ARTICLE

Bunch yield of interspecific hybrids of American oil palm with oil palm in the juvenile phase

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Abstract: *To identify superior genotypes, 42 progenies of interspecific hybrids between American oil palm and oil palm were evaluated in an area with incidence of bud rot. The following variables were assessed: total bunch yield (TBY), number of bunches (NB) and mean bunch weight (MBW) from the third to the sixth year of cultivation and estimates of genetic parameters obtained by REML/BLUP procedures. High heritability values of the evaluated traits were observed. The gain estimates for TBY were 14.49% for the selection of the five best progenies and 33.36% for the selection of the five best trees, considering multiplication by cloning. A medium correlation was observed between TBY and NB (r^2 = 0.33±0.021), a high correlation between TBY and MBW (r2 = 0.53±0.019) and a negative high correlation between NB and MBW (r^2 = –0.60±0.018). The results indicate a high expectation of gains with selection for TBY.*

Key words: Elaeis guineensis, Elaeis oleifera, *oil palm breeding, yield potential, REML/BLUP.*

INTRODUCTION

The world demand for vegetable oil is on the rise, with an estimated 240 million tons in 2050 for food consumption (Corley 2009). Palm oil, extracted from the oil palm fruit (*Elaeis guineensis* Jacq.), is the most widely produced and marketed vegetable oil worldwide (FAOSTAT 2014) and this condition is expected to continue in the coming decades. Oil palm is the most productive of all oil crops and readily adaptable to the climatic conditions of the humid tropics. In Brazil, more than 30 million hectares of zoned deforested areas suitable for oil palm cultivation are already available (Ramalho Filho et al. 2010). Although still insignificant at the global level, the cultivated area in the country has expanded remarkably in recent years (Villela et al. 2014). However, oil palm cultivation in Brazil and throughout Latin American has been threatened by the occurrence of *bud rot* (BR), a disorder of unknown etiology that has destroyed thousands of hectares of oil palm and is continuously expanding since the first reports in the country (De Franqueville 2003).

No resistance source to BR for African oil palm has been reported, but it is known that the American oil palm (*E. oleifera* (H.B.K) Cortés), a species native from America, is resistant and transfers this resistance to interspecific F1 hybrids between American oil palm and oil palm (HIE OxG). The American oil palm also has other traits of interest that are transmitted to HIE OxG, such as slow vertical

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stem growth, resistance or tolerance to diseases and a more unsaturated oil (Cunha et al. 2012). In South America, the leading breeding programs dealing with American oil palm are being carried out in Brazil and Colombia (Rey et al. 2004, Bastidas et al. 2007, Cunha et al. 2012).

In 2010, Embrapa released the first national HIE OxG cultivar, called BRS Manicoré (Cunha and Lopes 2010). Although the yields of this cultivar are similar to those of tenera oil palm, which has been improved in at least five decades of breeding, there is still a high genetic variability in American oil palm that can be exploited (Rios et al. 2011). Based on this variability, it is possible to predict high gains with selection and develop interspecific varieties with higher yields than the African oil palm (Lopes et al. 2012). In the last decade, the priority of the breeding program of Embrapa was the improvement of HIE OxG and progeny tests are being evaluated in States of Amazonas and Pará.

The best commercial plantations in Malaysia and Indonesia have a mean yield of 27 t ha^{-1} yr^{-1} of fresh fruit bunches (FFB), or 6 t ha^{-1} yr^{-1} of oil, with yields that exceed 40 t ha^{-1} yr^{-1} of FFB or 8 t ha^{-1} yr^{-1} of oil in some plots (Hoffman et al. 2014). However, this is still far below the yield potential of the species, estimated at up to 18 t oil ha^{-1} yr^{-1} (Barcelos et al. 2015), and significant gains with breeding are possible. In the reciprocal recurrent selection program for palm oil conducted by CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement), the oil yield was improved by increasing bunch yield and bunch oil content (Gascon et al. 1988). Total bunch yield is the key trait of productivity in oil palm, so the genetic control of this trait is an essential piece of information for breeding programs (Lopes et al. 2012). The total weight of bunches is the product of two other traits (number of bunches and mean bunch weight). The genetic parameters of the yield-related traits were estimated in different oil palm populations (Soh et al. 2003, Cedillo et al. 2008, Okwuagwu 2008, Okoye et al. 2009), but information about HIE OxG populations is still scarce (Lopes et al. 2012, Gomes Junior et al. 2014).

