plantain and banana (*Musa* spp. L.) polyploid hybrids have been obtained after interspecific hybridisation and ploidy manipulations (i.e., interploidy crosses). The identification of promising hybrids for cultivar release requires their field testing to assess agronomic performance. The potential of new polyploid hybrid selections was evaluated in comparison with their triploid ancestral landraces in two trials consisting of 25 and 30 genotypes, respectively. Twenty-six primary tetraploids, seven secondary triploids, three secondary tetraploids and one tertiary tetraploid hybrid were evaluated along with seven triploid landraces and three diploid ancestors from 1993 to 1996. Following this extensive on-station field testing and fruit taste panels, seven promising hybrids were selected based on their desirable attributes: desired resistance to biotic stresses, acceptable agronomic traits and adequate fruit quality. The selected hybrids were the black sigatoka-resistant and virus- tolerant primary tetraploids TMPx 7152-2 (plantain), TMPx 7356-1 (plantain), TMBx 5295-1 (starchy banana), and the secondary *Musa* triploids (TM3x) 14604-35, 15108-1, 15108-2, and 15108-6. This improved germplasm has been advanced for multilocational trials in Nigeria and for local testing in Uganda. After assessing their stability and local adaptation, they may be released as new cultivars in specific agroecozones. The final impact of these *Musa* hybrids in African agriculture will be measured when this new germplasm becomes an integral component of local farming and food systems.

***Key Words*: Banana, breeding, heterosis, hybrids, plantain, polyploidy**

RÉSUMÉ

L'hybridation et les manipulations ploödiques, c'est-à-dire les croisements interploïdiques, ont permis d'obtenir les hybrides polyploïdes des plantains et des banaiers (*Musa* spp. L.). L'identification des hybrides prometteurs susceptibles de donner lieu aux cultivars nécessite un essai au champ en vue d'évaluer leur performance agricole. Le potentiel de nouveaux hybrides sélectionnés a été évalué en les comparant à leurs races ancestrales triploïdes. Cette comparaison a été effectuée dans deux essais composés respectivement de 25 et 30 génotypes. 26 tétraploïde primaires, 7 triploïdes secondaires, 3 tétraploïdes secondaires et l'hybride tétraploïde tertiaire ont été évalués en même temps que 7 races terrestres triploïdes et 3 ancêtres diploïdes de 1993 à 1996. A partir de ce vaste essai en champ et de la liste des préférences des fruits, 7 hybrides prometteurs ont été sélectionnés en fonction des critères suivants: la résistance souhaitée aux contraintes du milieu, les traits agronomiques acceptables et la qualité adéquate des fruits. Les hybrides sélectionnés étaient les tétraploïdes primaires noirs résistants au sigatoka et tolérants aux virus. Il s'agit de tétraploïdes TMPx 7152-2 (plantain), TMPx 7356-1 (plantain), TMBx 5295-

1 (bananier féculent), et de triploïdes secondaires de *Musa* (TM3x) 14604-35, 15108-1, 15108-2, et 15108-6. Ce germoplasme amélioré a été introduit au Nigeria pour des essais multilocalités et en Ouganda pour des essais locaux. A près l'évaluation de leur stabilité et de leur adaptation au niveau local, on peut les promouvoir comme nouveaux cultivars dans les agroécozones spécifiques. L'impact final de ces hybrides de *Musa* dans l'agriculture africaine sera mesuré losque ce germoplasme deviendra une composante intégrale de l'agriculture locale et des systèmes alimentaires.

***Mots Clés*: Bananier, reproduction, hétérosis, hybrides, plantain, polyploïdes**

INTRODUCTION

Africa is the largest producer of plantains and cooking bananas (*Musa* spp. L.), followed by tropical America and Asia (FAO, 1993). The crop is grown mainly by African smallholders who produce plantains and bananas in their compound or home gardens (Vuylsteke *et al.*, 1993a). The most important cultivars are almost sterile triploids and are old landraces selected by farmers several hundred years ago (Simmonds, 1995).

Pest pressure has increased in recent years in Africa (Vuylsteke *et al.*, 1993a). Hence, breeding for resistance has been pursued actively to overcome yield losses due to the susceptibility of old landraces, especially to the fungal leaf spot black sigatoka (*Mycosphaerella fijiensis* Morelet) (Ortiz *et al.*, 1995).

