PERFORMANCE OF SOME *PISIFERA*S OF BINGA, EKONA, URT AND ANGOLAN ORIGINS: PART 2 – FRUIT BUNCH YIELDS, VEGETATIVE GROWTH AND PHYSIOLOGICAL TRAITS

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ABSTRACT

Pisifera*s of Binga (Congo), Ekona (Cameroon) and URT origins were progeny tested with Deli, African and African x Deli* dura*s in two trials. The widely used AVROS* pisifera*s were included as controls. In the first trial, the DxP progenies of an AVROS* pisifera *gave the highest fruit bunch and oil yields. Two Ekona and one Binga* pisifera *gave DxP progenies with estimated oil equivalent yields, or EOE (palm oil yield plus 60% of the kernel yield) within 10% of, and not significantly lower than AVROS. The other Binga and all the URT* pisifera*s tested gave poorer DxP progenies, with generally lower fresh fruit bunch (FFB) yield or bunch oil content or both. In the poorer environment of the second trial, the four best* pisifera*s were two from Ekona and one each from Binga and URT.*

For vegetative growth, URT DxP were the smallest - short with fewer and shorter fronds of small leaf area. The Ekona DxP progenies were the opposite with longer fronds of larger leaf and petiole cross-sectional areas. Although the latter produced similar numbers of fronds in both trials, their rankings by pisifera*s differed considerably. The AVROS DxPs were the tallest palms, confirming widespread observation of this characteristic of AVROS. The DxP of the different Binga* pisifera*s differed considerably for height, trunk diameter, rachis length, petiole cross-sectional and leaf areas but not for frond production for which they were the highest. This intra origin variation was also observed, albeit to a lesser extent, in all the origins but for different traits.*

The DxP of Ekona pisifera*s produced the most dry matter, whether vegetative or reproductive, those of URT the least while those of Binga varied considerably. Though both the Ekona and AVROS DxP progenies had similar leaf areas, the former with their large petioles had more dry matter supporting it. The progenies of URT* pisifera*s were low and those of Binga average for leaf area index and leaf area ratio.*

Keywords: *Elaeis guineensis*, *pisifera*s, origins, progeny testing.

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INTRODUCTION

Palm oil, is the second most important edible oil in the world. Like olive oil, it comes from the mesocarp of the fruit. This tropical palm produces the most oil of all crops. This inherent (natural) high yield has been further improved through breeding for better yielding *tenera* – a palm type bearing fruits with a thin-shell and small kernel and, hence, more oil-rich mesocarp. *Tenera* hybrids are produced by crossing *dura*s, or thick-shell palms, with tested *pisifera*s, or shell-less palms.

*Pisifera*s are generally female sterile and do not set seed and are hence, used exclusively as the male parents. As each palm produces copious amounts of pollen, a single *pisifera* suffices to pollinate a large number of *dura* palms as the female parents. Considerable effort is therefore made to identify the best *pisifera* palms to *father* the many *tenera* hybrid seeds required in commercial planting.

*Pisifera*s can only be selected based on the performance of their progenies because of their female sterility. Each *pisifera* is crossed to a number of *dura*s and the average performance of its DxP progenies gives an estimate of its general combining ability (GCA). In Part 1 of this communication (Lim *et al.*, 2003), we presented the progeny test data for fruit and bunch traits for four important groups of *pisifera*s. In this paper, we follow up by presenting the data for yield, vegetative growth and physiological traits. The four groups - Binga, Ekona, URT (Ulu Remis *Tenera* – a *tenera* population derived from crossing Deli *dura*s with pollen of Congo origin) and Angola - are of diverse origins and part of Pamol's genetic collection. As a *control* for comparison, the widely used AVROS (Allegumme Verening Rubber Oest kost Sumatra. A Dutch colonial organization in Sumatra that developed the AVROS *pisifera*s) *pisifera*s were included as a fifth group. These groups are also referred to interchangeably as origins or populations.

TRIAL DETAILS

The large number of crosses involved required planting in three sites at Pamol, Kluang, Malaysia in 1992. Trial 13A was planted on Rengam series soil, 13B on Beserah soil and 13C on mixed Rengam/Beserah soils. Rengam and Beserah are red-yellow rhodic nitisol and ferralsol respectively, developed from igneous rocks. As Rengam soil is naturally more fertile, a direct comparison between the trials would be biased. To avoid this bias (confirmed by a preliminary analysis of the data), it was decided to combine the three trials into two, *i.e.* Trial 13A by itself, and Trial 13B and Trial 13C together into Trial 13BC. The following traits were measured.

Yield

Oil palm usually starts fruiting about 27 months after field planting, but as these trials were underplanted, bearing started later. Thus, yield recording only commenced at 36 months (Chia *et al*., 2001). Further, because of the greater yield variability at the onset of production, only the yield from 48 months was used in this paper. Four years of FFB yield from July 1996 to June 2000 are reported.

The bunch analysis data are from Lim *et al*. (2003). The oil yield is the product of FFB and oil/bunch (O/B) while the EOE is the palm oil yield plus 60% of the kernel yield to as an approximation of kernel oil production.

Growth and Vegetative Measurements

The growth and vegetative traits were measured following Corley and Breure (1981). A common standard, Frond 1 (the youngest fully opened frond), was used for all the palms and marked at 5.5 and 7.5 years after field planting and measurements done the following year to the new Frond 1. The frond production and height increment are the new fronds produced and the height attained since the last marking.

Palm height increment was taken only once as studies in Indonesia found that height increment is rather constant after 3.5 years (Corley, 1991). The rachis length, petiole cross-section and leaf areas were taken on Frond 17, also the commonly used reference frond for such measurements. Trunk diameter was taken at 1.5 m above the ground level after removing the frond bases.

Physiological Traits

The non-destructive estimates of dry weights followed Corley and Breure (1981). Total dry matter (TDM), trunk dry matter (TrDM), bunch dry matter (BDM) and leaf dry matter (LDM) were estimated.

The bunch index (BI), similar to harvest index, is the ratio of the dry weight of the fruit to TDM production. Leaf area ratio (LAR) is the ratio of leaf area to its weight and is an index of the partitioning of vegetative dry matter into photosynthetic and non-photosynthetic tissues (Hardon *et al*., 1972). The crop growth rate (CGR) is the estimated annual TDM production per hectare while the leaf area index (LAI) is the ratio of the total leaf area to ground area covered.

EXPERIMENTAL MATERIALS

Details of the *pisifera*s and *dura*s in this progeny testing are given in Lim *et al*. (2003). A summary of the *pisifera* groups, families within each group and individual palms involved is given in *Appendix 1*.

RESULTS

Fresh Fruit Bunch (FFB) Components and Oil Yield

The progeny test results of the key traits - FFB, bunch number, bunch weight, O/B, kernel/bunch (K/B), oil yield (OY) and EOE (arranged by *pisifera*) - are shown in *Tables 1* and *2* for Trials 13A and 13BC respectively.

In Trial 13A, AVROS DxP gave the highest EOE yield, obtained from high FFB and high O/B. The DxP of Ekona *pisifera*s ranked next with a slightly, but not significantly lower, EOE. They had a smaller kernel than the DxP of the other *pisifera*s. The DxP from the two URT *pisifera*s were low in EOE from fewer bunches and low O/B although with high K/B. Of the three Binga *pisifera*s, the DxP of Bg142/B101/33 had a significantly lower EOE from low FFB and small bunches. Compared to the DxP of the AVROS and Ekona *pisifera*s, those of the URT *pisifera*s and Bg142/B101/33 had significantly lower FFB and EOE. The Angolan DxP, keeping in mind that it is represented by only one *pisifera* in these trials, had the highest bunch number and smallest bunch weight but its FFB was not significantly different from those of AVROS and Ekona DxP. Nevertheless, it had a lower EOE due to a low O/B.

In Trial 13BC, for FFB the DxP of several *pisifera*s of the other origins out-yielded AVROS DM742.316. For EOE, the best of the 20 *pisifera*s tested were of Ekona origin, namely Lb158/12/12433 and PSh1021/3169. Their DxP progenies had high FFB due to many moderately large bunches with superior O/B. However, Ekona *pisifera* Lb158/12/12440 produced DxP with low FFB because of low bunch number. Binga *pisifera*s gave DxP with average EOE except for PKg111/26/02 whose DxP had high EOE. Generally, DxP from the URT *pisifera*s (except for PSh1037/4295), had low FFB and EOE compared to that of the Ekona *pisifera*s.

Within the Binga, Ekona and URT origins, two to three families of each *pisifera* were tested *(Table 2)*. The differences between the families indicated the variation within each origin although it must be borne in mind that two to three families is a small number to describe an origin in any large sense other than as a breeding population of restricted origin (BPRO) as defined by Rosenquist (1986).