This study was based on methodologies using mixed linear models REML (restricted maximum likelihood) and BLUP (best linear unbiased prediction), which can estimate genetic parameters with high accuracy. These methodologies were successfully applied in oil palm breeding for the selection of parents (Soh 1994) and selection for crosses (Purba et al. 2001), and similar results are also expected in the selection for HIE OxG. The purpose of this study was to estimate genetic parameters and predict gains with selection for bunch yield in the juvenile stage of HIE OxG progenies.

MATERIAL AND METHODS

The experiments were initiated in February 2007, at the company Marborges Agroindústria S.A., municipality of Moju (lat 1° 58' 42" S, long 48° 36' 50" W and alt 35 m asl), State of Pará. The soil is a dystrophic yellow oxisol and the climate equatorial, with a mean annual rainfall of 2,890 mm (1994-2010) and a rainy season in the first half of the year. The study area is classified as highly suitable for oil palm cultivation, according to Zondendê (Ramalho Filho et al. 2010).

Forty-two HIE OxG progenies (Table 1) were divided into three experiments, each with 16 progenies, of which three were common to all three experiments (RUB 1195, RUB 1194 and RUB 1213). The experiments were arranged in randomized block design with 4 replications and 12 plants per plot (4 rows with 3 plants). As border, we used one row at either end of the experiment and one plant at the far end of each row.

The crosses and seed germination were carried out by Embrapa Western Amazon at CERU (Campo Experimental do Rio Urubu), Rio Preto da Eva, AM. The planting density was 143 plants ha^{-1} and the seedling production and planting systems followed recommendations of Pina (2010).

The bunch yield of all plants of the field was recorded at commercial maturity, characterized by the detachment of at least one fruit bunch, every 15 to 20 days, from July 2010 (3^{rd} year after planting) to December 2013 (6^{th} year after planting), with a total of 3.5 years of evaluation. The ripe bunches were harvested and weighed with a 50 kgf dynamometer and the number of bunches (NB) and total bunch yield per plant (TBY) were recorded. The mean bunch weight (MBW) was computed as ratio of TBY by NB.

Estimates of genetic parameters were obtained via linear mixed models REML/BLUP, using the Selegen-Reml software/ Blup (Resende 2002), according to the statistical model:

$y = Xr + Zg + Wp + Tb + e$, where y is the data vector; r the vector of population effects (assumed as fixed), added to the general mean (including the mean of the population and common controls); *g* is the vector of genotypic effects (assumed as random); p the vector of the plot effect (random); b is the vector of the block effects (random); and *e* is the vector of errors and residues (random). The capital letters X, Z, W, and T represent the incidence matrices for the effects r, g, p, and b, respectively.

Table 1. Genealogy of the 42 evaluated interspecífic hybrids of American oil palm x oil palm