Musa breeders of the Plantain and Banana Improvement Programme (PBIP) of the International Institute of Tropical Agriculture (IITA) are developing improved plantain and banana germplasm with resistance to pests, high and stable yield, and good fruit quality (Vuylsteke *et al.*, 1993b, 1995). New selections are released after testing their performance in at least early and preliminary yield trials (PYTs) in the breeding station. This paper discusses the results from preliminary yield trials carried out in southeastern Nigeria from 1993 to 1996. Primary and secondary polyploids along with their parents were tested in these experiments.

MATERIALS AND METHODS

Two preliminary yield trials (PYT-93 and PYT-94) were planted in IITA's High Rainfall Station at Onne (southeastern Nigeria). Data were collected for the plant crop and successive ratoons of PYT-93 and for the plant crop of PYT-94. Selection of hybrid entries for both PYTs was done in plant and ratoon crops of unreplicated early evaluation trials.

Plant materials. ***PYT-93.*** Twenty-five clones (listed in Tables 1 and 2) were assessed in this trial: 17 tetraploid plantain hybrids, 3 tetraploid cooking and starchy banana hybrids, 3 triploid plantain landraces, 1 triploid cooking banana and 1 triploid starchy banana. All hybrids were derived from interploidy crosses between a triploid plantain or banana and a wild or cultivated diploid banana. The trial was planted with *in vitro* propagules (Vuylsteke, 1989).

PYT-94. Thirty clones (listed in Table 3) were assessed in this trial: seven secondary triploid plantain-derived hybrids, three secondary tetraploid plantain-derived hybrids, seven primary tetraploid plantain hybrids (mostly parents of secondary polyploid hybrids), four primary tetraploid cooking banana hybrids, one tertiary tetraploid cooking banana hybrid, two triploid plantain landraces (grandmothers of secondary polyploid hybrids), three cooking banana landraces (ancestors of cooking banana hybrids), one selected diploid hybrid (parent of some secondary triploid hybrids), one plantain-derived diploid (parent of some secondary triploids), and one wild banana (grandparent of all secondary polyploid hybrids). Secondary triploids were obtained from tetraploid-diploid crosses between primary tetraploid plantain hybrids and selected diploid banana or plantain-derived parents. Secondary tetraploids were selected after intermating primary tetraploid hybrids. This trial was also planted with *in vitro* propagules.

Site characterisation and crop management. Onne (4°43'N, 7°1'E), a humid forest site, is located in the secondary centre of plantain diversification. Annual rainfall is monomodal in distribution and commonly greater than 2400 mm. The soils are ultisols derived from coastal sediments of the Niger Delta region. They have low pH (< 4.3) and low cation exchange capacity. The fields were left to fallow with *Pueraria phaseoloides* L. for at least two years before planting the PYTs, and prepared with minimum disturbance by manual clearing.

Plants were fertilised at an annual rate of 300 kg N ha^{-1} and 450 kg K ha^{-1} split over six applications during the rainy season and using urea and muriate of potash, respectively. In addition, approximately 10 kg of mulch from elephant grass (*Pennisetum purpureum* L.) and 10 kg of pig manure were applied once to each plant in the ratoon. Plants were treated with an insecticide-nematicide (2 g a.i. isofenphos in 1.5 l water per plant, about every 4 months) to control banana weevil and nematodes.

TABLE 1. Preliminary yield trial in sole crop of *Musa* germplasm at Onne (1993-94)

