Journal of Oil Palm Research Vol. 23 December 2011 p. 1210-1221

PERFORMANCE OF *TENERA* OIL PALM POPULATION DERIVED FROM CROSSES BETWEEN DELI *DURA* AND *PISIFERA* FROM DIFFERENT SOURCES ON INLAND SOILS

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ABSTRACT

FELDA Agricultural Sdn Bhd (FASSB) has been exploiting various germplasm and advanced materials to broaden the narrow genetic base of its breeding population since 1968. The utilisation of these materials has resulted in more than 200 progeny test trials. From a total of 25 progenies analysed in this study, performance tended to group the teneras, *according to their* pisifera *sources. Cluster analysis shows that the* pisifera *Dumpy AVROS and La Me were closely related populations in terms of performance while the* pisifera *Yangambi was the most different* pisifera *group. The highest bunch weight production was dominated by all the DxP (Yangambi) progenies for the young mature, mature and eight-year mean periods at 130.42, 217.00 and 175.34 kg palm^{-1} yr^{-1}, respectively. In addition, DxP (Yangambi) progenies also scored highest for oil to bunch ratio at 29.50%, which differed significantly from the other* pisifera *sources. The highest bunch index and bunch dry matter were also attained by DxP (Yangambi) progenies at 0.41 and 12.65 t ha^{-1} yr^{-1}, respectively. The highly significant differences indicated in the bunch yield, bunch components, vegetative and physiological traits from the analysis of variance revealed the existence of genetic variability among these traits which may allow for further improvement and exploitation.*

Keywords: *tenera*, *pisifera*, breeding population, genetic variability, oil palm progeny.

Date received: 10 August 2009; **Sent for revision:** 3 December 2009; **Received in final form:** 23 April 2011; **Accepted:** 25 July 2011.

INTRODUCTION

Within the 40 years of involvement in the field of oil palm breeding, FELDA through its subsidiary company, FELDA Agricultural Services Sdn Bhd (FASSB), has exploited various germplasm and advanced materials to broaden the narrow genetic base of its breeding population. Initially, most of the advanced materials were obtained from the Department of Agriculture, Serdang, a public research institution in Malaysia, and from CIRAD (the French institute for oil crops research) (Chin *et al*., 1999). As for germplasm materials, the bulk of them were received from the Malaysian Palm Oil Board (MPOB), starting way back from 1989 (Chin *et al*., 1999; Kushairi and Rajanaidu, 2000; Rajanaidu *et al*., 2000).

Since then, *tenera* × *pisifera* (TxP), *tenera* × *tenera* (T×T) and *dura* × *dura* (DxD) crosses have been made to create FELDA parental lines followed by their progeny test trials. To date more than 200 progeny test trials have been laid to test *tenera*s derived from various combinations of FELDA *dura* and FELDA *pisifera*, or FELDA *tenera*s. To ensure that the FELDA breeding programmes benefit seed buyers, the programmes are geared towards developing high oil yield and improved planting materials.

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Selections are based on extensive evaluation for bunch yield and bunch quality components over at least six consecutive years.

Significant achievement and progress in FELDA's oil palm breeding and selection have been documented in many publications (Chin *et al*., 1999; 2005; Chin and Junaidah, 2007; Junaidah *et al*., 2007). The D×P planting materials produced which initially catered for FELDA internal requirements are now being shared with other industry members. Significant acceptance has been recorded because more than 80% of the D×P planting materials produced has been sold to the industry. This reflects the confidence among industry members in the performance and quality of FELDA planting materials. To boost further improvements, breeding research has continued with several series of breeding schemes, and various strategies have been established. In this study, the performance of 25 *tenera* progenies derived from crosses between Deli *dura* and *pisifera*s from different sources was evaluated in a FELDA progeny test trial planted on inland soils in 1998, and the results are discussed.

MATERIALS AND METHODS

A total of 25 D×P progenies derived from crosses between Deli *dura*s and *pisifera* from four different sources, namely, AVROS, Dumpy AVROS, La Me and Yangambi, were evaluated in this study. The trial was planted in June 1998 as Trial T156 at Kota Gelanggi 6, Jerantut, Pahang, with one common standard cross (SC 5). The materials were planted on inland soils (Katong series) in a randomised complete block design (RCBD) with 16 palms per plot at 9.1 m triangular spacing and five replications. Among the progenies, five were D×P (AVROS), 16 D×P (Yangambi), two D×P (Dumpy AVROS) and two D×P (La Me).