Progeny	American oil palm (female parent)		Oil palm (male parent)			Test
	Subsample	Genitor	Origin	Descendence	Parent	
-	**Manicoré**	-	-	-	-	-
RUB 1195	RUC 107	RU 1604 D	LM 10 T	LM 12011	RU 56 P	1, 2 and 3
RUB 1196	RUC 107	RU 2841 D	LM 2 T	LM 13582	RU 2692 P	3
RUB 1197	RUC 107	RU 2842 D	LM 10 T	LM 13751	RU 2730 P	3
RUB 1198	RUC 107	RU 2842 D	LM 2 T	LM 12437	RU 2707 P	3
RUB 1199	RUC 109	RU 3099 D	LM 2 T	LM 13582	RU 2693 P	3
RUB 1200	RUC 109	RU 3089 D	LM 10 T	LM 13751	RU 2730 P	3
RUB 1201	RUC 109	RU 3089 D	LM 10 T	LM 12011	RU 2710 P	3
RUB 1202	RUC 93	RU 1608 D	LM 2 T	LM 13582	RU 2749 P	3
RUB 1203	RUC 95	RU 1778 D	LM 10 T	LM 12252	RU 2698 P	3
RUB 1204	RUC 96	RU 3170 D	LM 10 T	LM 12011	RU 2710 P	3
RUB 1205	RUC 96	RU 3123 D	LM 10 T	LM 12252	RU 2700 P	3
RUB 1206	RUC 96	RU 3169 D	LM 10 T	LM 12252	RU 2700 P	3
RUB 1208	RUC 80	RU 2905 D	LM 2 T	LM 13582	RU 2693 P	3
RUB 1209	RUC 43	RU 2787 D	LM 10 T	LM 12252	RU 2733 P	2
RUB 1210	RUC 76	RU 3308 D	LM 2 T	LM 13582	RU 2691 P	2
RUB 1211	RUC 76	RU 3111 D	LM 2 T	LM 13582	RU 2693 P	2
RUB 1212	RUC 76	RU 3111 D	LM 10 T	LM 12252	RU 2700 P	2
RUB 1213	RUC 76	RU 1724 D	LM 10 T	LM 12011	RU 2710 P	1, 2 and 3
RUB 1214	RUC 77	RU 2914 D	LM 10 T	LM 12252	RU 2700 P	2
RUB 1215	RUC 78	RU 3359 D	LM 10 T	LM 12252	RU 2700 P	2
RUB 1217	RUC 224	RU 1578 D	LM 10 T	LM 13751	RU 2730 P	2
RUB 1218	RUC 79	RU 2900 D	LM 2 T	LM 13582	RU 2693 P	2
RUB 1219	RUC 79	RU 2901 D	LM 2 T	LM 13582	RU 2693 P	2
RUB 1220	RUC 79	RU 1588 D	LM 10 T	LM 13751	RU 2730 P	2
RUB 1221	RUC 114	RU 101 D	LM 10 T	LM 12011	RU 2710 P	2
RUB 1223	RUC 224	RU 1578 D	LM 10 T	LM 12011	RU 2710 P	2
RUB 1224	RUC 102	RU 2845 D	LM 10 T	LM 13751	RU 2729 P	2
RUB 1225	RUC 102	RU 2839 D	LM 10 T	LM 12011	RU 56 P	1
RUB 1226	RUC 102	RU 78 D	LM 2 T	LM 12785	RU 53 P	1
RUB 1227	RUC 102	RU 2846 D	LM 2 T	LM 13582	RU 2692 P	1
RUB 1231	RUC 103	RU 92 D	LM 10 T	LM 12011	RU 56 P	1
RUB 1232	RUC 104	RU 3079 D	LM 2 T	LM 13582	RU 2749 P	1
RUB 1233	RUC 104	RU 3101 D	LM 10 T	LM 12011	RU 56 P	1
RUB 1234	RUC 105	RU 3189 D	LM 10 T	LM 12011	RU 2710 P	1
RUB 1250	RUC 97	RU 1605 D	LM 10 T	LM 13751	RU 2730 P	1
RUB 1271	RUC 224	RU 1578 D	LM 2 T	LM 13582	RU 2691 P	1
RUB 1274	RUC 224	RU 1578 D	LM 2 T	LM 13582	RU 2692 P	1
RUB 1277	RUC 79	RU 1586 D	LM 10 T	LM 13751	RU 2730 P	1
RUB 1283	RUC 103	RU 92 D	LM 2 T	LM 13582	RU 2692 P	1
-	**Manicoré x São Bartolomeu**	-		-	-	-
RUB 1193	RUC 223	RU 3795 D	LM 2 T	LM 13582	RU 2749 P	3
RUB 1194	RUC 223	RU 3791 D	LM 2 T	LM 13582	RU 2692 P	1, 2 and 3
-	**Coari**	-	-	-	-	-
RUB 1237	RUC 228	RU 3856 D	LM 2 T	LM 13582	RU 2691 P	1

RESULTS AND DISCUSSION

The coefficients of determination of the effects of plots (c^2_{plot}) (2-3%) and the coefficients of determination of the effects of genotype – environment interaction (c^2_{int}) (0.06-1%) were below 10%, indicating good experimental accuracy, according to the classification of Resende (2007).