Clone	DF days	TNL #	PH cm	NSLf #	YLSf #	HTSh cm	DFF days	BW kg	H #	F #	FL cm	FC cm
Tetraploid plantain hybrids												
548-4*	295	28	299	11	8	206	105	7.6	6	72	17	12
548-9*	253	25	293	13	11	312	115	11.3	6	84	17	13
582-4	254	25	240	12	10	202	120	8.4	6	82	17	12
1112-1*	268	22	287	10	9	213	118	7.4	7	96	17	11
2637-49*	289	29	304	11	10	200	108	8.9	6	83	19	12
2776-20	260	22	272	9	7	186	82	3.3	5	64	12	10
2796-5*	258	26	306	14	12	210	113	11.8	6	89	19	13
4479-1*	303	26	265	11	8	174	102	8.1	6	76	17	12
4698-1*	314	29	276	9	7	178	118	7.8	8	99	18	11
4744-1	248	26	283	13	12	240	122	8.8	6	72	16	13
5706-1*	284	27	295	10	8	173	111	7.2	7	90	16	12
5860-1	173	24	233	12	11	186	114	4.0	4	45	18	11
6930-1OT	339	25	249	9	6	216	99	4.5	6	69	14	11
7152-2	239	25	278	12	12	243	116	8.0	6	79	20	11
7356-1	260	26	311	11	10	278	111	9.4	6	80	19	12
10091-2	311	25	240	9	6	188	100	6.2	6	77	18	12
Triploid plantain landraces (check cultivars)												
Agbagba	262	29	300	10	6	160	95	5.9	5	20	26	15
B. Tannap	346	28	272	6	4	142	82	4.2	6	63	15	11
O.l'Ewai	303	29	311	9	7	113	98	9.1	7	75	20	13
Tetraploid banana hybrids												
612-74	237	23	282	15	14	260	146	10.3	6	67	18	14
5295-1	363	27	314	8	7	110	89	11.0	7	84	24	13
5748-1	346	30	277	8	5	170	98	3.7	6	71	15	10
Triploid bananas												
Cardaba	353	23	269	8	5	138	99	4.7	5	56	14	12
Pisang Kelat	310	26	268	12	10	202	129	4.5	6	78	13	10
P (F-test)	0.004	<0.001	0.001	<0.001	<0.001	0.007	0.011	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	14	11	7	20	24	14	26	26	10	15	11	10

DF = days to flowering; TNL = total number of leaves; PH = plant height; NSLf= number of standing leaves at flowering; YLSf = youngest leaf spotted at flowering; HTSh = height of tallest sucker at harvest; DFF = days to fruit filling; BW = bunch weight plant^{-1}; H = number of hands; F = number of fruits; FL = fruit length; FC = fruit circumference, CV = coefficient of variation, OT = offtype.
* registered hybrid (Vuylsteke *et al.*, 1993a, 1995)

No artificial inoculation was required to assess black sigatoka since the causal pathogen is ubiquitous at Onne (Ortiz and Vuylsteke, 1994a).

Field layout and data recording. Experimental designs and plot sizes were those recommended by Ortiz and Vuylsteke (1995) for preliminary on-station yield trials. The PYT-93 was planted in a simple square lattice design with 2 replications of 5 plants while the PYT-94 was a simple rectangular lattice design with 2 replications of 4 plants. Distances between rows were 3m and distances between plants within rows were 2m, giving a plant density of 1667 ha^{-1}.

Data were recorded on individual plants, i.e., one plant was considered as the basic experimental unit. Bunches were harvested only from virus symptomless plants when green fruits from the oldest hands started yellowing. The characters evaluated were:

TABLE 2. *Preliminary yield trial in sole crop of Musa germplasm at Onne (ratoon1994-96). Most of the bunch weight and its components were recorded on virus-symptomless plants*

Clone	DF days	TNL #	PH cm	NSLf #	YLSf #	HTSh cm	DFF days	BW kg	H #	F #	FL cm	FC cm
Tetraploid plantain hybrids												
548-4*	-^{z}	23	287	11	9	268	128	9.0	5	81	18	13
548-9*	95	26	326	11	10	269	119	17.4	6	104	18	14
582-4*	92	26	291	11	8	219	120	11.2	6	88	18	13
2637-49 *	156	28	333	11	9	274	121	9.6	6	84	18	12
2796-5*	-^{z}	27	350	13	11	280	112	20.0	6	107	20	14
4479-1*	185	26	321	11	10	245	122	13.4	6	94	21	14
4744-1	144	26	334	12	9	269	117	8.8	6	83	16	13
5706-1	154	26	318	8	6	265	103	4.6	6	76	14	10
6930-1 OT	106	23	274	10	7	211	129	4.1	6	81	12	9
7152-2	96	28	332	12	10	270	118	12.4	7	99	22	12
7356-1	173	26	363	12	9	248	115	12.6	7	99	20	13
10091-2	135	23	266	8	6	206	98	5.8	5	65	13	10
Triploid plantain landraces (check cultivars)												
Agbagba	177	23	325	9	5	178	84	5.3	6	19	24	15
B. Tannap	205	25	292	8	6	160	94	8.0	6	78	17	12
O.l'Ewai	-^{z}	26	328	9	7	161	97	8.6	7	71	19	13
Tetraploid banana hybrids												
612-74	99	26	344	13	10	253	132	14.2	6	82	18	15
5295-1	299	28	336	11	9	142	88	15.4	8	98	25	13
5748-1	175	28	335	11	9	282	115	6.8	7	81	17	11
Triploid bananas												
Cardaba	212	23	299	10	8	199	121	8.8	6	65	15	14
Pisang Kelat	146	26	269	12	10	190	130	4.2	6	78	11	9
P (F-test)	< 0.001	0.060	<0.001	<0.001	<0.001	0.046	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	38	11	7	14	20	26	11	23	12	18	11	10