Yield and bunch analysis data were recorded from 2001 to 2008. Vegetative measurements were made in 2007. The yield data were analysed for the young mature and mature periods. The young mature yield period is from the first to third year of harvesting while the mature period is from the fourth to the sixth year of harvesting. Measurements on and calculation of vegetative and physiological traits were made according to the non-destructive methods suggested by Corley and Breure (1981) in only two of the replications.

Analyses were made on individual data as well as data categorised based on the progenies and *pisifera* groups of the planting materials. The analysis of variance (ANOVA), Duncan New Multiple Range (DNMRT) and the Least Significant Difference (LSD) tests were computed using the Statistical Analysis System (SAS) package. The algorithms used for the construction of the dendrogram by SAS in the cluster analysis were based on Anderberg (1973).

RESULTS AND DISCUSSION

Pisifera Performance

The ANOVA showed high significance for bunch yield components in the blocks (B), *pisifera* groups (PG), progenies within *pisifera* group (G/PG) and the interaction between blocks and progenies within *pisifera* group (R×G/PG) (*Table 1*), indicating the existence of significant amounts of genetic variability for the bunch yield traits among the *pisifera*s groups (*i.e*. sources). ANOVA on bunch quality components and vegetative and physiological traits for PG and G/PG sources of variation showed significant differences for all the traits except total dry matter.

The performance of the D×P (*tenera*) populations in Trial T156 by *pisifera* sources based on means for bunch yield, bunch components, and vegetative and physiological traits is shown in *Table 2*. Overall trial yield means for the young mature period (1st to 3rd year of harvesting), mature period (4th to 6th year of harvesting) and for an 8-year period (2001 to 2008) were 128.71, 212.73 and 172 kg palm^{-1} yr^{-1}, respectively. Progenies derived from Deli *dura* crossed with Yangambi *pisifera* recorded the highest fresh fruit bunch (FFB) yields during both the young mature and mature periods at 130.42 and 217.00 kg palm^{-1} yr^{-1}, respectively, as well as the highest 8-year mean at 175.34 kg palm^{-1} yr^{-1}.

During its young mature period, the FFB yield of D×P (Yangambi) was not significantly different according to DNMRT from that of D×P (La Me) and D×P (AVROS), but its yield was significantly different in the mature period. The highly significant FFB yield achieved by D×P (Yangambi) was attributed to the high number of bunches during both its young mature and mature periods although it recorded a non-significant difference with D×P (La Me) in the young mature period. On the other hand, the highest average bunch weight was shown by D×P (AVROS) in the two recording periods (young mature and mature) at 9.82 kg and 17.37 kg palm^{-1} yr^{-1}, respectively. The highest FFB yield coupled with the highest oil to bunch ratio at 29.50% attained by D×P (Yangambi) resulted in the highest 8-year mean oil yield at 7.20 t ha^{-1} yr^{-1}. These results which were statistically different from the other D×Ps groups achieved due to the combination of high mesocarp to fruit (84.59%), oil to dry mesorcarp (78.94%), oil to wet mesocarp (52.93%) and fruit to bunch (65.88%) ratios. In addition, D×P (Yangambi) recorded the lowest shell to fruit (8.34%), followed by D×P (La Me) at 5.46%. The highest frond number production recorded

TABLE 1. ANALYSIS OF VARIANCE (ANOVA) FOR BUNCH YIELD, BUNCH QUALITY, VEGETATIVE AND PHYSIOLOGICAL TRAITS BY *PISIFERA* GROUPS