TABLE 1. YIELDS* AND YIELD COMPONENTS OF DxP PROGENIES OF *PISIFERA*S OF FIVE ORIGINS (Trial 13A)

Origin	*Pisifera*	FFB	Bunch No.	Bunch wt.	Oil/ bunch	Kernel/ bunch	Oil yield	EOE yield
AVROS	DM742.316	142 a**	16.1 cd	8.8 ab	25.5 a	5.4 bcd	36.2 a	40.7 a
Ekona	Lb158/12/12640	133 a	14.3 e	9.3 a	25.8 a	4.1 e	34.3 ab	37.5 ab
Ekona	PSh1019/2949	138 a	17.4 cd	7.9 cd	24.2 b	3.9 e	33.5 ab	36.7 ab
Binga	PKg111/16/01	132 a	15.8 d	8.3 bc	24.1 b	6.1 a	31.6 b	36.4 ab
Binga	Bg142/B062/04	132 a	17.6 b	7.5 de	23.6 bc	5.3 cd	31.1 b	35.3 b
Angola	Lb135/12/2709	132 a	20.1 a	6.6 g	22.8 cd	5.5 bc	29.9 b	34.2 bc
URT	PSh1042/4313	114 b	16.0 d	7.1 ef	22.2 d	5.8 ab	25.4 c	29.3 cd
URT	PSh1037/4252	111 b	12.4 f	9.0 ab	20.6 e	6.2 a	22.9 c	27.0 d
Binga	Bg142/B101/33	93 c	14.9 de	6.2 g	23.5 cd	4.9 d	21.9 c	24.6 d
Trial mean		125	16.0	7.9	23.8	5.2	29.9	33.7

Notes: *FFB: mean FFB (kg palm^{-1} yr^{-1}); Oil yield: oil in kg palm^{-1} yr^{-1}; EOE yield: palm oil yield + 60% kernel production in kg palm^{-1} yr^{-1}.
** Means followed by the same letter are not significantly different at the 5% level.

TABLE 2. YIELDS* AND YIELD COMPONENTS OF DxP PROGENIES OF *PISIFERA*S OF FIVE ORIGINS (Trial 13BC)

Origin	*Pisifera*	FFB	Bunch No.	Bunch wt.	Oil/ bunch	Kernel/ bunch	Oil yield	EOE yield
Ekona	Lb158/12/12433	146 a**	19.2 ab	7.6 abcd	26.4 a	4.2 hi	38.6 a	42.2 a
Ekona	PSh1021/3169	137 ab	19.9 bc	6.9 efgh	24.8 bc	5.6 cdef	33.8 ab	38.4 ab
Binga	PKg111/26/02	133 ab	16.9 cd	7.9 abc	24.1 bcd	6.4 ab	32.2 bc	37.3 abc
URT	PSh1037/4295	133 abc	17.7 bcd	7.5 bcde	23.6 bcde	6.1 bcd	31.5 bcd	36.3 abcd
Binga	PKg111/21/08	128 abcd	17.7 bcd	7.2 cdef	23.0 def	6.3 ab	29.5 bcde	34.3 bcde
Ekona	PSh1021/3207	131 abc	20.2 a	6.5 gh	22.5 efg	4.2 hi	29.4 bcde	32.6 bcdef
AVROS	DM742.316	113 cdef	13.9 gh	8.2 ab	25.0 ab	5.3 efg	28.3 cdef	31.9 cdefg
URT	PSh1042/4344	117 bdef	18.6 abc	6.3 gh	22.7 defg	6.2 abc	26.7 defg	31.1 defgh
Binga	Bg271/E046/17	118 bcde	18.5 abc	6.4 gh	22.8 defg	5.5 defg	27.0 cdefg	30.9 defgh
Binga	PKg111/21/14	105 ef	12.6 gh	8.4 a	23.3 def	6.3 abc	24.5 efg	28.4 efgh
Binga	PKg111/26/07	108 ef	16.1 cde	6.7 fgh	22.4 efg	6.0 bcd	24.4 efg	28.3 fgh
Binga	Bg142/B116/12	109 def	14.3 efg	7.7 abcd	22.2 fg	5.8 bcde	24.2 efg	28.0 fgh
Ekona	Lb158/12/12440	108 ef	15.8 def	6.8 efgh	23.0 def	4.9 fg	24.8 efg	28.0 fgh
URT	PSh1042/4350	108 ef	16.0 def	6.8 efgh	22.5 efg	5.2 efg	24.5 efg	27.9 fgh
AVROS	DM742.112	103 ef	13.2 gh	7.8 abc	24.1 bcd	4.8 gh	24.7 efg	27.7 fgh
URT	PSh0984/171	100 ef	12.0 h	8.3 a	23.3 def	6.9 a	23.5 fg	27.7 fgh
URT	PSh0984/175	107 ef	15.7 def	6.8 efgh	23.4 cdef	3.7 hi	25.2 efg	27.5 fgh
URT	PSh1037/4292	107 ef	14.5 efg	7.4 cdef	21.4 g	6.1 bcd	23.1 fg	27.0 fgh
URT	PSh0984/165	101 ef	14.5 efg	6.9 defg	22.6 efg	5.5 defg	22.9 g	26.3 gh
Binga	Bg142/B079/19	99 f	16.1 de	6.1 h	22.1 fg	5.8 bcde	21.8 g	25.2 h
Trial mean		115	16.1	7.2	23.3	5.5	26.9	30.7

Notes: *FFB: mean FFB (kg palm^{-1} yr^{-1}); Oil yield: oil in kg palm^{-1} yr^{-1}; EOE yield: palm oil yield + 60% kernel production in kg palm^{-1} yr^{-1} .
** Means followed by the same letter are not significantly different at the 5% level.

The Binga *pisifera* families were Bg142, PKg111 and Bg271. Overall, the DxP progenies of PKg111 *pisifera*s had the best FFB, mainly due to larger bunches. The single *pisifera* of Bg271 gave progenies with the highest bunch numbers but low bunch weight while the progenies from Bg142 *pisifera*s had only average bunch weight.

Perhaps because the two Ekona *pisifera* families, Lb158 and PSh1021, were half sibs, the FFB production of their DxP progenies were comparable but, interestingly, from opposite contributions - the *pisifera*s of Lb158 gave DxP with bigger but fewer bunches, whereas the DxP of PSh1021 *pisifera*s had more but smaller bunches.

Like in the Ekona families, the three URT families, PSh0984, PSh1037 and PSh1042, were half sibs. The FFB production of the DxP of PSh1037 and PSh1042 *pisifera*s was comparable except that in the former, the bunches were fewer but bigger. The DxP yield of PSh0984 *pisifera*s was the lowest due to very low bunch numbers.

Within some families, the sib *pisifera*s differed considerably in their DxP progeny performance. In Trial 13A for example, the DxP of *pisifera* Bg142/B101/33 were (to indicate more than one DP progeny or more than one DP palm within a progeny) markedly inferior with fewer and smaller bunches compared to the DxP progenies of *pisifera* Bg142/062/04, and similarly between *pisifera*s 12/12433 and 12/12440 of Lb158. The *pisifera*s of family PKg111 in Trial 13BC showed even more contrasting sib differences, as exemplified by the large differences in both bunch number and bunch weight. *Pisifera*s PKg111/26/02 and PKg111/26/08 for example, gave DxP with good FFB from high bunch number and good bunch weight whereas the DxP of PKg111/21/14 had low FFB from low bunch number despite large bunches. Among the three URT *pisifera* families, PSh0984 showed more intra family DxP progeny variation for bunch weight than PSh1037 and PSh1042. On the other hand, within Ekona and AVROS, the families PSh1021 and DM742 showed less intra family DxP progeny variation.

As for female parents, the African *dura*s were generally superior to Deli *dura*s for FFB production as their DxP produced more, albeit smaller, bunches *(Table 3)*. The high bunch weight of the DxP from the mixed *dura* family, PKg208, is not surprising as one of its grandparents was of Deli origin. The progeny, PKg256, of Yaligimba x Pobe origin, produced the smallest bunches, a well-known feature of the Pobe palms and their derivatives.