DF = days to flowering; TNL = total number of leaves; PH = plant height; NSLf= number of standing leaves at flowering; YLSf = youngest leaf spotted at flowering; HTSh = height of tallest sucker at harvest; DFF = days to fruit filling; BW = bunch weight $plant^{-1}$; H = number of hands; F = number of fruits; FL = fruit length; FC = fruit circumference, CV = coefficient of variation, * registered hybrid (Vuylsteke et al. 1993b), - = missing data; OT = offtype

^{z} *Mother plants were destroyed before flowering by strong wind damage in the ratoons. Therefore, calculation of DF may be biased towards high values. The other data were collected on the best follower which became the mother plant on the respective ratoon cycle*

TABLE 3. Preliminary yield trial in sole crop of *Musa* cultivars at Onne (plant crop, 1994- 1996)

Clone	DF days	TNL #	PH cm	NSLf #	YLSf #	HTSh cm	DFF days	BW kg	H #	F #	FL cm	FC cm
Secondary plantain-derived triploids												
14123-5	340	24	256	11	8	151	103	9.0	5	65	19	13
14123-6	546^{z}	21	213	8	6	160	91	BSV				
14604-35	302	28	275	14	13	209	125	14.0	7	112	21	13
14604-37	250	30	229	13	10	254	117	6.4	7	92	17	10
15108-1	333	21	215	12	9	64	116	11.6	8	119	16	11
15108-2	321	27	268	14	12	47	102	12.7	7	106	22	12
15108-6	329	27	239	9	7	223	133	14.4	7	127	18	13
Secondary plantain-derived tetraploids												
15090-102	241	25	229	12	10	281	153	9.1	6	112	18	3
15090-130	290	25	201	13	12	215	163	6.8	7	112	14	11
15955-3	313	25	265	9	7	293	97	6.9	8	110	17	11
Primary tetraploid parents of secondary plantain-derived triploids												
548-4*	BSV + WD											
582-4*	274	25	211	11	9	236	119	7.2	5	69	16	12
1187-8 (BSS)	387	21	179	9	7	158	117	2.2	6	65	12	10
4479-1*	321	24	276	11	9	229	111	9.0	6	74	20	13
4698-1*	364	29	276	11	9	224	108	9.5	7	95	18	12
6930-1*	339	28	238	12	8	151	124	8.9	7	84	17	12
15063-1	343	23	265	11	8	136	112	8.1	6	69	20	13
Selected diploid parents of secondary plantain-derived triploids												
1549-7	204	26	186	13	8	234	109	1.2	7	85	7	4
SH-3362	529	29	240	9	7	226	114	7.8	11	141	14	9
Grandparental triploid plantain landraces												
B. Tannap	353	26	298	8	6	74	89	7.2	6	[illegible]	21	13
O. I' Ewai	396	24	290	8	5	70	72^{z}	3.2^{z}	5^{z}	59^{z}	17^{z}	11^{z}
Grandparental diploid wild banana												
Calcutta 4	208	22	174	12	-	247	126	0.5	6	81	6	4
Parental triploid cooking banana landraces												
Bluggoe	345	27	311	10	7	256	126	10.8	5	52	19	16
Cardaba	313	28	300	11	9	269	136	13.6	6	77	17	15
Fougamou	376	32	303	12	8	308	116	5.8^{y}	9	135	10^{z}	9^{z}
Cooking banana primary tetraploids												
612-74 OT:												
CAM	266	24	260	15	13	265	156	9.7	6	64	17	14
KUL	287	23	251	14	11	237	152	9.4	6	58	17	14
Onne	319	25	206	13	11	174	160	6.6	5	45	17	14
1378	399	29	311	12	9	206	118	4.1^{y}	8	113	9^{z}	9^{z}
Cooking banana tertiary tetraploid												
FHIA-3	318	26	266	11	9	80	102	16.9	8	125	17	14
P (F-test)	< 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	10	12	8	13	19	18	11	23	11	17	11	10