Character	Source of variation					
	Blocks (B)	*Pisifera* groups (PG)	Progenies within PG (G/PG)	B x PG	B x G/PG	Within palms
Mean Squares for Bunch Yield Components						
a. *Young mature period (1st to 3rd year of harvest)*						
Degrees of freedom	4	3	21	12	84	1 775
1 Fresh fruit bunch yield	25 978.54**	6 795.98**	11 772.09**	4 481.54**	3 499.62**	716.90
2 Bunch number	540.04**	955.19**	178.65**	57.77**	38.33**	8.96
3 Average bunch weight	19.04**	242.38**	19.75**	3.82*	3.62**	1.71
b. *Mature period (4th to 6th year of harvest)*						
4 Fresh fruit bunch yield	54 173.60**	19 343.57**	24 386.04**	2 948.61*	3 676.10**	1 637.71
5 Bunch number	120.01**	690.37**	167.49**	9.60	16.21**	6.57
6 Average bunch weight	37.16**	447.94**	71.50**	6.04	8.04**	3.48
c. *8-year mean (2001 to 2008)*						
7 Fresh fruit bunch yield	27 025.40**	9 849.16**	13 027.45**	1 973.45**	1 658.40**	679.50
8 Bunch number	41.98**	577.81**	101.52**	8.99*	10.39**	3.93
9 Average bunch weight	53.70**	339.74**	32.74**	3.22*	4.21**	1.64
Mean Squares for Bunch Quality Components						
Degrees of freedom	4	3	21	12	82	752
10 Mean fruit weight	6.52	112.59**	55.41**	5.35	8.47*	6.01
11 Mesocarp to fruit	43.09*	161.01**	184.42**	7.29	22.75**	13.92
12 Kernel to fruit	5.70	95.82**	30.87**	2.08	5.24**	3.28
13 Shell to fruit	21.12**	19.61*	76.06**	3.49	8.75**	4.90
14 Oil to dry mesocarp	34.39*	227.42**	15.50**	8.45*	8.82**	4.28
15 Oil to wet mesocarp	22.20	289.53**	57.21**	23.82	27.56**	14.15
16 Fruit to bunch	59.01**	128.63**	48.72**	17.97	16.74	15.17
17 Oil to bunch	65.06**	408.85**	40.82**	7.46	14.53**	9.08
18 Kernel to bunch	4.16*	38.82**	15.09**	1.21	2.43**	1.55
19 Oil yield	22.06**	43.96**	11.85**	1.76	2.43**	1.62
20 Kernel yield	0.35*	1.95**	1.29**	0.10	0.20**	0.11
Mean Squares for Vegetative and Physiological Traits						
Degrees of freedom	1	3	21	3	21	674
21 Frond production	4.17	298.26**	48.77**	8.14	6.91	4.97
22 Petiole cross-section	1 561.97**	1 862.59**	719.36**	143.33*	167.38**	40.27
23 Rachis length	2.71**	6.91**	3.13**	0.60*	0.51**	0.18
24 Leaflet length	21.62	202.07**	952.38**	53.10	63.06	53.63
25 Leaflet width	13.14**	8.47**	4.37**	1.13**	0.82**	0.22
26 Leaflet number	172.99	810.67**	527.66**	504.32**	313.79**	83.82
27 Palm height	12.86**	9.16**	4.80**	5.31**	1.60**	0.29
28 Leaf area	67.73**	89.28**	41.50**	10.78**	6.08**	2.22
29 Leaf area index	19.78**	25.99**	12.10**	3.15**	1.77**	0.65
30 Diameter	0.001	0.12**	0.02**	0.001	0.01**	0.001
31 Leaf dry weight	16.37**	19.53**	7.52**	1.51	1.75**	0.42
32 Trunk dry weight	435.39**	557.50**	174.72**	166.98**	120.11**	22.46
33 Frond dry weight	14 310.48**	3 110.90**	3 369.57**	1 558.45**	10.91.24**	369.76
34 Leaf area ratio	17.95	44.46**	92.52**	6.48	11.07**	5.07
35 Vegetative dry matter	365.14**	44.97**	81.35**	44.49**	25.69**	8.27
36 Bunch dry matter	79.23**	28.82**	33.13**	0.19	9.01**	3.52
37 Total dry matter	104.15*	29.86	104.45**	45.55*	42.69**	14.14
38 Bunch index	0.18**	0.03**	0.03**	0.01*	0.01**	0.001
39 Net assimilation rate	411.34**	1 561.18**	524.00**	29.82	78.20*	42.58

Note: **,* significant at $P \leq 0.01$ and $P \leq 0.05$, respectively.