TABLE 3. INFLUENCE OF FEMALE PARENTS ON THE FRESH FRUIT BUNCH (FFB)* YIELD OF DxP PROGENIES (Trial 13BC)

Dura	Female family	N	FFB	Bunch No.	Bunch wt.
Deli	PKg103	231	104.6 e**	12.7 hi	8.3 ab
Deli	PKg106	211	101.7 e	11.9 I	8.5 a
Deli	PKg108	322	114.3 cde	16.4 de	7.0 fg
Deli	PKg117	236	104.5 e	13.7 gh	7.6 cde
Deli	PKg118	390	115.1 cde	14.5 fg	7.9 bc
Deli	PKg119	236	115.0 cde	15.5 ef	7.4 def
Deli x African	PKg208	48	143.3 a	18.6 abc	7.7 cd
African	PKg217	81	127.6 bc	19.2 ab	6.7 gh
African	PKg230	189	138.0 ab	19.4 a	7.1 efg
African	PKg231	364	118.9 cd	17.7 cd	6.7 gh
African	PKg240	192	125.0 bcd	17.9 bc	7.0 fg
African	PKg256	176	115.7 cde	18.2 abc	6.4 h
African	PKg259	178	110.9 de	15.8 ef	7.0 fg
Mean pure Deli		1 626	111.0	14.4	7.8
Mean African & mixed		1 228	122.8	18.1	6.8
Trial mean		2 854	115.8	15.9	7.4

Notes: * FFB: mean FFB (kg palm^{-1} yr^{-1}); Bunch No.: mean bunch number; Bunch wt.: mean bunch wt. (kg)
**Means followed by the same letter are not significantly different at the 5% level.
n: number of palms.

Vegetative and Growth Measurements

Rachis length (RL), petiole cross-section area (PxS) and leaf area (LA). The Angolan and most of the URT DxP progenies had small fronds - short with small leaf areas though large petioles. The former, tested only in Trial 13A, had the smallest leaf area of all the progenies in the trial *(Tables 4* and *5)*. Although the URT *pisifera*s generally produced fronds with smaller petioles, two of its crosses in Trial 13BC, PKg259/159 x PSh0984/175 and PKg231/02 x PSh0984/165, had large petioles *(Appendices 2* and *3)*.

In contrast, the Ekona DxP progenies generally had larger and longer fronds with very large petioles and large leaf areas. Nevertheless within the origin, the DxP of *pisifera* Lb158/12/12440 had small fronds except for progeny PKg103/34/16 x Lb158/12440, which had petioles of average size. *Pisifera* PSh1021/3207 also produced DxP progenies with small petioles.

The petiole cross-sectional area of AVROS DxP progenies in Trial 13A was average but, in Trial 13BC, the smallest. Within the Binga origin, the two families performed very differently. *Pisifera*s from PKg111 gave DxP progenies with large fronds and the longest rachis of all the families in both trials whereas the DxP progenies of *pisifera*s of the family Bg142 produced very small fronds.

Frond production (FP). The URT DxP progenies produced fewer fronds on average *(Tables 4* and *5)*,were the lowest in Trial 13BC and the lowest but one after Ekona in Trial 13A. The ranking of Ekona DxP progenies for FP differed considerably between Trials 13A and 13BC, being notably lower than the other origins in the former but average in the latter. The Angola, AVROS and Binga DxP progenies generally had higher FP. Interestingly, the Angolan *pisifera*, when crossed to sib Deli *dura* palms, produced DxP progenies that differed considerably for FP - progeny PKg108/12/15 x Lb135/12/2709 being average whereas PKg108/12/09 x Lb135/12/2709 had the second highest FP in Trial 13A. This suggests some specific combining ability (SCA). The Binga DxP progenies had the highest FP in both trials. Within the Ekona origin, the progeny PKg231/02 x Lb158/12/12433 had one of the lowest FP among all the crosses in Trial 13BC *(Appendices 2* and *3)*. Unlike the Ekona DxP, which had similar FP in both trials, the FP of the DxP progenies of the other origins was higher in Trial 13A than in Trial 13BC with its poorer growing conditions.

Height increment (HI). Height differences were generally very small between the progenies, especially in Trial 13BC. On average, the URT DxP progenies were the shortest in both trials *(Tables 4* and *5)* but within this origin, progeny PKg256/24/16 x PSh1037/4295 was of average height, and progenies PKg106/01/10 x PSh1042/4350 and PK259/159 x PSh1042/4350 were tall *(Appendix 2)*. Like URT, the Angola DxP progenies were also short. However, SCA effects may be involved as the Ekona DxP cross, PKg108/12/15 x Lb135/12/2709 gave

very short palms whereas the half-sib cross, PKg108/12/09 x Lb135/12/2709 were palms of average height *(Appendices 2* and *3)*.

The Binga DxP progenies were of average height in Trial 13A but among the shortest in Trial 13BC with exceptions - *pisifera* PKg111/26/02 and, within the family Bg142, progeny PKg256/24/16 x Bg142/79/19, gave tall palms.

The AVROS DxP progenies were the tallest palms in both trials, confirming the widespread observation of this characteristic. The Ekona DxP progenies were generally tall, some from the *pisifera*s of Lb158 in particular, but *pisifera*s Lb158/12/12440 and PSh1019/3207 produced short palms. Overall, height increment was higher in the better growing conditions of Trial 13A than in Trial 13BC.

Trunk diameter (TD). Etiolation may be the reason why in the better growing conditions in Trial 13A, the TD of the palms was generally smaller than that in Trial 13BC. The variation within each trial was small. The AVROS and Angolan DxP had a small TD with the former having the leanest trunks on average in both trials. The former were also the tallest as noted in the proceeding section. Within the AVROS family, *pisifera* DM742.316 produced DxP with smaller TD than its sib, DM742.112 *(Tables 4* and *5)*. However, there were exceptions. Progenies PKg108/22/04 x DM742.112 and PKg256/24/16 x DM742.112 had very small TD in both the trials *(Appendices 2* and *3)*.

The Ekona and Binga DxP progenies on the other hand, had a large TD but there were also differences within these origins. Within Ekona, *pisifera* PSh1019/2949 produced small palms, *i.e.* short with a small TD. One specific cross, PKg119/60/10 x PSh1019/2949, had the leanest palms of all the crosses in Trial 13A. Within the Binga origin, family PKg111 had a large TD compared to families Bg271 and Bg142 with average TD.

Physiological Traits: Trunk Dry Matter (TrDM), Leaf Dry Matter (LDM) and Vegetative Dry Matter (VDM)

The DxP of *pisifera*s from both the Angolan and URT origins had lower VDM from both less TrDM and LDM. AVROS DxP had high VDM in Trial 13A especially from high TrDM, but in Trial 13BC, it was the lowest for VDM from low LDM and particularly low TrDM. The DxP of Binga *pisifera*s were generally intermediate in both trials for VDM and its two components *(Tables 6* and *7)*.

Within each origin, the DxP of the different *pisifera*s performed somewhat differently for the mentioned traits. Of the two Ekona *pisifera*s in Trial 13A, for example, the DxP of PSh1019/2949 had lower VDM. The two URT *pisifera*s in Trial 13A were similar for the physiological traits of their DxP progenies, with those of PSh1037/4252 being only slightly more vigorous. However, there were more pronounced differences in Trial 13BC with the DxP of PSh1037/4295 being more vigorous than that of the other three URT *pisifera*s.

Total Dry Matter (TDM) and Bunch Index (BI)

Overall for TDM production, the DxP of Ekona *pisifera*s were the most productive and those of URT the least. Of the three Binga *pisifera*s in Trial 13A, their DxP, all with Deli *dura*s, and those of Bg142/B101/33 had low TDM production whereas the DxP of Bg142/B062/04 were quite similar to those of PKg111/16/01. In Trial 13BC, the DxP of both the Bg142 *pisifera*s had lower TDM production than those of PKg111 *pisifera*s. The DxP of Bg142/B079/19 had very low TDM including bunch production despite the female parents being mixed *dura*s.

The BI varied considerably in the good growing environment of Trial 13A, from 0.38 - 0.46, as against 0.42 - 0.48 in Trial 13BC. The DxP of Ekona *pisifera*s in Trial 13BC gave a much lower LDM than those in Trial 13A, resulting in the BI increasing from 0.44 to 0.48 between the two trials (*Tables 6* and *7*). Of all the Binga *pisifera*s, the DxP of PKg111/21/08 had the best BI. The DxP of the two Ekona *pisifera*s in Trial 13A had similar TDM but the BI of PSh1019/2949 DxP was better from higher yield and lower VDM. There were larger differences in Trial 13BC, with PSh1037/4295 DxP being more vigorous and having a higher yield and larger canopy than the other three URT *pisifera*s.