The overall mean of TBY was 144.07 Kg of fresh fruit bunches (FFB) plant^{-1} yr^{-1} (Table 2), equivalent to 20.6 t ha^{-1} yr^{-1} of FFB. Lower TBY values were observed in commercial oil palm plantations in the juvenile phase (Gomes Junior 2010). In adult HIE OxG progenies from different origins, under different soil and climate conditions in Amazonas, Lopes et al. (2012) observed a mean TBY of 99.3 kg plant^{-1} yr^{-1} of FFB, i.e., 14.2 t ha^{-1} yr^{-1} of FFB. The high mean recorded in this study indicates the potential for selection of superior genotypes in the HIE OxG population under study.

The estimates of genetic variability and heritability for TBY were high, and the adjusted mean genotypic heritability (h^2_{mc} = 0.88) higher than the individual narrow-sense heritability (h^2_a = 0.45) and the additive heritability within plots (h^2_{ad} = 0.30) (Table 2). The heritability values for MBW (h^2_{mc} = 0.94; h^2_a = 0.95; h^2_{ad} = 0.96) and NB (h^2_{mc} = 0.92; h^2_a = 0.69; h^2_{ad} = 0.55) were higher than those of TBY, and the MBW superior to NB. These parameters indicate favorable conditions for gains both for the selection of progenies and for the selection of plants for cloning. In the first two years of production of the same experiments, Gomes Junior et al. (2014) observed higher genetic variability and heritability than recorded in this study. This can be explained by the lower competition between plants in the early development stages, when still only part of the cultivation area is occupied and by the lower environmental effect in the early years of evaluation (Sparnaaij 1969). However, for accurate estimates of the yield potential of progenies in the mature stage of the trees, at least four years of evaluation of already mature plants are required, as of the sixth year after planting (Chia et al. 2009).

The high genetic variability of the evaluated progenies can be explained by the wide genetic base, primarily from American oil palm parents, whose sub-samples were obtained from open-pollinated bunches of natural populations. Similar results with high heritability in HIE OxG were presented by Gomes Junior et al. (2014) and Lopes et al. (2012), with higher heritability values among families than within families and with higher or equal heritability of MBW as the NB. High heritability estimates for NB (0.78), MBW (0.88) and TBY (0.70) were also reported by Okwuagwu et al. (2008) for an oil palm population with wide genetic variability. In the same study however, lower values were observed for two other populations (0.27 and 0.05 for NB, 0.41 and 0.32 for MBW and 0.24 and 0.20 for TBY). For the oil palm progenies Nigerian dura x AVROS pisifera, low heritability values for TBY and high values for MBW and NB were observed (Marhalil et al. 2013). For oil palm, Soh et al. (2003) reported heritability values of 0.22 to 0.36 for TBY, NB and MBW. In a study

Table 2. Estimates of genetic parameters for bunch yield components, from the 3rd to 6th year after planting of 42 interspecific hybrids of American oil palm x oil palm

	Bunch yield (kg plant^{-1} year^{-1})	Number of bunches	Mean bunch weight (kg bunch^{-1})
V_g	211.98	45.44	0.95
V_{parc}	29.26	3.56	0.04
V_{int}	0.92	0.09	0.03
V_{dentro}	702.57	82.08	0.99
V_f	944.72	131.18	2.01
h^2_a	0.45 ± 0.06	0.69 ± 0.07	0.95 ± 0.08
h^2_{ad}	0.30	0.55	0.96
h^2_{mc}	0.88	0.92	0.94
c^2_{parc}	0.03	0.03	0.02
c^2_{int}	0.001	0.0007	0.01
Overall mean	144.07	61.38	8.22