TABLE 2. *PISIFERA* GROUP MEANS FOR BUNCH YIELD, VEGETATIVE AND PHYSIOLOGICAL TRAITS OF *TENERA* POPULATIONS

Character	*Pisifera* group				
	Yangambi	La Me	Dumpy-AVROS	AVROS	Mean
Bunch Yield Components					
a. *Young mature period (1st to 3rd year of harvest)*					
1 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	130.42a	127.92a	120.09b	126.94a	128.71
2 Bunch number (bunches palm^{-1} yr^{-1})	15.58a	15.98a	12.60b	13.03b	14.87
3 Average bunch weight (kg bunch^{-1})	8.46b	8.03c	9.59a	9.82a	8.79
b. *Mature period (4th to 6th year of harvest)*					
4 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	217.00a	206.82b	204.83b	205.27b	212.73
5 Bunch number (bunches palm^{-1} yr^{-1})	14.34a	13.06b	12.31c	11.90c	13.58
6 Average bunch weight (kg bunch $^{-1}$)	15.31d	15.92c	16.64b	17.37a	15.88
c. *8-year mean (2001 to 2008)*					
7 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	175.34a	174.06a	165.74b	166.77b	172.54
8 Bunch number (bunches palm^{-1} yr^{-1})	13.43a	13.22a	11.42b	11.27b	12.80
9 Average bunch weight (kg bunch^{-1})	13.16c	13.21c	14.58b	14.88a	13.64
Bunch Quality Components					
10 Mean fruit weight (g)	11.52b	11.58b	12.94a	13.00a	11.87
11 Mesocarp to fruit (%)	84.59b	86.05a	84.89b	83.13c	84.46
12 Kernel to fruit (%)	7.09b	5.46d	6.31c	7.73a	7.02
13 Shell to fruit (%)	8.34a	8.48a	8.79a	9.01a	8.50
14 Oil to dry mesocarp (%)	78.94a	75.98d	77.00c	78.26b	78.46
15 Oil to wet mesocarp (%)	52.93a	49.54bc	48.49c	50.04a	51.87
16 Fruit to bunch (%)	65.88a	65.77a	64.3b	64.32b	65.50
17 Oil to bunch (%)	29.50a	28.02b	26.45c	26.79c	28.72
18 Kernel to bunch (%)	4.67a	3.58c	4.05b	4.95a	4.60
19 Oil yield (t ha^{-1} yr^{-1})	7.20a	6.84b	6.43c	6.22c	6.95
20 Kernel yield (t ha^{-1} yr^{-1})	1.14a	0.87c	0.98b	1.15a	1.11
Vegetative and Physiological Traits					
21 Frond production (No. palm^{-1} yr^{-1})	27.05a	23.65c	24.98b	25.47b	26.26
22 Petiole cross-section (cm^2)	39.34b	44.78a	45.81a	44.86a	41.49
23 Rachis length (m)	6.29c	6.83a	6.64b	6.38c	6.38
24 Leaflet length (cm)	95.9b	97.1b	103.9a	95.6b	96.6
25 Leaflet width (cm)	6.16d	6.69a	6.37c	6.52b	6.30
26 Leaflet number (No. palm^{-1} yr^{-1})	172.78b	177.19a	178.31a	174.42b	173.95
27 Palm height (m)	4.23a	3.70b	3.68b	4.08a	4.11
28 Leaf area (cm^2)	11.68c	13.15a	13.43a	12.40b	12.10
29 Leaf area index	6.31c	7.10a	7.25a	6.70b	6.53
30 Diameter (m)	0.55a	0.54a	0.52b	0.54a	0.54
31 Leaf dry weight (kg palm^{-1})	4.23b	4.79a	4.89a	4.80a	4.45
32 Trunk dry weight (kg palm^{-1})	21.42a	17.66b	16.85b	20.22a	20.47
33 Frond dry weight (kg palm^{-1})	113.91b	113.40b	121.37a	121.82a	116.13
34 Leaf area ratio	17.39a	17.72a	17.99a	16.52b	17.29
35 Vegetative dry matter (t ha^{-1} yr^{-1})	18.40bc	17.82c	18.80ab	19.32a	18.58
36 Bunch dry matter (t ha^{-1} yr^{-1})	12.65a	12.03b	12.07b	11.87b	12.39
37 Total dry matter (t ha^{-1} yr^{-1})	31.06a	29.85b	30.87ab	31.19a	30.97
38 Bunch index	0.41a	0.40a	0.39b	0.38b	0.40
39 Net assimilation rate	47.81a	40.70c	41.16c	45.27b	46.13

Note: means within a row bearing the same letter are not significantly different from one another at $P \leq 0.05$ according to the Duncan New Multiple Range test (DNMRT).

by D×P (Yangambi) at 27.05 fronds palm^{-1} yr^{-1} was found to be correlated with the highest mean bunch number (14.34 bunches palm^{-1} yr^{-1}) and palm height (4.23 m), followed by bunch dry matter (12.65 kg palm^{-1} yr^{-1}) and bunch index (0.41).

Progeny Performance

ANOVA of the 25 progenies showed highly significant differences among the progenies for all bunch yield, bunch quality, vegetative and physiological traits (*Table 3*). Noh *et al*. (2010), in their study on 40 D×P progenies derived from crosses between Deli *dura* from different sources with AVROS *pisifera*, reported highly significant differences among progenies for yield and all yield components, bunch quality and vegetative traits except oil to wet mesocarp.