DF=days to flowering, TNL=total number of leaves, PH=plant height, NSLf=number of standing leaves at flowering, YLSf=youngest leaf spotted at flowering, HTSh = height of tallest sucker at harvest, DFF = days for fruit filling, BW = bunch weight plant^{-1}, H = hands bunch^{-1}, F = fruits bunch^{-1}, FL=fruit length, FC=fruit girth, CV= coefficient of variation, BSV=plants were rogued due to BSV, BSS=black sigatoka (BS) susceptible, WD=strong wind broke pseudostem bearing inflorescences and/or bunch, *registered BS resistant hybrid (Vuylsteke et al. 1993b), OT=offtype, -=no leaf spots

^{z} Late flowering because original mother plants were rogued due to strong BSV infection

^{y} Fruits affected by unknown pest during fruit filling

• plant height at flowering (cm), measured to the nearest 1 cm from soil surface to the "V" point, i.e., where the petioles of the two youngest fully opened leaves meet each other;
• days to flowering, which are the number of days from planting to shooting (i.e., inflorescence emergence) in the plant crop, and from harvest to shooting in the successive ratoons;
• total number of leaves produced by the plant throughout its growth cycle;
• number of standing leaves at flowering, counted from the youngest (i.e., the highest) unrolled leaf downwards;
• youngest leaf spotted by black sigatoka, recorded as the first leaf showing a necrotic dry centre;
• height of tallest sucker (cm), measured to the nearest 1 cm from soil surface to the "V" point;
• days for fruit filling or the number of days from shooting to harvest;
• bunch weight (kg) to the nearest 0.1 kg;
• number of hands or nodal clusters of fruits per bunch;
• number of fruits per bunch;
• fruit length (cm) of a representative sample from the second hand to the nearest 1 cm; and
• fruit girth (cm) of a representative sample from the second hand.

RESULTS AND DISCUSSION

All plants from the primary tetraploid hybrid 4424-4 and some from other selected primary tetraploid hybrids, except TMPx 4479-1, TMPx 7152-2, TMPx 7356-1, TMBx 612-74 and TMBx 5295-1, showed virus symptoms and were eliminated prior to flowering in the plant crop PYT-93. Also, all plants of the primary tetraploid hybrids 2776-20, 5860-1, TMPx 1112-1 and TMPx 4698-1 were rogued in the ratoon crop of PYT-93 due to their high susceptibility to *Musa* viruses. Plants of TMPx 6930-1 were not true-to-type, exhibiting an abnormally poor bunch phenotype in the PYT-93. This abnormal phenotype could have been caused by somaclonal variation arising from *in vitro* multiplication (Vuylsteke *et al.* 1991).

All plants of the secondary triploid 14123-6 and some plants of TMPx 548-4 were rogued in the PYT-94 because they showed virus symptoms. Also strong winds damaged flowering mother plants of 'Obino l'Ewai' twice during the fruit filling time, and those of TMPx 548-4 before shooting in the plant crop of PYT-94. The fruits of the primary tetraploid cooking banana TMBx 1378, as well as those of its triploid landrace parent 'Fougamou', were infected by an unknown pest during the fruit filling time in the PYT-94. All offtypes of TMBx 612-74, obtained after *in vitro* propagation, showed abnormal phenotypes with poor horticultural performance in the PYT-94.

Because of the virus susceptibility of some hybrids and the generation of offtypes after micropropagation, results are discussed below among groups. Specific comparisons are only made for those promising hybrids which did not show virus susceptibility and whose phenotype resembles the original true-to-type.