V_g: genotypic variance among full-sib progenies, equal to (1/2) of the additive genetic variance plus (1/4) of the genetic variance of dominance, ignoring epistasis; V_{plot}: environmental variance among plots; V_{int}: variance of genotype - environment interaction; V_{within}: residual variance within plots; V_{ph}: individual phenotypic variance; h^2_a: individual heritability in the strict sense, ignoring the fraction (1/4) of the genetic variance of dominance; h^2_{ad}: additive heritability within plot, ignoring the fraction (1/4) of the genetic variance of dominance; h^2_{mc}: adjusted mean genotypic heritability, assuming 100% survival; c^2_{plot}: coefficient of determination of the plot effects; c^2_{int}: coefficient of determination of the effects of genotype - environment interaction.

of 40 oil palm progenies Deli dura x AVROS pisifera, low levels of genetic variation coefficient and heritability were observed (Noh et al. 2010). The heritability values for NB, TBY and MBW obtained from oil palm vary from low to high, and this variation resulting from the study population, reaching the highest values in populations with greater genetic variability, and also due to differences in the environmental impact of each experiment. The values recorded for the HIE OxG populations with high variability corroborated the results observed in oil palm.

The genetic correlations between yield-related traits were medium ($TBY \times NB$ = 0.3±0.021) to high ($TBY \times MBW$ = 0.53±0.19; $NB \times MBW$ = –0.61±0.018) all of which were statistically significant. In a study based on the first two years of production of the same population, Gomes Junior et al. (2014) showed high correlation values between TBY and MBW (0.96), TBY and NB (0.95) and MBW and NB (-0.95). The results indicate that the increase in NB and MBW was associated with the increase in TBY, and that due to the negative association between NB and MBW, a gain in one induces a reduction in the other trait. Thus, the highest TBY is expected in genotypes with a better balance between NB and MBW, i.e., which have satisfactory or good results of both traits simultaneously. In the development of cultivars, genotypes with a very high MBW should be avoided, which can cause operational problems because the harvesting and manual loading of bunches is hampered, and the greater difficulty of industrial processing. Comparatively, Lopes et al. (2012) reported a high positive correlation (0.52) between TBY and MBW and between TBY and NB (0.84) in HIE OxG, and almost zero between NB and MBW (0.06). High and positive correlations between NB and TBY (0.68 to 0.86) were found in oil palm populations evaluated by Okwuagwu et al. (2008) and of 0.65 in a study of Okoye et al. (2009). Positive, low to medium correlations (0.18 to 0.24) between MBW and TBY were found in the populations studied by Okwuagwu et al. (2008), and 0.21 in the population evaluated by Okoye et al. (2009). For the correlation between NB and MBW, negative, mean to high values were observed in the study of Okwuagwu et al. (2008) (-0.22 and -0.37) as well as of Okoye et al. (2009) (-0.57).

The phenotypic value (FV) for TBY between the 3rd and 6th year after planting in the 42 progenies ranged from 127.55 to 184.25 kg plant^{-1} yr^{-1} and the genotypic value (GV) from 117.05 to 173.63 kg plant^{-1} yr^{-1}, highlighting the performance of the progenies RUB 1199, RUB 1209, RUB 1218, RUB 1232, and RUB 1205, with genotypic values of 173.63, 165.97, 163.82, 161.55, and 157.95 kg plant^{-1} yr^{-1}, respectively (Table 3). In the evaluation of the first two years of production of the same population, Gomes Junior et al. (2014) identified the progenies RUB 1210, RUB 1274, RUB 1199, and RUB 1232 as the most productive.