The individual progeny performance for bunch yield components, bunch quality components, vegetative and physiological characteristics is summarised in *Table 4*. Seventy-five percent or 12 out of the 16 Deli x Yangambi progenies had FFB yields above the trial mean during the young mature and mature periods. On the other hand, only 50% each of Deli x La Me, Deli x AVROS and Deli x Dumpy AVROS progenies yielded above the trial mean. The best performer for FFB in the young mature and mature periods was progeny DA30 at 153.34 kg palm^{-1} yr^{-1} and progeny DA15 at 252.16 kg palm^{-1} yr^{-1}. Both progenies were derived from Deli *dura* x Yangambi *pisifera*. The bunches produced by D×P (Yangambi) ranged from 13 to 18 bunches palm^{-1} yr^{-1} during its young mature and mature periods. As for D×P (Dumpy AVROS), the bunches produced ranged from 11 to 14 palm^{-1} yr^{-1} while D×P (La Me) recorded between 13 and 16 bunches palm^{-1} yr^{-1} and for D×P (AVROS) it ranged from 10 to 17 bunches palm^{-1} yr^{-1} during their young mature and mature periods. The 8-year mean data revealed that the D×P (AVROS) progeny, namely, DA33, recorded the highest average bunch weight at 15.38 kg bunch^{-1} followed by progeny DA43 at 15.23 kg bunch^{-1}, and these were statistically different from other progenies.

Apart from recording the highest average bunch weight, the D×P (AVROS) progenies were noted for high mean fruit weight, with the highest attained by progeny DA33 at 14.17 g. On the other hand, the smallest fruitlets were recorded by the D×P (La Me) progeny SC5 at 8.25g. D×P (Yangambi) and D×P (Dumpy AVROS) shared medium fruit weight ranging from 10 to 13 g. For the other important bunch component traits such as fruit to bunch, mesocarp to fruit, oil to dry mesocarp and oil to wet mesocarp ratios, the D×P (Yangambi) progenies, namely, DA30, DA81, DA30 and DA30, scored highest at 67.75%, 88.38%, 80.30% and 54.94%, respectively. These characteristics resulted in higher oil to bunch values for D×P (Yangambi), led by progeny DA81 at 30.96%. The LSD test (LSD α = 0.05) indicated significant differences among progenies derived from D×P (Yangambi), D×P (La Me), D×P (AVROS) and D×P (Dumpy AVROS) for oil yield. The seven top ranked progenies were all from D×P (Yangambi) with progeny DA30 having the highest oil yield at 7.99 t ha^{-1} yr^{-1}. The results indicate D×P (Yangambi) to be a high oil yield population in this study, and this is found to be in line with the earlier findings reported by Chin *et al*. (2005).

Among the vegetative characteristics, the trial mean for frond production was 26.26 fronds palm^{-1} yr^{-1}. The D×P (Yangambi) progeny DA80 produced the most fronds at 28.86 palm^{-1} yr^{-1}. At the other extreme, the D×P (La Me) progeny SC5 had the least fronds at 22.78 palm^{-1} yr^{-1}. The frond production of nine progenies, two D×P (Yangambi), four D×P (AVROS), one D×P (Dumpy AVROS) and two D×P (La Me) was found to be lower than the trial mean.

The D×P (AVROS) and D×P (Dumpy AVROS) progenies were noted for their larger petiole cross-section with 85%, or six out of seven, of the test progenies recording petiole cross-sections which exceeded the trial mean (41.49 cm^2). These results are in contrast to the petiole cross-sections for the D×P (Yangambi) progenies in which 85% of them recorded smaller petiole cross-sections than the trial mean.

The trial mean for rachis length was 6.38 m, ranging from 5.60 to 6.79 m long. Data on this trait may be useful as a guideline to determine the planting density of specific progenies in a unit area. The D×P (Yangambi) progeny DA84 recorded the shortest rachis length at 5.60 m while progeny DA39 was the longest at 6.79 m. The D×P (Dumpy AVROS) progeny DA39 recorded the longest leaflet length at 111.32 cm. Leaf area and leaf area index of the progenies varied from 9.09 to 14.11 cm^2 and from 5.28 to 7.44, respectively. Seventy-two percent of the progenies were found to have equal or higher leaf area than the trial mean of 12.10 cm^2. The highest bunch index was recorded for progeny DA15 at 0.47, which also recorded a lower vegetative dry matter production (16.78 t ha^{-1} yr^{-1}) but gave the highest mean FFB production (201.04 kg palm^{-1} yr^{-1}) with medium leaf area (11.94 m^2) (*Figure 1*).

The trial means for physiological traits such as vegetative dry matter, bunch dry matter, total dry matter and bunch index were 18.58 t ha^{-1} yr^{-1}, 12.39 t ha^{-1} yr^{-1}, 30 t ha^{-1} yr^{-1} and 0.40, respectively. The most and the least vegetative dry matter were produced by progeny DA81 at 21.79 t ha^{-1} yr^{-1} and progeny SC5 at 16.32 t ha^{-1} yr^{-1}, respectively. Two progenies, DA15 and DA42, shared the highest bunch index at 0.47, which was 17% higher than the trial mean.