TABLE 4. VEGETATIVE TRAITS* OF DxP PROGENIES OF *PISIFERA*S FROM FIVE ORIGINS (Trial 13A)

Origin	*Pisifera*	RL	PxS	LA	FP	HI	TD
AVROS	DM742.316	5.14 bc**	22.70 cd	7.79 b	30.8 a	49.3 a	57.8 c
Binga	Bg142/B062/04	5.15 bc	22.28 cde	7.10 cd	31.0 a	43.0 bc	59.0 bc
Binga	Bg142/B101/33	4.55 d	20.56 def	6.19 e	28.8 b	33.8 d	60.8 abc
Binga	PKg111/16/01	5.41 a	24.08 c	7.63 bc	30.5 a	40.8 c	63.5 a
Ekona	Lb158/12/12640	5.38 a	30.54 a	8.77 a	27.5 c	47.0 ab	62.8 ab
Ekona	PSh1019/2949	5.34 ab	27.77 b	8.16 ab	27.8 bc	40.0 c	58.3 c
URT	PSh1037/4252	4.95 c	23.56 c	7.01 d	28.0 bc	39.0 cd	60.0 abc
URT	PSh1042/4313	4.72 d	19.88 ef	6.61 de	30.0 a	37.3 cd	59.5 bc
Angola	Lb135/12/2709	4.65 d	19.38 f	6.27 e	30.3 a	39.0 cd	59.3 bc
Trial mean		5.04	23.46	7.34	58.32	0.41	60.2

Notes: *RL: rachis length (m); PxS: petiole cross-section area (cm^2); LA: leaf area (m^2); FP: frond production; HI: height increment ($cm\ yr^{-1}$); TD: trunk diameter (cm).
** Means followed by the same letter are not significantly different at the 5% level.

TABLE 5. VEGETATIVE TRAITS* OF DxP PROGENIES OF *PISIFERA*S FROM FIVE ORIGINS (Trial 13BC)

Origin	*Pisifera*	RL	PxS	LA	FP	HI	TD
AVROS	DM742.112	4.66 efg**	19.55 ef	6.98 de	26.3 de	41.5 bcde	60.5 fg
AVROS	DM742.316	4.86 cde	18.86 f	7.39 abcd	27.8 ab	42.5 bcd	60.3 g
Binga	Bg142/B079/19	4.40 h	15.12 g	5.98 c	28.5 a	40.0 bcdefg	61.3 efg
Binga	Bg142/B116/12	4.64 efg	18.63 f	6.80 de	26.8 cd	40.0 bcdefg	61.3 efg
Binga	Bg271/E046/17	4.91 bcd	22.53 bcd	7.32 bcd	27.3 bc	38.3 bcdef	63.3 cdef
Binga	PKg111/21/08	5.24 a	20.76 def	8.11 ab	26.8 cd	37.5 defgh	66.3 ab
Binga	PKg111/21/14	4.95 bc	19.72 ef	7.50 abcd	26.8 cd	31.0 hi	65.0 bc
Binga	PKg111/26/02	5.14 ab	23.92 ab	7.78 abc	27.0 bcd	44.5 ab	65.5 abc
Binga	PKg111/26/07	4.94 bc	20.74 def	7.41 abcd	27.0 bcd	35.8 fghi	68.3 a
Ekona	Lb158/12/12433	5.12 ab	25.47 a	8.16 a	25.8 ef	49.5 a	64.5 bcd
Ekona	Lb158/12/12440	4.49 gh	18.87 f	6.42 ef	27.3 bc	33.5 hi	63.0 cdefg
Ekona	PSh1021/3169	4.97 bc	23.15 abc	8.07 ab	26.3 de	43.5 bc	64.0 bcde
Ekona	PSh1021/3207	4.62 fgh	18.53 f	6.86 de	27.8 ab	36.5 efghi	62.8 cdefg
URT	PSh0984/165	4.52 gh	20.36 def	6.36 ef	25.0 gh	37.3 defgh	62.0 defg
URT	PSh0984/171	4.58 gh	19.27 ef	6.45 ef	27.0 bcd	35.0 ghi	64.0 bcde
URT	PSh0984/175	4.57 gh	20.49 def	6.71 def	24.8 g	38.5 cdefgh	60.8 fg
URT	PSh1037/4292	4.67 efg	19.91 ef	6.44 ef	27.0 bcd	34.8 ghi	63.3 cdef
URT	PSh1037/4295	4.68 defg	19.35 ef	6.79 de	28.5 a	45.5 ab	60.5 fg
URT	PSh1042/4344	4.57 gh	20.47 def	6.38 ef	27.5 bc	36.8 efgh	62.0 defg
URT	PSh1042/4350	4.84 cdef	21.38 cde	6.99 cde	25.8 ef	41.3 bcdef	61.0 fg
Trial mean		4.77	20.33	7.05	53.1	0.39	62.9

Notes: *RL: rachis length (m); PxS: petiole cross-section area (cm^2); LA: leaf area (m^2); FP: frond production; HI: height increment ($cm\ yr^{-1}$); TD: trunk diameter (cm).
** Means followed by the same letter are not significantly different at the 5% level.

Crop Growth Rate (CGR), Leaf Area Index (LAI) and Leaf Area Ratio (LAR)

The DxP of Ekona origin had the highest rate of dry matter production or CGR in both trials. AVROS was next highest in Trial 13A but in Trial 13BC, it ranked the last but one. While the Ekona DxP progenies generally had a large LAI and a low LAR, the AVROS DxP progenies were consistently superior for the latter. Clearly, the Ekona DxP progenies had large leaf areas supported by considerable LDM whereas the equally large leaf areas of AVROS DxP were only supported by an average or small LDM.

The URT DxP progenies on average had lower CGR and LAI but the Binga DxP progenies had higher values for these measures of photosynthetic surface than the trial mean *(Tables 6* and *7)*.

Of the three Binga *pisifera*s in Trial 13A, the DxP of Bg142/B101/33 had low CGR, LAI and LAR on top of the low TDM and BI mentioned in the previous section. The DxP of Bg142/B079/19 had a very low CGR too. The DxP of the two Ekona *pisifera*s in Trial 13A were similar for CGR but those of PSh1042/4313 had somewhat lower LAI and LAR. There were larger differences among the DxP progenies of URT *pisifera*s in Trial 13BC, the DxP of PSh1037/4295 has the largest canopy among the other three *pisifera*s.

DISCUSSION

Since a single *pisifera*, or male parent palm provides sufficient pollen to pollinate several female *dura* parents, any *pisifera* used for breeding must be carefully selected. The superiority can be in yield from FFB production or O/B, or both, or from desirable vegetative and growth characteristics.

The test results of all the DxP progenies for the key traits – FFB production, O/B, K/B, OY and EOE - are shown in *Appendices 2* and *3* and their summaries by origin in *Tables 8* and *9*. The results from 13A and 13BC are presented separately because of location effects.

The high FFB yields of the AVROS DxP progenies and their superior bunch oil content, both evident in Trial 13A *(Table 8)*, explain the continued popularity of AVROS *pisifera*s for commercial DxP seed production. The high FFB is due to many large bunches while the superior bunch oil content is because the fruits have a very thick oil-rich mesocarp, traits for which AVROS is well-known. Also well-known, and evident in Trial 13A, are the thin trunks and rapid HI of AVROS DxP, resulting in a high trunk dry matter. The fourth characteristic of AVROS, *i.e.* thin rachis, resulted in the DxP having the highest LAR in our trials. Similarly, the high FFB production means high BDM and a good BI while the overall vigour of AVROS DxP, in both crop production and HI and with high frond production is reflected in the high CGR.

The ranking of *pisifera* origins for FFB yield in Trial 13BC differed from that in Trial 13A. Where DM742.316 was the best *pisifera* in Trial 13A, several *pisifera*s of other origins out yielded it by ≥15% in Trial 13BC *(Tables 1* and *2)*. The most likely explanation for this was simply that the other *pisifera*s were better in the latter trial. An alternative explanation could be that the AVROS material was more affected by the poorer growing conditions, but this could not be tested as there were no common *pisifera*s between the trials.

TABLE 6. PHYSIOLOGICAL TRAITS* OF THE DxP PROGENIES OF ANGOLA, BINGA, EKONA AND URT *PISIFERA*S (Trial 13A)

Origin	*Pisifera*	TrDM	LDM	VDM	TDM	BI	CGR	LAI	LAR
AVROS	DM742.316	18.4 abc**	76.8 bc	95.1 bc	171.1 b	0.44 ab	23.6 ab	4.3 b	2.5 a
Binga	Bg142/B062/04	16.8 bcd	76.6 bc	93.4 bc	163.3 bc	0.43 bc	22.5 bc	3.9 cd	2.3 abc
Binga	PKg111/16/01	18.5 ab	81.1 b	99.6 b	170.8 ab	0.42 bc	23.6 ab	4.2 bc	2.3 bc
Binga	PKg142/B101/33	13.9 e	65.9 d	79.8 d	128.2 e	0.38 e	17.7 e	3.4 e	2.2 cd
Ekona	Lb158/12/12640	20.7 a	91.4 a	112.1 a	182.4 a	0.39 de	25.2 a	4.8 a	2.1 d
Ekona	PSh1019/2949	15.1 de	83.6 ab	98.8 b	172.2 ab	0.43 bc	23.8 ab	4.5 ab	2.3 bcd
URT	PSh1037/4252	15.7 cde	72.1 cd	87.7 cd	147.3 cd	0.41 cd	20.3 cd	3.9 cd	2.2 cd
URT	PSh1042/4313	14.8 de	66.7 d	81.5 d	142.0 de	0.43 bc	19.6 de	3.7 de	2.4 ab
Angola	Lb135/12/2709	15.4 de	66.0 d	81.4 d	151.6 cd	0.47 a	20.9 cd	3.5 e	2.3 bc
Trial mean		16.8	75.7	92.5	159.1	0.42	22.0	4.1	2.3

Notes: *TrDM: trunk dry matter (kg palm^{-1} yr^{-1}); LDM: leaf dry matter (kg palm^{-1} yr^{-1}), VDM: vegetative dry matter (kg palm^{-1} yr^{-1}), TDM: total dry matter (kg palm^{-1} yr^{-1}); BI: bunch index (ratio of BDM to TDM); CGR: crop growth rate (t ha^{-1} yr^{-1}), the annual dry matter production; LAI: leaf area index, ratio of leaf area to area of ground covered by the canopy; LAR: leaf area ratio (m^2 kg^{-1}), ratio of leaf area to leaf weight.
**Means followed by the same letter are not significantly different at the 5% level.