With the selection of best-classified progeny (selection pressure of 2.4%) the estimated selection gain (SG) in TBY was 29.88 kg plant^{-1} yr^{-1} (20.8% of the overall mean) and the mean of the improved population 173.63 kg plant^{-1} yr^{-1}. The SG with the best five progenies (selection pressure of 11.9%) was 20.83 kg plant^{-1} yr^{-1} (14.5% of the overall mean) and the improved population mean 164.58 kg plant^{-1} yr^{-1}. At a selection pressure of 28.6%, i.e., selecting the 12 best progenies, the SG was 15.14 kg plant^{-1} yr^{-1}, 10.53% higher than the overall mean and the mean of the new population 158.89 kg plant^{-1} yr^{-1}. In the first and second reciprocal recurrent selection cycle for oil palm conducted by CIRAD, one of the most successful oil palm breeding programs in in the world, the SG was 18% (Gascon et al. 1988). Similar or higher SGs can be obtained at selection pressure of or higher than 11.9%, therefore, the potential of the HIE OxG population for breeding is promising. Reciprocal recurrent selection provided gains in distinct oil palm populations (Bakoumé and Louise 2007, Bakoumé et al. 2010, Noh et al. 2012) and should also be effective for breeding of HIE OxG.

Despite the high estimated selection gains in this study, the loss of genetic variability by selection should be avoided as well as the use of a small number of parents for the composition of future generations of breeding, since this could lead to a narrowing of the genetic base by reducing the effective population size, as was the case with the oil palm populations Delhi, La Mé, Yagambi and Avros (Corley and Tinker 2003). Higher selection pressures can be used for parents used in commercial seed production, i.e., for the release of cultivars, obtaining higher gains. However, to compose population of the following recurrent selection cycle, the selection pressure of the parents to be recombined should be lower, maintaining a high genetic variability in the breeding program to ensure future gains. Considering the possibility of cloning propagation, high gains can be achieved with the selection of superior trees. The mean PhV of the best 15 trees (selection pressure of 0.66%) for TBY was 226.0 kg plant^{-1} yr^{-1} (between 209.9 and 259.1 kg plant^{-1} yr^{-1}) and for GV, 187.4 kg plant^{-1} yr^{-1} (between 183.2 and 195.3 kg plant^{-1} yr^{-1}) (Table 4). The estimate of SG ranged from 43.35 (30.1%) to 51.24 (35.6%) kg plant^{-1} yr^{-1}, considering the selection of 15 trees and of the best tree, respectively. Because of the possibility of exploiting the genetic variability among and within progenies, the gains with individual selection are far superior to those obtained by selection of families that only explore the genetic variability among progenies. The progeny with highest TBY, RUB 1199, was also best represented among the best 15 trees. When considering the selection of the five trees with highest TBY, four (80%) are of the progeny RUB1199 (Manicoré x La Mé). When selecting the 10 best classified trees, seven (70%) are derived from this progeny, and among the 15 best classified trees, it accounts for 11 trees (73%).

Table 3. Phenotypic value (PhV), genotypic (GV) and selection gain (SG) for bunch yield, evaluated from the 3rd to 6th year after planting 42 progenies of interspecific hybrids of American oil palm x oil palm