TABLE 3. ANALYSIS OF VARIANCE (ANOVA) FOR BUNCH YIELD, BUNCH QUALITY, VEGETATIVE AND PHYSIOLOGICAL TRAITS BY PROGENIES

Character	Source of variation			
	Blocks (B)	Progenies (G)	B x G	Within palms
Mean Squares for Bunch Yield Components				
Degrees of freedom	4	24	96	1 775
a. *Young mature period (1st to 3rd year of harvest)*				
1 Fresh fruit bunch yield	25 978.54**	11 022.78**	3 662.07**	716.89
2 Bunch number	540.04**	276.00**	40.76**	8.96
3 Average bunch weight	19.04**	46.92**	3.65**	1.71
b. *Mature period (4th to 6th year of harvest)*				
4 Fresh fruit bunch yield	54 173.60**	23 755.63**	3 585.15**	1 637.71
5 Bunch number	120.01**	232.62**	15.39**	6.57
6 Average bunch weight	37.16**	119.69**	7.79**	3.48
c. *8-year mean (2001 to 2008)*				
7 Fresh fruit bunch yield	27 025.40**	12 790.58**	1 697.78**	679.50
8 Bunch number	41.98**	158.74**	10.35**	3.93
9 Average bunch weight	53.70**	71.07**	4.08**	1.64
Mean Squares for Bunch Quality Components				
Degrees of freedom	4	24	94	752
10 Mean fruit weight	6.52	48.45**	8.07*	6.01
11 Mesocarp to fruit	43.09*	141.40**	20.76**	13.92
12 Kernel to fruit	5.70	31.07**	4.83**	3.28
13 Shell to fruit	21.12**	54.48**	8.08**	4.90
14 Oil to dry mesocarp	34.39*	33.69**	8.78**	4.28
15 Oil to wet mesocarp	22.20	115.47**	27.02**	14.15
16 Fruit to bunch	59.01**	44.71**	16.89	15.17
17 Oil to bunch	65.06**	71.16**	13.63**	9.08
18 Kernel to bunch	4.16*	14.31**	2.28**	1.55
19 Oil yield	22.06**	11.46**	2.34*	1.62
20 Kernel yield	0.35*	1.01**	0.19**	0.11
Mean Squares for Vegetative and Physiological Traits				
Degrees of freedom	1	24	24	674
21 Frond production	4.17	79.39**	7.08	4.97
22 Petiole cross-section	1 561.97**	855.00**	164.38**	40.27
23 Rachis length	2.71**	3.59**	0.52**	0.18
24 Leaflet length	21.72	1085.94**	61.82	53.62
25 Leaflet width	13.14**	4.92**	0.86**	0.22
26 Leaflet number	172.99	554.57**	337.61**	83.82
27 Palm height	12.86**	5.49**	2.06**	0.29
28 Leaf area	67.73**	47.43**	6.67**	2.22
29 Leaf area index	19.78**	13.83**	1.94**	0.65
30 Diameter	0.001	0.02**	0.01**	0.001
31 Leaf dry weight	16.37**	8.95**	1.72**	0.42
32 Trunk dry weight	435.39**	228.89**	125.97**	22.46
33 Frond dry weight	14 310.48**	3 293.09**	1 149.65**	369.76
34 Leaf area ratio	17.95	86.40**	10.50**	5.07
35 Vegetative dry matter	365.14**	76.23**	28.04**	8.27
36 Bunch dry matter	79.23**	33.08**	7.91**	3.52
37 Total dry matter	104.15*	96.80**	43.05**	14.14
38 Bunch index	0.18**	0.03**	0.01**	0.001
39 Net assimilation rate	411.34**	649.19**	72.15*	42.58

Note: **,* significant at $P \leq 0.01$ and $P \leq 0.05$, respectively.