Analysis of variation for growth and bunch characters in PYTs. There were significant differences ($P<0.01$) among all clones for flowering, plant stature, and sucker growth in both PYTs (Tables 1, 2 and 3). Clones showed significant ($P<0.01$) variation for total number of leaves in the plant crop of both PYTs but not in the ratoons of PYT-93. The selected primary tetraploid plantain hybrids (TMPx) showed better ratooning, as judged by the height of the tallest sucker, than their plantain parental landraces. This is due to the hybrids' regulated suckering behaviour controlled by the gene *Ad* (Ortiz and Vuylsteke, 1994b). The fast growth of TMPx may explain why they had a shorter flowering time than their landraces in the successive ratoons.

Days to flowering showed a high coefficient of variation in the ratoon of PYT-93 because there were follower plants, especially in the hybrids, which sometimes flowered even before the mother plant was harvested. The black sigatoka resistant TMPx exhibited a longer fruit filling time than their plantain landraces, yet the growth cycle of the latter was longer because of their late flowering. SH-3362, an improved diploid banana from Fundacion Hondurena de Investigacion Agricola (Rowe and Rosales, 1993), flowered late in PYT-94 (Table 3).

The hybrids showed a significant ($P< 0.001$) variation in their response to black sigatoka (Tables 1, 2 and 3). The previously selected polyploid hybrids, exhibited their partial black sigatoka resistant response in both PYTs. The highest levels of black sigatoka resistance were observed in TMBx 612-74 and its somaclonal variants (612-74 CAM, 612-74 KUL, 612-74 ONNE). In contrast, the parental plantain landraces were susceptible to black sigatoka.

Significant differences ($P<0.001$) were observed among the clones for bunch weight, fruit filling time, number of hands, number of fruits, and fruit size (Tables 1, 2 and 3). In general, black sigatoka resistant genotypes outyielded susceptible clones. The heaviest bunches were harvested from healthy plants of TMPx 548-9 and TMPx 2796-5 in the PYT-93. However, many plants of both hybrids were rogued throughout the experiment because they showed virus symptoms. FHIA-3 had the highest yielding bunches in PYT-94, but the taste of its unripe or ripe cooked fruit was not accepted by the Nigerian panelists (data not shown). Although somaclonal variation did not affect the high resistance to black sigatoka of TMBx 612-74, its somaclonal variants had low bunch weights. This suggests that somaclonal variants are of limited use for the improvement of yield in this cooking banana, as is the case in plantains (Vuylsteke *et al.*, 1996).

The results also showed that high yields are not necessarily associated with the ploidy level. Some secondary triploids significantly ($P<0.001$) outyielded triploid landraces in PYT-94 (Table 3), while bunches of some black sigatoka susceptible tetraploid hybrids did not exceed the weight of the susceptible triploid landraces. Furthermore, the late flowering SH-3362 had a very high bunch weight for a diploid in the PYT-94. This was not surprising since this selected diploid hybrid was developed after three cycles of phenotypic recurrent selection (PRS) (for a review of its pedigree see Ortiz *et al.*, 1995). This PRS scheme made genetic gains through the elimination of deleterious recessive alleles and the accumulation of favourable additive alleles (Ortiz and Vuylsteke, 1994c). However, the bunch of SH-3362 had many small fruits in PYT-94 (Table 3). This result indicated that the increment in the bunch weight of SH-3362 was based on the production of more fruits but at the expense of individual fruit size.

The breeding value of potential parents for interploidy crosses cannot be established through their phenotype *per se* since non-additive gene action seems to be very important to achieve heterosis for high yield in *Musa* (Ortiz, 1995). This was corroborated by the poor yields of TMP2x 1549-7, a plantain-derived diploid which was the male parent of the high yielding secondary triploid 14604-35. Non-additive gene action (i.e., intra- and inter-locus interaction) to maximise yields have been reported in other vegetatively propagated polyploid crops (for a review see Peloquin and Ortiz, 1992).

New germplasm releases. Based on the results from these PYTs, seven polyploid hybrids, discussed below, have been selected by IITA for further testing and potential cultivar releases in Africa and elsewhere (Table 4). These selected hybrids should be assessed in multilocational trials in the targeted ecozones, because genotype-by-environment interaction significantly influences their agronomic performance (De Cauwer *et al.*, 1995). They have been sent to recognised virus-indexing centres in accordance with the technical guidelines for the safe movement of *Musa* germplasm (Diekmann and Putter, 1996) before their international distribution.