TABLE 7. PHYSIOLOGICAL TRAITS* OF THE DxP PROGENIES OF BINGA, EKONA AND URT *PISIFERA*S (Trial 13BC)

Origin	*Pisifera*	TrDM	LDM	VDM	TDM	BI	CGR	LAI	LAR
AVROS	DM742.112	17.0 defg**	57.1 c	74.2 ef	128.6 fgh	0.42 efg	17.7 gf	3.9 de	2.4 cde
AVROS	DM742.316	17.3 def	58.7 c	76.1 de	136.3 defgh	0.44 bcdef	18.8 defg	4.1 abcd	2.7 bc
Binga	Bg142/B079/19	16.8 defg	49.7 d	66.4 f	119.0 h	0.44 bcdef	16.4 g	3.3 f	2.6 abc
Binga	Bg142/B116/12	16.9 defg	56.0 cd	72.9 ef	130.8 efgh	0.44 bcdef	18.1 efg	3.8 de	2.5 bcd
Binga	Bg271/E046/17	17.1 defg	67.8 ab	84.9 bcd	147.6 bcdef	0.43 defg	20.4 bcde	4.0 bcd	2.3 defgh
Binga	PKg111/21/08	18.5 bcd	61.7 bc	80.2 bcd	148.4 bcde	0.46 abc	20.5 bcde	4.5 ab	2.7 ab
Binga	PKg111/21/14	14.7 g	59.0 c	73.7 ef	130.8 efgh	0.44 cdefg	18.1 efg	4.1 abcd	2.7 a
Binga	PKg111/26/02	21.4 ab	71.0 a	92.4 ab	164.9 ab	0.44 abcde	22.8 ab	4.3 abc	2.3 efgh
Binga	PKg111/26/07	18.7 cd	62.0 bc	80.7 cde	138.7 defg	0.42 fg	19.1 def	4.1 abcd	2.5 cde
Ekona	Lb158/12/12433	23.2 a	72.1 a	95.2 a	172.7 a	0.45 abcde	23.8 a	4.5 a	2.2 gh
Ekona	Lb158/12/12440	14.9 defg	57.7 c	72.6 ef	129.7 efgh	0.44 cdef	17.9 efg	3.5 ef	2.4 cdefg
Ekona	PSh1021/3169	20.0 bc	67.7 ab	87.7 abc	160.6 abc	0.45 abcd	22.2 abc	4.5 ab	2.4 cdef
Ekona	PSh1021/3207	16.1 defg	57.8 c	73.9 ef	142.5 cdefg	0.48 a	19.7 cdef	3.8 de	2.6 abc
URT	PSh0984/165	16.1 defg	56.8 cd	72.9 ef	125.2 gh	0.41 g	17.3 fg	3.5 ef	2.2 h
URT	PSh0984/171	16.0 efg	57.8 c	73.8 ef	127.0 gh	0.42 fg	17.5 fg	3.6 ef	2.3 defgh
URT	PSh0984/175	15.9 fg	57.1 c	73.0 ef	126.3 gh	0.42 efg	17.4 fg	3.7 def	2.3 defgh
URT	PSh1037/4292	15.6 fg	60.6 bc	76.2 de	133.3 defgh	0.43 defg	18.4 defg	3.6 ef	2.3 defgh
URT	PSh1037/4295	18.7 cd	61.6 ab	80.3 cde	150.9 bcd	0.47 ab	20.8 bcd	3.7 de	2.4 cdefg
URT	PSh1042/4344	15.8 fg	62.6 ab	78.5 cde	140.6 defg	0.44 bcdef	19.4 def	3.5 ef	2.2 fgh
URT	PSh1042/4350	17.2 defg	61.1 ab	78.2 cde	134.6 defgh	0.42 fg	18.6 defg	3.9 cde	2.3 defgh
Trial mean		17.4	60.7	78.0	139.1	0.44	19.2	3.9	2.4

Notes: * TrDM: trunk dry matter (kg palm^{-1} yr^{-1}); LDM: leaf dry matter (kg palm^{-1} yr^{-1}), VDM: vegetative dry matter (kg palm^{-1} yr^{-1}), TDM: total dry matter (kg palm^{-1} yr^{-1}); BI: bunch index (ratio of BDM to TDM); CGR: crop growth rate (t ha^{-1} yr^{-1}), the annual dry matter production; LAI: leaf area index, ratio of leaf area to area of ground covered by the canopy; LAR: leaf area ratio (m^2 kg^{-1}), ratio of leaf area to leaf weight.

**Means followed by the same letter are not significantly different at the 5% level.

As for the Binga *pisifera*s, their DxP performed poorly for FFB, OY, EOE and O/B especially in Trial 13A. The poor FFB was largely due to low bunch weight and low O/B because of a thin mesocarp and to a lesser extent, poor O/WM although fruit/bunch (F/B) was satisfactory. Although this origin gave DxP progenies with large kernel and thick shell, the EOE yield was below AVROS and Ekona DxP. Likewise, though Binga DxP produced more bunches than any other DxP, their FFB yield was poor. Vegetatively, their fronds were long with large petioles, hence, a high LDM. However for LA, LAR and LAI, the DxP progenies differed markedly, ranking low in Trial 13A but the highest in Trial 13BC. The Binga DxP progenies were of average height but had the largest trunks in both trials. The BI was poor especially in Trial 13A because of the low FFB production,

Within the Binga populations, the *pisifera*s of PKg111 generally gave better DxP than those of Bg142 and to a lesser extent, Bg271. The better FFB was mainly due to better bunch size, and with the better O/B contributed to a higher OY and EOE. The superior O/B of PKg111 DxP was entirely due to a better F/B whereas the DxP of the Bg271 and Bg142 *pisifera*s had higher WM/F and O/WM. The PKg111 DxP progenies had the largest canopies but lowest FP compared to the DxP of the other two families although height was generally similar among them. The DxP from Pkg111 *pisifera*s produced fewer fronds than the DxP of *pisifera*s from the other two families.

The DxP progenies of the Ekona *pisifera*s in both trials were characterized by high VDM production, especially LDM, leading to high TDM production and a high CGR. The large petioles, long rachis and large leaflets contributed to the high LDM, in contrast to the AVROS DxP where the high LDM was due to high FP. FFB production was also high in Ekona DxP. The bunch oil content was good, stemming from a good F/B and thick mesocarp, the latter at the expense of K/F for which Ekona DxP had the lowest values. The OY and EOE were lower than AVROS DxP in Trial 13A but in Trial 13BC, the EOE yields of Lb158/12/12433 and PSh1021/3169 at 42.2 and 38.4 kg palm^{-1} respectively were significantly higher than those of AVROS DM742.316 *(Table 2)*. Though taller than the other origins, the Ekona DxP progenies were still noticeably shorter than AVROS DxP.

The Ekona *pisifera* population in this study comprised three half sib families, the common parents being 2/2311 (Cwn6) and Lb158, its selfed progeny (Lim *et al.*, 2003). The *pisifera*s thus performed similarly, especially in the poorer environment of Trial 13BC. In Trial 13A, the FFB production difference between the DxP of Lb158 and PSh1019 *pisifera*s was due to differences in both the bunch weight and bunch number. The former was taller and had thicker trunks. In Trial 13BC, the DxP

of Lb158 was noticeably different from those of PSh1021 only in having a larger petiole cross-sectional area. While the *pisifera*s from all the three families gave DxP with excellent O/B, those of Lb158 were particularly high in O/WM.