Ranking	Progeny	PhV (kg plant^{-1} year^{-1})	GV (kg plant^{-1} year^{-1})	SG (kg plant^{-1} year^{-1})	SG (%)	New mean (kg plant^{-1} year^{-1})
1	RUB 1199	189.97	173.63	29.88	20.78	173.63
2	RUB 1209	181.53	165.97	26.05	18.12	169.80
3	RUB 1218	179.16	163.82	24.05	16.73	167.80
4	RUB 1232	176.82	161.55	22.49	15.64	166.24
5	RUB 1205	172.66	157.95	20.83	14.49	164.58
6	RUB 1274	171.58	156.77	19.53	13.58	163.28
7	RUB 1250	170.30	155.73	18.45	12.83	162.20
8	RUB 1195	155.24	155.22	17.57	12.23	161.33
9	RUB 1226	169.05	154.60	16.83	11.71	160.58
10	RUB 1283	168.92	154.48	16.22	11.28	159.97
11	RUB 1210	167.92	153.63	15.64	10.88	159.39
12	RUB 1219	167.72	153.35	15.14	10.53	158.89
13	RUB 1227	167.47	153.17	14.70	10.22	158.45
14	RUB 1200	166.96	152.63	14.28	9.93	158.03
15	RUB 1196	166.03	151.94	13.87	9.65	157.63
16	RUB 1215	165.63	151.55	13.49	9.39	157.25
17	RUB 1271	165.09	151.00	13.13	9.13	156.88
18	RUB 1198	163.45	149.60	12.72	8.85	156.48
19	RUB 1225	160.99	147.29	12.24	8.51	155.99
20	RUB 1231	160.88	147.19	11.80	8.21	155.55
21	RUB 1208	158.91	145.48	11.32	7.87	155.07
22	RUB 1224	157.12	143.91	10.81	7.52	154.57
23	RUB 1212	156.47	143.25	10.32	7.18	154.07
24	RUB 1214	156.20	143.01	9.86	6.86	153.61
25	RUB 1197	154.45	141.45	9.37	6.52	153.13
26	RUB 1206	153.93	140.98	8.91	6.2	152.66
27	RUB 1217	153.15	140.25	8.45	5.88	152.20
28	RUB 1202	152.09	139.37	7.99	5.56	151.74
29	RUB 1233	148.78	136.24	7.45	5.19	151.21
30	RUB 1211	148.20	135.76	6.94	4.83	150.69
31	RUB 1237	147.69	135.19	6.44	4.48	150.19
32	RUB 1194	134.23	134.15	5.94	4.13	149.69
33	RUB 1201	143.22	131.19	5.38	3.74	149.13
34	RUB 1277	142.04	130.12	4.82	3.35	148.57
35	RUB 1213	129.55	129.52	4.27	2.97	148.03
36	RUB 1220	137.51	126.34	3.67	2.55	147.42
37	RUB 1204	137.42	126.01	3.09	2.15	146.85
38	RUB 1223	134.14	123.05	2.47	1.72	146.22
39	RUB 1203	133.50	122.85	1.87	1.30	145.62
40	RUB 1193	131.63	120.98	1.25	0.87	145.00
41	RUB 1234	131.31	120.40	0.65	0.45	144.40
42	RUB 1221	127.55	117.05	0.00	0.00	143.75

The Embrapa breeding program also addresses the introgression of American oil palm germplasm into oil palm for to breed high-yielding, resistant BR and highly fertile genotypes, since the HIE OxG are only partially fertile and require assisted pollination to fully express their yield potential, which increases production costs. Therefore, it is also of interest to select HIE OxG F1 trees with high GV as parents in backcrosses of the program. Table 5 shows the 15 trees with highest GV, considering additive effects for TBY. The PhV ranged from 209.94 to 259.14 kg plant^{-1} yr^{-1} and GV 179.86 to 189.12 kg plant^{-1} yr^{-1}. The progeny with the highest number of trees among the 15 with highest GV was RUB 1199, with 12 trees, with a particularly good performance of the five trees with highest GV.

All progenies and trees selected in this study are Manicoré x La Mé, while the other sources tested had low performance. The progenies RUB 1193 and RUB 1194 derived from (Manicoré x São Bartolomeu) x La Mé, ranked 40th and 32nd in the genotypic value of the family, respectively (Table 3). Progeny RUB 1237 (Coari x La Mé) ranked 31st. However, it must be

Table 4. Phenotypic value (PhV), genotypic value (GV) and selection gain (SG) (all of them in kg plant^{-1} year^{-1}) of the 15 best trees for cloning propagation, based on bunch yield, evaluated from the 3rd to 6th year after planting in 42 progenies of interspecific hybrids of American oil palm x oil palm