PITA-14 and PITA-18: Short cycling black sigatoka resistant plantain hybrids with field tolerance to virus(es). TMPx 7152-2 (hereafter PITA-14) and TMPx 7356-1 (PITA-18) are black sigatoka-resistant primary tetraploid hybrids derived from the female-fertile French plantains 'Mbi Egome-1' and 'Obino l' Ewai', respectively. The male parent of both hybrids was 'Calcutta 4'. In addition to their black sigatoka resistance, both hybrids had a significantly ($P< 0.05$) shorter growth cycle than the female landrace parent (Tables 1 and 2) and field tolerance to virus(es) after several years of testing at Onne station. PITA-18 (Fig. 1) is the only hybrid offspring derived from Obino l'Ewai with field tolerance to virus(es) at Onne.

This result confirms the complex epistatic nature of virus symptom expression in *Musa* (Ortiz, 1996). Furthermore, it also suggests that it could be possible to select virus-tolerant black sigatoka-resistant tetraploid hybrids by increasing the population size in the tetraploid hybrid offspring

TABLE 4. Hybrids in the process of release

Genotype	IITA No.	Selected in	Attributes	Release after
TMBx 5295-1*	BITA-3	1992	BSLS, big fruits, VT	Preliminary on-station yield trial
TMPx 7152-2*	PITA-14	1992	BSR, VT	Preliminary on-station yield trial
TMPx 7356-1	PITA-18	1992	BSR, VT	Preliminary on-station yield trial
TM3x 14604-35	PITA-20	1993-1994	BSR	Preliminary on-station yield trial
TM3x 15108-1	PITA-19	1993-1994	BSR, FWR?, NR?, VT	Preliminary on-station yield trial
TM3x 15108-2	PITA-15	1993-1994	BSR, FWR?, NR?	Preliminary on-station yield trial
TM3x 15108-6	PITA-16	1993-1994	BSR, FWR?, NR?, VT	Preliminary on-station yield trial

* Virus tested stock available from the Transit Centre of the International Network for the Improvement of Banana Plantain of the International Plant Genetic Resources Institute
BSR: partially resistant to black sigatoka; BSHR: highly resistant to black sigatoka; BSLS: less susceptible to black sigatoka, BWR: banana weevil resistant, FWR?: potential for fusarium wilt resistant, MET: multilocational evaluation trial; NR?: potential for nematode resistance; VT: field tolerant to virus (no virus-like symptoms after several years in field surrounded by susceptible plants showing virus symptoms); IITA: International Institute of Tropical Agriculture

Figure1. PITA-18 (or TMPx 7356-1), a black sigatoka partially resistant tetraploid hybrid (centre), obtained by crossing the susceptible triploid plantain landrace 'Obino l' Ewai' (left) with the highly resistant wild non-edible diploid banana 'Calcutta-4' (right).

derived from triploid-diploid crosses between plantain landraces and wild bananas.

In the plant crop, both hybrids had similar (P>0.05) bunch weight to Obino l'Ewai (Table 1), but they significantly (P< 0.05) outyielded this plantain landrace in the ratoon at Onne (Table 2). PITA-14 has a lax bunch with long fruit. Both female-fertile hybrids have pendulous bunches with deciduous hermaphrodite flowers and imbricated male bud, and regulated suckering behaviour. In 1995, PITA-18 was rated as the best plantain hybrid by Nigerian taste panelists for unripe boiled and fried ripe fruits (data not shown). PITA-14 was advanced in 1995 for testing in multilocational trials at IITA stations in Nigeria (Abuja, Ibadan and Onne) and for local testing in Uganda.

BITA-3: Black sigatoka and virus tolerant starchy banana. TMBx 5295-1 (BITA-3) is a tetraploid banana hybrid showing tolerance to black sigatoka. Also, this hybrid has not shown virus-like symptoms in early or preliminary yield trials at Onne.

BITA-3 is a hybrid from the cross 'Laknau' (AAB starchy banana) X 'Tjau Lagada' (AA banana). This hybrid significantly (P< 0.05) outyielded the plantain landraces at Onne (Tables 1 and 2). Taste panels showed that fried ripe fruit of BITA-3 was preferred by 38% of the panelists when compared with that of the False Horn plantain 'Agbaga' in a Nigerian dish called Dodo, and by 40% of the panelists when compared with the fruit of the registered hybrid TMPx 2796-5.