The URT-derived DxP performed the poorest in both trials with low FFB, OY, EOE and TDM, and poor vegetative growth. The bunch oil content was also the lowest from poor F/B, oil/mesocarp (O/WM) and mesocarp/fruit (WM/F), although the last was somewhat compensated for by a high kernel/fruit (K/F). They were also the shortest. The three *pisifera* families in the URT population were related as half sibs with UR378/2 (of Deli x Yangambi mixed pollen) being the common parent. Additionally, it may be noted that PSh0984 was a self of UR378/2. The *pisifera*s from PSh1037 and PSh1042 were similar for their DxP yields but different in their yield components - the former producing fewer but larger bunches. Except for frond production, the DxP of PSh1037 was the more vigorous but interestingly, PSh1042 DxP grew better in the poorer conditions of Trial 13BC. The latter was also superior for the fruit bunch traits, particularly O/B from better O/WM. *Pisifera*s from PSh0984 (a self of UR378/2), showed considerable variation between their DxP, especially for the yield and vegetative traits.

In summary, the best *pisifera*s in Trial 13A were AVROS, the two Ekonas and one of the Binga *pisifera*s, all of which gave DxP progenies not significantly different in EOE yield *(Table 1)*. The FFB yields from the four *pisifera*s were among the best, and their O/B was superior to any of the other *pisifera*s tested. The AVROS and one of the Ekona *pisifera*s gave very tall DxP progenies *(Table 4)*.

In Trial 13BC, the top four *pisifera*s for EOE yield, again not significantly different from each other, were two from Ekona, one from Binga and one from URT *(Table 2)*. They gave the best FFB yields, combined with good (though not necessarily the best) O/B. They also gave the tallest DxP progenies *(Table 5)*.

The female parents of the DxP progenies in Trial 13BC were either Deli *dura*s, African *dura*s or Deli x African *dura*s, the latter two grouped as mixed *dura*s for purposes of discussion. Since the *pisifera*s from the different origins were crossed to both types of *dura*s, it is possible to compare the average performance of the different types of *dura*s across all the *pisifera*s *(Table 9)*.

The mixed *dura*s gave higher yielding DxP progenies, the gain being entirely from bunch number, while Deli, not surprisingly, imparted a higher bunch weight. Deli was also slightly superior for bunch oil content from better WM/F but at the expense of K/F. The mixed *dura*s gave vegetatively more vigorous DxP progenies - the fronds and canopies were larger, petioles thicker and trunk taller and thicker. The net result was higher TDM than the DxP of Deli *dura*s - 149.3 kg palm^{-1} *vs.* 133.2 kg palm^{-1}. But because of the balance between yield and vegetative growth, the BI of both the groups of *dura*s was the same at 0.44.

There is a general view in the industry that the Deli *dura* origin should be kept pure so that its superior bunch characteristics are not lost. These results show that the possible gains in FFB yield from outcrossing to unrelated African *dura*s greatly outweigh any loss in O/B, resulting in improvements in oil and EOE yields.

CONCLUSION

Evaluation of some *pisifera*s from five distinct origins confirmed that the DxP of AVROS *pisifera*s produce high FFB and oil yields but suffer rapid height increment and strong vegetative growth.

The DxP of Ekona *pisifera*s were equal or superior to those of AVROS for FFB production, bunch oil content and EOE yield. The high bunch oil content of AVROS DxP derived mostly from better WM/F while Ekona DxP tended to have better O/WM, an important difference noted before (Rao *et al*., 1999).

The Binga *pisifera*s on average, were not as good as Ekona in DxP testing, but the best gave DxP progenies with EOE yields not significantly different from those of the best Ekonas. With one exception, the *pisifera*s of URT origin were the poorest for DxP FFB production due to fewer and smaller bunches. Bunch oil content was also poorer due to lower F/B, less oil in the mesocarp and, especially, thinner mesocarp. Vegetatively, the URT DxP palms were less vigorous and the shortest among all the DxP progenies evaluated.

The *dura*s involved in the progeny testing comprised African, Deli and African x Deli or mixed *dura*s. The African and mixed *dura*s produced more vigorous and higher yielding DxP progenies. On average, the EOE yield was 12% better in the DxP of mixed *dura*s than those of Deli *dura*s. Thus, there is no justification for persisting exclusively with pure Deli *dura*s as seed parents.

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TABLE 8. DxP PERFORMANCE OF *PISIFERA*S OF DIFFERENT ORIGINS (Trial 13A)

Topic*	Trait**	*Pisifera* population/origin				
		Angola	**AVROS**	**Binga**	**Ekona**	**URT**
No. of *pisifera*s		1	1	3	3	2
Yield	FFB	131.6	141.6	124.4	135.0	113.0
	B. No.	20.1	16.1	16.5	15.5	14.5
	B. wt.	6.6	8.8	7.5	8.7	7.8
	OY	29.97	36.08	29.59	33.83	24.34
	EOE	34.28	40.58	33.71	37.07	28.37
VM	RL	4.64	5.14	5.15	5.36	4.79
	PXS	19.4	22.7	22.7	29.1	21.1
	LA	6.27	7.80	7.15	8.48	6.74
	FP	30	30	31.5	27.5	29
	HI	38.5	49	40	43.5	37.5
	TD	59	58	61	61	60
PT	TrD	15.1	18.6	16.8	18.3	15.3
	BDM	69.7	75.6	65.9	71.6	59.9
	LDM	65.7	75.8	77.1	87.4	68.4
	VDM	80.8	94.4	93.9	105.7	83.7
	TDM	150.5	170.0	159.9	177.2	143.6
	BI	0.46	0.44	0.41	0.40	0.42
	CGR	20.8	23.5	22.1	24.5	19.8
	LAI	3.5	4.3	4.0	4.7	3.7
	LAR	2.3	2.5	2.3	2.2	2.3
BA	F/B	65.06	66.34	64.74	63.11	63.75
	WM/F	82.25	83.01	81.39	83.33	80.64
	O/WM	42.82	46.51	45.23	47.61	42.12
	K/F	8.17	7.90	8.35	6.22	9.11
	O/B	22.81	25.57	23.79	25.06	21.54
	K/B	5.47	5.32	5.52	4.00	5.94
	F/W	10.37	11.62	10.71	9.64	11.32

Notes: *Yield: yield (kg palm^{-1}); VM: vegetative measurement; PT: physiological traits; BA: bunch analysis.
**FFB: fresh fruit bunch; B. No.: bunch number; B.wt.: bunch weight, OY: % oil/bunch on FFB (kg palm^{-1}); EOE: palm oil yield + 60% kernel production (kg palm^{-1}); RL: rachis length (m); PxS: petiole cross-section area (cm^2); LA: leaf area (m^2); FP: frond production; HI: height increment (cm yr^{-1}); TD: trunk diameter (cm); TrDM: trunk dry matter (kg palm^{-1} yr^{-1}); LDM: leaf dry matter (kg palm^{-1} yr^{-1}); VDM: vegetative dry matter (kg palm^{-1} yr^{-1}), the sum of TrDM and LDM; BDM: bunch dry matter (kg palm^{-1} yr^{-1}); TDM: total dry matter (kg palm^{-1} yr^{-1}), the sum of VDM and BDM; BI: bunch index, the ratio of BDM to TDM; CGR: crop growth rate (t ha^{-1} yr^{-1}), the annual dry matter production; LAI: leaf area index, ratio of leaf area to the area of ground covered by the canopy; LAR: leaf area ratio (m^{2}kg^{-1}), the ratio of leaf area to leaf weight; F/B: fruit-to-bunch; WM/F: mesocarp/fruit; O/WM: oil/wet mesocarp; K/F: kernel/fruit; O/B: oil-to-bunch; K/B: kernel/bunch; F/W: fruit weight.