TABLE 4. PROGENY MEANS FOR YIELD, BUNCH QUALITY, VEGETATIVE AND PHYSIOLOGY TRAITS IN *TENERA* POPULATIONS

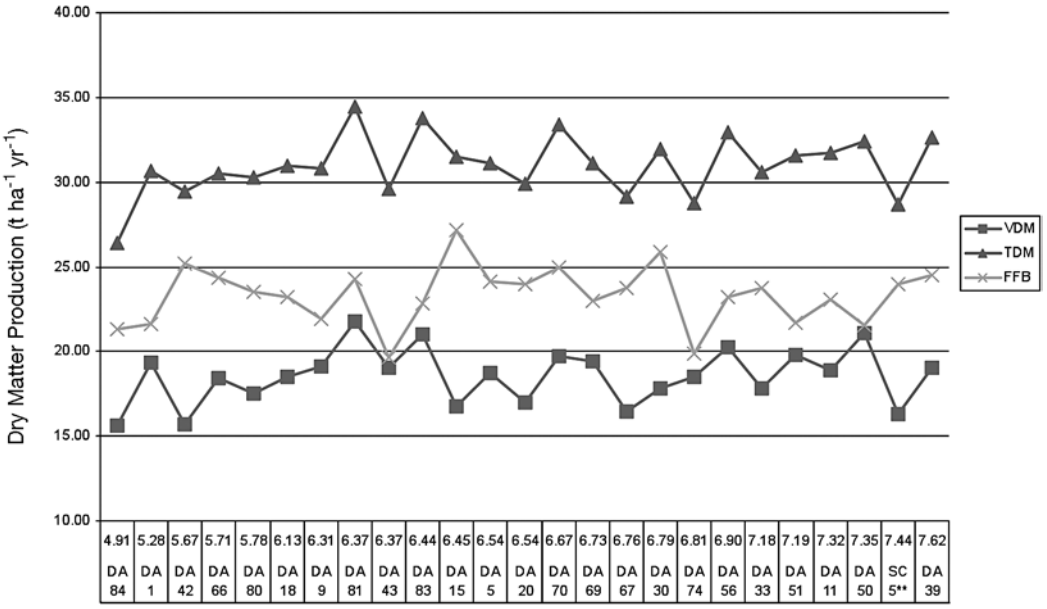
Pisifera group	Yangambi									
Character/progeny	**DA1**	**DA5**	**DA9**	**DA11**	**DA15**	**DA18**	**DA20**	**DA30**	**DA42**	**DA51**
Bunch Yield Components										
Number of palms (N)	72	77	72	77	77	78	73	79	75	75
a. *Young mature period (1st to 3rd year of harvest)*										
1 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	123.93	134.68	129.05	131.50	141.46	127.08	139.29	153.34	134.10	114.58
2 Bunch number (bunches palm^{-1} yr^{-1})	17.17	16.04	15.90	14.53	16.60	15.32	15.36	17.69	16.50	12.90
3 Average bunch weight (kg bunch^{-1})	7.23	8.47	8.19	9.14	8.58	8.38	9.31	8.73	8.12	8.96
b. *Mature period (4th to 6th year of harvest)*										
4 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	199.51	220.20	200.42	203.39	252.16	211.93	225.27	239.55	228.96	199.66
5 Bunch number (bunches palm^{-1} yr^{-1})	15.19	13.12	13.10	12.54	16.69	13.65	14.64	15.81	17.70	12.57
6 Average bunch weight (kg bunch^{-1})	13.29	13.12	15.38	16.30	15.18	15.59	15.61	15.27	17.70	15.96
c. *8-year mean (2001 to 2008)*										
7 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	160.43	178.78	162.67	170.63	201.04	171.78	177.40	191.89	186.77	160.54
8 Bunch number (bunches palm^{-1} yr^{-1})	14.25	13.11	12.74	12.23	15.10	13.01	13.25	14.74	15.54	11.61
9 Average bunch weight (kg bunch^{-1})	11.33	13.68	12.84	14.03	13.35	13.30	13.58	13.10	12.07	13.87
Bunch Quality Components										
Number of palms (N)	31	27	35	55	26	44	40	42	53	31
10 Mean fruit weight (g)	11.32	13.84	11.37	11.32	11.26	11.07	10.52	11.03	9.95	12.23
11 Mesocarp to fruit (%)	85.20	87.28	85.22	80.29	82.21	85.54	84.04	82.15	84.60	86.81
12 Kernel to fruit (%)	7.53	5.18	6.96	8.30	8.18	7.08	7.95	7.91	6.95	5.70
13 Shell to fruit (%)	7.28	7.53	7.83	11.40	9.62	7.39	8.01	9.95	8.45	7.49
14 Oil to dry mesocarp (%)	78.64	78.79	79.32	78.93	78.06	78.68	79.28	80.30	78.59	79.65
15 Oil to wet mesocarp (%)	51.69	53.29	52.85	52.11	51.08	54.29	53.10	54.94	53.16	53.09
16 Fruit to bunch (%)	64.78	64.27	65.70	66.92	65.75	64.56	66.60	67.75	66.08	65.46
17 Oil to bunch (%)	28.59	29.91	29.52	27.98	27.62	30.06	29.75	30.60	29.76	30.20
18 Kernel to bunch (%)	4.88	3.33	4.55	5.55	5.40	4.56	5.26	5.36	4.58	3.73
19 Oil yield (t ha^{-1} yr^{-1})	6.55	7.45	6.48	6.45	7.96	7.09	7.49	7.99	7.62	6.97
20 Kernel yield (t ha^{-1} yr^{-1})	1.11	0.83	0.99	1.27	1.55	1.07	1.33	1.39	1.18	0.85
Vegetative and Physiological Traits										
Number of palms (N)	30	30	31	31	27	32	25	31	26	28
21 Frond production (No. palm^{-1} yr^{-1})	28.53	27.53	28.42	25.68	26.33	26.34	26.92	23.86	27.59	27.44
22 Petiole cross-section (cm^2)	38.74	39.44	38.61	41.93	35.65	41.64	36.27	49.15	40.82	34.56
23 Rachis length (m)	6.40	6.38	6.32	6.60	6.18	6.44	5.97	6.77	6.40	6.14
24 Leaflet length (cm)	92.9	99.9	100.3	102.1	97.3	96.8	94.0	103.6	91.4	101.6
25 Leaflet width (cm)	5.19	6.16	6.05	6.51	6.41	5.95	6.70	6.23	6.81	6.33
26 Leaflet number (No. palm^{-1} yr^{-1})	177.32	172.30	168.81	178.68	168.00	172.45	168.26	181.09	174.21	170.70
27 Palm height (m)	4.03	3.89	4.54	4.54	4.20	3.96	4.20	3.82	4.77	3.98
28 Leaf area (cm^2)	9.78	12.11	11.68	13.55	11.94	11.36	12.12	13.31	12.34	12.52
29 Leaf area index	5.28	6.54	6.31	7.32	6.45	6.13	6.54	7.19	6.67	6.76
30 Diameter (m)	0.59	0.56	0.54	0.55	0.56	0.53	0.52	0.57	0.55	0.52
31 Leaf dry weight (kg)	4.17	4.24	4.16	4.50	3.85	4.47	3.92	4.10	3.55	5.21
32 Trunk dry weight (kg)	23.20	20.54	22.29	23.58	21.93	19.01	19.12	23.35	17.43	24.25
33 Frond dry weight (kg)	118.85	116.94	118.00	115.44	101.48	117.02	105.53	107.96	97.56	136.01
34 Leaf area ratio	14.49	17.94	17.61	18.57	18.89	16.24	19.40	18.66	16.23	14.21
35 Vegetative dry matter (kg palm^{-1} yr^{-1})	19.32	18.70	19.08	18.91	16.78	18.50	16.95	17.86	15.64	21.79
36 Bunch dry matter (kg palm^{-1} yr^{-1})	11.35	12.42	11.71	12.80	14.68	12.49	12.97	14.09	10.73	12.64
37 Total dry matter (kg palm^{-1} yr^{-1})	30.67	31.11	30.79	31.70	31.47	30.99	29.93	31.95	26.37	34.43
38 Bunch index	0.37	0.40	0.38	0.40	0.47	0.41	0.43	0.44	0.41	0.37
39 Net assimilation rate	57.14	45.86	46.99	41.78	46.86	48.69	44.03	45.35	51.54	52.24