This hybrid (BITA-3) is female-fertile, has a pendulous lax bunch with long fruit pedicels, deciduous neutral flowers and imbricated male bud. It exhibits slow sucker development (Tables 1 and 2). BITA-3 has been advanced for multilocational trials in Nigerian humid lowlands, forest-transition zone and Southern Guinea savanna. It has also been sent to Uganda for local testing in the East African mid-altitudes.

TM3x: Secondary triploid plantain hybrids with black sigatoka resistance. TM3x 15108-1 (hereafter PITA-19), TM3x 15108-2 (or PITA-15) and TM3x 15108-6 (or PITA-16) are black sigatoka-resistant secondary triploid hybrids derived from the cross TMPx 4479-1 X SH-3362 (Ortiz and Vuylsteke, 1994d). TMPx 4479-1 is a selected primary tetraploid hybrid developed by crossing 'Bobby Tannap' and 'Calcutta 4' (Vuylsteke *et al.*, 1993). PITA-16 shows tolerance to virus(es) at Onne. The diploid parent of PITA-16 has shown resistance to fusarium wilt, and its paternal grandparent, SH-3142, is an improved nematode resistant diploid. SH-3142 was developed by FHIA from the highly nematode resistant diploid banana 'Pisang jari buaya' (Rowe and Rosales, 1993). Hence, PITA-16 and its full-sibs may have resistance to fusarium wilt and nematodes, but this remains to be tested.

TM3x 14604-35 (or PITA-20), also a black sigatoka resistant secondary triploid hybrid, was obtained from crossing the selected full-sibs TMPx 6930-1 (tetraploid) and TMP2x 1549-7 (Ortiz and Vuylsteke, 1994d). Both primary euploid hybrids were derived from 'Obino l' Ewai' X 'Calcutta 4' and are partially resistant to black sigatoka (Vuylsteke *et al.*, 1993b; Vuylsteke and Ortiz, 1995).

These selected secondary triploid hybrids (Fig. 2) significantly outyielded (P< 0.05) their parents and grandparents in the plant crop at Onne. Sometimes PITA-16 and PITA-19 exhibited shorter (P<0.05) fruit size than the French plantain landraces (Table 3).

The best fruit quality for unripe boiled preparation among the secondary triploids tested in Nigerian taste panels was recorded on PITA-15 (data not shown). Seventeen percent of the panelists preferred the unripe boiled fruits of this hybrid to those of the popular False Horn plantain 'Agbagba'. Also, a similar percentage of panelists favoured the unripe boiled fruits of PITA-15 to those of the registered TMPx 4479-1 (PITA 17). On average, the panelists found that unriped boiled fruits of PITA-15 had acceptable quality. However, when the fruits of this hybrid were compared to those of PITA-16 for "dodo" (fried ripe fruit), 63% of the panelist favoured the latter. This example highlights the problems of breeding a crop with multiple end-uses. Hence, *Musa* breeders should consider the implications of genotype-by-end use interaction in the development of their improved germplasm. Other preliminary results from taste panels showed that, among the secondary triploids, the most preferred fruit for "dodo" was that harvested from 14604-2. This

Figure 2. TM3x, black sigatoka-resistant secondary triploid hybrids (bottom, center), obtained from crossing a black sigatoka-resistant tetraploid hybrid (bottom, left) and an improved diploid banana from FHIA (bottom, right). The tetraploid parent was developed at IITA by crossing the susceptible plantain (top, left) with a high resistant wild non-edible diploid banana (top, right).

hybrid is another secondary triploid derived from crosses between TMPx 6930-1 X TMP2x 1549-7 (data not shown). This result may be explained by the fact that secondary triploids obtained by crossing euploid plantain derived hybrids (e.g. PITA-20) may have more plantain alleles than those derived from the cross 15108, which inherited at least 1/3 of their alleles from the diploid banana parent SH-3362.

PITA-16, the highest yielding secondary triploid, has a pendulous dense bunch with curved angular bottlenecked fruits, few persistent neutral flowers and imbricated male bud. This male-sterile triploid hybrid exhibited regulated suckering behaviour (Table 3). PITA-20, also a male-sterile triploid, produces a pendulous dense bunch with persistent neutral flowers. PITA-16 has been advanced for multilocational trials in Nigeria and together with PITA-15 and PITA-19 are being evaluated in Uganda.

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