TABLE 9. DxP PERFORMANCE OF *PISIFERA*S OF DIFFERENT ORIGINS (Trial 13BC)

Topic*	Trait**	*Pisifera* population/origin				Deli/mixed *dura*s	
		AVROS	Binga	Ekona	URT	Deli	Mixed
No. of *Pisifera*s		2	7	4	7		
Yield	FFB	107.7	117.5	130.0	111.6	110.5	123.4
	B. No.	13.5	16.3	18.8	15.8	14.4	18.3
	B. wt.	8.0	7.2	6.9	7.1	7.76	6.77
	OY	25.93	26.32	34.27	25.03	26.10	28.93
	EOE	29.07	30.27	37.50	28.61	29.55	33.15
VM	RL	4.75	4.92	4.79	4.67	4.72	4.9
	PxS	19.3	20.8	21.4	20.4	19.39	21.7
	LA	7.18	7.33	7.31	6.69	6.98	7.5
	FP	26.5	27	26.5	26	26	27
	HI	42	39	40.5	39	39	42
	TD	60	64	63	62	62	63
PT	TrD	17.1	18.0	18.2	16.9	16.8	18.7
	BDM	57.1	62.3	68.9	57.0	58.8	65.1
	LDM	57.9	62.9	63.5	59.5	57.6	65.5
	VDM	75.0	80.9	81.6	76.4	74.4	84.2
	TDM	132.1	143.2	150.5	133.5	133.2	149.3
	BI	0.43	0.43	0.46	0.43	0.44	0.44
	CGR	18.2	19.8	20.8	18.4	18.4	20.6
	LAI	4.0	4.1	4.0	3.7	3.9	4.2
	LAR	2.5	2.5	2.4	2.3	2.5	2.4
BA	F/B	63.74	64.12	62.16	89.74	64.04	63.09
	WM/F	84.91	81.25	83.32	80.60	82.99	80.9
	O/WM	44.46	43.20	50.89	46.78	44.54	46.06
	K/F	7.41	8.40	6.53	8.55	7.89	8.80
	O/B	24.08	22.40	26.36	22.43	23.62	23.40
	K/B	4.86	5.60	4.14	5.34	5.20	5.70
	F/W	10.28	11.06	8.66	9.28	10.52	9.70

Notes: * Yield: yield (kg palm^{-1}); VM: vegetative measurement; PT: physiological traits; BA: bunch analysis.
**FFB: fresh fruit bunch; B. No.: bunch number; B. wt.: bunch weight, OY: % oil/bunch on FFB (kg palm^{-1}); EOE: palm oil yield + 60% kernel production (kg palm^{-1}); RL: rachis length (m); PxS: petiole cross-section area (cm^2); LA: leaf area (m^2); FP: frond production; HI: height increment (cm yr^{-1}); TD: trunk diameter (cm); TrDM: trunk dry matter (kg palm^{-1}yr^{-1}); LDM: leaf dry matter (kg palm^{-1} yr^{-1}); VDM: vegetative dry matter (kg palm^{-1} yr^{-1}), the sum of TrDM and LDM; BDM: bunch dry matter; TDM: total dry matter (kg palm^{-1} yr^{-1}), the sum of VDM and BDM; BI: bunch index, the ratio of BDM to TDM; CGR: crop growth rate (t ha^{-1} yr^{-1}), the annual dry matter production; LAI: leaf area index, ratio of leaf area to the area of ground covered by the canopy; LAR: leaf area ratio (m^{2}kg^{-1}), the ratio of leaf area to leaf weight; F/B: fruit/bunch; WM/F: mesocarp/fruit; O/WM: oil/wet mesocarp; K/F: kernel/fruit; O/B: oil/bunch; K/B: kernel/bunch; F/W: fruit weight.

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Appendix 1

DETAILS OF THE MALE PARENTS, THEIR ORIGINS AND POPULATIONS

Trial	Origin	Male parent	n_1	n_2
13A	Angola	Lb135/12/2709	2	91
13A	Binga	Bg142/B062/04	4	189
13A	Binga	Bg142/B101/33	2	91
13A	Binga	PKg111/16/01	4	191
13A	Ekona	Lb158/12/12428	1	12
13A	Ekona	Lb158/12/12640	3	142
13A	Ekona	PSh1019/2949	3	143
13A	URT	PSh1037/4252	2	94
13A	URT	PSh1042/4313	4	186
13A	AVROS	DM742.316	5	237
		Total		**1 376**
13BC	Binga	Bg142/B079/19	3	118
13BC	Binga	Bg142/B116/12	3	144
13BC	Binga	Bg271/E046/17	4	172
13BC	Binga	PKg111/21/08	3	143
13BC	Binga	PKg111/21/14	1	48
13BC	Binga	PKg111/26/02	4	190
13BC	Binga	PKg111/26/07	4	116
13BC	Ekona	Lb158/12/12433	4	156
13BC	Ekona	Lb158/12/12440	4	151
13BC	Ekona	PSh1021/3169	2	93
13BC	Ekona	PSh1021/3207	3	143
13BC	URT	PSh0984/165	2	70
13BC	URT	PSh0984/171	1	47
13BC	URT	PSh0984/175	3	105
13BC	URT	PSh1037/4292	3	142
13BC	URT	PSh1037/4295	2	96
13BC	URT	PSh1042/4344	1	46
13BC	URT	PSh1042/4350	3	131
13BC	AVROS	DM742.112	10	412
13BC	AVROS	DM742.316	5	319
		Total		**2 842**

Notes: n_1 - number of progenies; n_2 - number of palms.

Appendix 2

YIELD* AND VEGETATIVE TRAITS OF DxP PROGENIES OF BINGA, EKONA, URT, AVROS AND ANGOLA *PISIFERA*S WITHIN EACH *PISIFERA* FAMILY (Trial 13A)**

Female parent	Male parent	FFB	B. No	B.wt.	RL	PxS	LA	FP	HI	TD
PKg108/43/11	Bg142/B062/04	128.1	16.3	7.9	5.1	20.7	6.8	32	43.5	61
PKg117/58/05	Bg142/B062/04	155.2	17.0	9.1	5.7	27.1	8.0	29	51.0	57
PKg118/54/16	Bg142/B062/04	133.7	19.0	7.0	5.0	22.0	6.8	31	42.0	58
PKg118/61/09	Bg142/B062/04	110.7	17.5	6.3	4.8	19.3	6.8	33	35.0	60
PKg100/40/04	Bg142/B101/33	92.7	13.0	7.1	4.7	22.7	6.3	29	32.5	64
PKg118/54/16	Bg142/B101/33	94.2	16.5	5.7	4.4	18.6	6.1	29	34.5	58
PKg106/50/08	DM742.316	140.2	16.3	8.6	5.1	25.8	8.1	30	46.0	58
PKg117/73/12	DM742.316	133.2	14.0	9.5	5.2	21.2	7.6	30	51.0	57
PKg118/54/16	DM742.316	160.3	17.8	9.0	5.3	23.7	8.2	29	61.0	55
PKg118/61/12	DM742.316	141.8	14.8	9.6	5.2	24.0	7.8	31	49.5	60
PKg119/60/10	DM742.316	133.3	17.0	7.8	4.8	19.2	7.4	32	38.0	57
PKg108/12/09	Lb135/12/2709	137.5	20.3	6.8	4.7	20.9	6.5	32	41.0	60
PKg108/12/15	Lb135/12/2709	125.4	20.0	6.3	4.6	17.9	6.1	29	36.5	58
PKg100/40/04	Lb158/12/12640	145.0	15.3	9.5	5.4	30.2	8.7	28	49.5	64
PKg106/28/15	Lb158/12/12640	118.4	12.5	9.5	5.3	33.5	9.0	27	45.5	64
PKg117/73/01	Lb158/12/12640	134.7	15.3	8.8	5.4	27.6	8.6	27	45.0	60
PKg100/40/04	PKg111/16/01	148.7	15.3	9.7	5.7	26.3	8.3	31	44.0	64
PKg108/12/09	PKg111/16/01	134.6	16.3	8.3	5.7	24.6	8.1	31	44.5	63
PKg117/58/05	PKg111/16/01	122.9	14.8	8.3	5.5	25.6	7.3	31	38.5	67
PKg119/60/10	PKg111/16/01	120.5	16.8	7.2	4.8	19.7	6.9	30	35.0	60
PKg108/12/15	PSh1019/2949	119.1	14.8	8.1	5.2	26.0	7.8	28	35.0	64
PKg108/61/15	PSh1019/2949	149.0	18.0	8.3	5.7	29.9	8.6	28	41.5	58
PKg119/60/10	PSh1019/2949	147.3	19.0	7.8	5.1	27.4	8.1	28	42.0	54
PKg106/50/08	PSh1037/4252	114.5	13.5	8.5	4.9	24.3	6.6	26	36.5	61
PKg108/12/15	PSh1037/4252	107.5	11.0	9.8	5.0	22.9	7.4	29	40.5	60
PKg106/28/15	PSh1042/4313	129.0	14.8	8.7	4.8	21.7	7.1	30	41.5	63
PKg106/50/08	PSh1042/4313	98.6	16.5	6.0	4.5	18.4	5.9	29	32.5	56
PKg117/58/05	PSh1042/4313	104.8	14.8	7.1	5.0	19.8	6.7	31	37.5	60
PKg118/61/15	PSh1042/4313	123.7	17.5	7.1	4.7	19.6	6.8	30	36.0	60

Notes: *FFB: fresh fruit bunch (kg palm^{-1}); B. No.: bunch number; B. wt.: bunch weight (kg).
** RL: rachis length (m); PxS: petiole cross-section area (cm^2); LA: leaf area (m^2); FP: frond production; HI: height increment (cm yr^{-1}); TD: trunk diameter (cm).