Ranking	Tree* (row plant)	Progeny	PhV	GV	SG	SG (%)	New mean
1	113/04	RUB 1199	238.57	195.32	51.25	35.57	195.32
2	127/17	RUB 1199	235.74	192.86	50.02	34.72	194.09
3	036/20	RUB 1250	259.14	192.47	49.48	34.34	193.55
4	108/23	RUB 1199	230.57	191.39	48.94	33.97	193.01
5	111/25	RUB 1199	224.00	188.62	48.06	33.36	192.13
6	067/24	RUB 1209	234.23	188.57	47.47	32.95	191.54
7	124/19	RUB 1199	224.74	188.21	44.14	30.64	188.21
8	068/25	RUB 1218	232.17	186.73	46.45	32.24	190.52
9	104/05	RUB 1199	211.80	184.64	45.80	31.79	189.87
10	124/17	RUB 1199	215.54	184.33	45.24	31.40	189.31
11	045/02	RUB 1274	238.57	184.19	44.78	31.08	188.85
12	109/25	RUB 1199	213.06	183.99	44.37	30.80	188.44
13	112/02	RUB 1199	210.46	183.44	43.99	30.53	188.06
14	109/24	RUB 1199	211.46	183.32	43.65	30.30	187.72
15	113/02	RUB 1199	209.94	183.22	43.35	30.09	187.42

* Identified according to their location row/plant in the commercial plot C22 of the company Marborges Agroindústria S.A.

Table 5. Phenotypic (PhV) and genotypic value (GV) of the 15 best classified trees as potential parents for bunch yield evaluated from the 3rd to 6th year after planting in 42 progenies of interspecific hybrids of American oil palm x oil palm

Ranking	Tree* (row plant)	Progeny	PhV (kg plant^{-1} year^{-1})	GV (kg plant^{-1} year^{-1})
1	113/04	RUB 1199	238.57	189.12
2	127/17	RUB 1199	235.74	187.37
3	108/23	RUB 1199	230.57	186.32
4	111/25	RUB 1199	224.00	184.33
5	124/19	RUB 1199	224.74	184.05
6	067/24	RUB 1209	234.23	182.11
7	036/20	RUB 1250	259.14	181.97
8	104/05	RUB 1199	211.80	181.49
9	124/17	RUB 1199	215.54	181.27
10	109/25	RUB 1199	213.06	181.03
11	112/02	RUB 1199	210.46	180.64
12	109/24	RUB 1199	211.46	180.55
13	113/02	RUB 1199	209.94	180.48
14	068/25	RUB 1218	232.17	180.19
15	124/18	RUB 1199	210.86	179.86

* Identified according to their location row/plant in the commercial plot C22 of the company Marborges Agroindústria S.A.

emphasized that the sample to compare these origins was restricted. In 2010, Embrapa carried out another progeny test of HIE OxG, where the origins Coari and Tonantins were represented by more families, to detect the presence of good American oil palm parents in different origins.

The TBY of the best progeny was 24.83 t ha^{-1} yr^{-1} of FFB, while the mean of the best five progenies was 23.54 t ha^{-1} yr^{-1} of FFB. The performance of the best plant, a potential parent for cloning, had a TBY of 27.93 t ha^{-1} yr^{-1} of FFB, and the mean TBY of the 15 trees with best performance was 26.80 t ha^{-1} yr^{-1} of FFB. According to Lopes et al. (2012), the most productive adult HIE OxG trees, from the sixth year after planting, produced yields between 26.1 and 31.6 t ha^{-1} yr^{-1} of FFB. Oil palm production begins in the third year after planting, increasing gradually until the sixth/seventh year. In a comparison of the productivity of the best progenies and best HIE OxG trees of this study in the young stage, before reaching the yield plateau of the crop, the population seems highly promising and the genetic gain is expected to exceed the productivity of the current HIE OxG cultivars. In the coming years, the oil extraction rate of the progenies should be assessed, and measurements of the TBY, NB and MBW continued as a basis for yield estimates of the adult tree stage.

The population has a high genetic variability for bunch yield components with favorable conditions for the development of new cultivars, both for the selection of progenies and of trees for cloning or as parents in backcrosses.

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