Appendix 3

YIELD* AND VEGETATIVE TRAITS OF DxP PROGENIES OF BINGA, EKONA, URT AND AVROS *PISIFERA*S WITHIN EACH *PISIFERA* FAMILY (Trial 13BC)**

Female parent	Male parent	FFB	B. No	B. wt.	RL	PxS	LA	FP	HI	TD
PKg118/54/09	Bg142/B079/19	80.6	13.0	6.2	4.2	12.9	5.4	28	30.0	61
PKg256/24/16	Bg142/B079/19	122.6	19.8	6.2	4.6	17.1	7.0	30	50.5	61
PKg259/159	Bg142/B079/19	86.3	13.3	6.5	4.3	16.4	5.7	28	37.5	60
PKg103/49/16	Bg142/B116/12	111.9	12.8	8.7	4.6	19.5	6.6	27	41.5	61
PKg108/43/12	Bg142/B116/12	97.0	15.0	6.5	4.6	16.9	6.6	26	37.5	60
PKg118/54/07	Bg142/B116/12	118.9	15.3	7.8	4.8	19.6	7.3	27	40.5	63
PKg108/43/13	Bg271/E046/17	110.3	17.0	6.5	4.7	19.6	7.0	27	35.5	62
PKg119/75/04	Bg271/E046/17	120.8	17.8	6.8	4.9	24.7	7.1	26	42.0	64
PKg217/128	Bg271/E046/17	121.3	19.8	6.1	5.1	23.0	7.9	29	41.0	67
PKg230/118/8	Bg271/E046/17	119.8	19.8	6.1	5.0	22.6	7.4	27	35.0	61
PKg106/01/10	DM742.112	82.8	9.8	8.5	4.7	20.9	6.7	25	39.5	60
PKg106/47/16	DM742.112	100.7	10.8	9.3	4.8	22.4	7.2	25	45.5	61
PKg108/22/04	DM742.112	112.3	14.8	7.6	4.7	18.6	7.5	27	43.5	58
PKg117/58/09	DM742.112	98.1	11.5	8.5	4.5	16.2	6.7	26	36.5	61
PKg118/54/07	DM742.112	102.5	11.8	8.7	4.6	20.8	6.9	27	40.5	64
PKg118/74/14	DM742.112	118.7	15.3	7.8	4.6	19.3	7.5	26	43.0	60
PKg119/75/04	DM742.112	123.9	15.8	7.8	4.6	21.4	7.1	26	45.5	60
PKg256/24/16	DM742.112	84.3	17.3	4.9	4.4	17.9	6.1	27	39.0	57
PKg256/44/30	DM742.112	96.4	14.8	6.5	4.8	19.4	6.9	26	40.5	61
PKg117/73/12	DM742.316	100.7	12.5	8.1	4.8	17.2	6.9	28	39.5	62
PKg118/54/07	DM742.316	120.4	13.8	8.7	5.0	19.8	7.7	27	43.0	60
PKg118/61/12	DM742.316	119.6	13.0	9.2	4.9	19.1	7.5	28	44.0	60
PKg231/18/12	DM742.316	122.5	18.3	6.7	4.9	21.3	7.9	28	43.0	59
PKg240/34/23	DM742.316	111.1	15.0	7.4	4.8	18.9	7.6	27	42.5	59
PKg108/22/07	Lb158/12/12433	145.0	18.5	7.8	5.2	23.1	7.9	26	47.0	66
PKg230/84/58	Lb158/12/12433	148.5	19.3	7.7	5.2	26.1	8.7	26	54.0	61
PKg231/02	Lb158/12/12433	147.6	19.0	7.8	5.1	28.5	8.1	25	49.0	65
PKg256/24/16	Lb158/12/12433	141.6	21.5	6.6	5.0	19.9	7.3	27	42.0	64
PKg103/34/16	Lb158/12/12440	111.4	14.5	7.7	4.7	22.1	7.4	27	34.0	67
PKg108/43/13	Lb158/12/12440	112.4	16.5	6.8	4.4	17.6	5.8	27	34.0	64
PKg117/58/09	Lb158/12/12440	96.9	15.3	6.3	4.4	15.9	5.9	28	30.0	60
PKg231/18/12	Lb158/12/12440	117.2	18.5	6.3	4.7	21.2	6.8	28	37.5	60
PKg117/58/09	PKg111/21/08	126.1	16.0	7.9	5.1	19.6	7.6	26	36.0	64
PKg217/128	PKg111/21/08	132.6	19.0	7.0	5.6	22.9	8.9	27	41.0	68
PKg240/34/23	PKg111/21/08	125.3	17.8	7.0	5.0	19.9	7.8	27	35.0	67

Appendix 3

YIELD* AND VEGETATIVE TRAITS OF DxP PROGENIES OF BINGA, EKONA, URT AND AVROS *PISIFERA*S WITHIN EACH *PISIFERA* FAMILY (Trial 13BC) -** CONTINUED

Female parent	Male parent	FFB	B. No	B. wt.	RL	PxS	LA	FP	HI	TD
PKg103/49/16	PKg111/21/14	105.1	12.5	8.4	5.0	19.7	7.5	27	30.5	65
PKg106/47/16	PKg111/26/02	120.3	13.5	8.9	5.1	24.2	7.9	26	40.0	65
PKg208/23/15	PKg111/26/02	143.3	18.5	7.8	5.4	24.5	8.5	28	43.5	67
PKg230/84/58	PKg111/26/02	145.6	19.0	7.7	5.3	25.3	7.8	27	52.0	65
PKg259/159	PKg111/26/02	123.2	16.0	7.7	4.8	21.9	7.0	27	42.0	64
PKg106/47/16	PKg111/26/07	111.0	13.0	8.5	5.1	20.0	7.5	25	40.0	70
PKg119/75/15	PKg111/26/07	108.8	14.5	7.5	4.9	19.8	7.8	26	34.0	66
PKg231/02	PKg111/26/07	112.3	16.3	6.9	5.1	23.5	7.5	28	38.0	70
PKg231/22/15	PKg111/26/07	116.3	19.8	5.9	4.9	18.7	7.1	27	35.5	66
PKg118/54/09	PSh0984/165	98.9	16.0	6.2	4.2	15.9	5.2	26	33.5	60
PKg231/02	PSh0984/165	108.4	14.5	7.5	4.7	22.8	7.0	25	40.0	62
PKg103/34/16	PSh0984/171	100.3	12.0	8.4	4.6	19.2	6.5	27	34.5	64
PKg108/22/07	PSh0984/175	98.4	15.5	6.4	4.5	17.3	6.5	25	36.5	59
PKg119/75/15	PSh0984/175	115.1	15.5	7.4	4.8	22.2	6.8	24	38.5	60
PKg259/159	PSh0984/175	116.3	16.0	7.3	4.6	23.2	7.3	25	41.5	62
PKg230/84/58	PSh1021/3169	137.5	19.0	7.2	5.1	24.1	7.9	27	46.5	64
PKg231/22/15	PSh1021/3169	136.2	20.3	6.7	4.8	22.3	8.2	26	40.5	64
PKg108/43/13	PSh1021/3207	117.9	18.0	6.6	4.6	17.7	6.4	27	35.0	62
PKg118/54/09	PSh1021/3207	139.3	20.8	6.7	4.5	17.4	6.2	28	36.5	62
PKg240/34/23	PSh1021/3207	134.1	21.3	6.3	4.8	20.6	8.0	28	38.0	63
PKg103/34/16	PSh1037/4292	94.9	12.0	7.9	4.7	20.3	6.6	27	30.5	65
PKg119/75/04	PSh1037/4292	98.0	14.0	7.0	4.6	19.9	5.9	27	34.0	61
PKg240/34/23	PSh1037/4292	129.2	17.5	7.4	4.7	19.4	6.8	28	38.0	64
PKg119/75/15	PSh1037/4295	126.3	15.3	8.3	4.7	21.1	6.9	26	41.5	61
PKg256/24/16	PSh1037/4295	139.6	20.5	6.8	4.7	17.6	6.6	30	49.0	60
PKg231/18/12	PSh1042/4344	117.0	18.3	6.4	4.6	20.5	6.4	27	36.5	62
PKg106/01/10	PSh1042/4350	109.4	13.8	7.9	5.0	22.1	7.4	25	43.0	61
PKg231/02	PSh1042/4350	102.4	17.0	6.0	4.7	20.6	6.5	25	37.5	60
PKg259/159	PSh1042/4350	116.3	18.0	6.5	4.9	21.9	7.0	27	43.5	61

Notes: *FFB: fresh fruit bunch (kg palm^{-1}); B. No.: bunch number; B. wt.: bunch weight (kg).
**RL: rachis length (m); PxS: petiole cross-section area (cm^2); LA: leaf area (m^2); FP: frond production; HI: height increment (cm yr^{-1}); TD: trunk diameter (cm).