TABLE 4. PROGENY MEANS FOR YIELD, BUNCH QUALITY, VEGETATIVE AND PHYSIOLOGY TRAITS IN *TENERA* POPULATIONS (continued)

Pisifera group	Yangambi						La Me		Dumpy-AVROS	
Character/progeny	**DA67**	**DA70**	**DA80**	**DA81**	**DA83**	**DA84**	**SC5**	**DA69**	**DA39**	**DA74**
Bunch Yield Components										
Number of palms (N)	75	78	75	75	76	76	77	79	79	66
a. *Young mature period (1st to 3rd year of harvest)*										
1 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	131.12	140.07	126.67	129.85	128.79	99.53	129.58	126.31	129.73	108.54
2 Bunch number (bunches palm^{-1} yr^{-1})	13.99	17.65	14.70	16.22	16.32	12.36	15.80	16.16	13.67	11.31
3 Average bunch weight (kg bunch^{-1})	9.54	8.01	8.60	8.06	7.91	8.13	8.21	7.85	9.50	9.70
b. *Mature period (4th to 6th year of harvest)*										
4 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	214.11	228.20	210.02	232.88	208.21	192.37	204.75	208.83	227.89	177.21
5 Bunch number (bunches palm^{-1} yr^{-1})	13.10	15.71	13.78	15.07	13.08	13.50	12.81	13.31	13.57	10.80
6 Average bunch weight (kg bunch^{-1})	16.50	14.61	15.40	15.55	15.95	14.26	16.07	15.76	13.57	16.51
c. *8-year mean (2001 to 2008)*										
7 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	175.99	184.84	173.98	179.76	169.39	157.76	177.77	170.45	181.35	147.06
8 Bunch number (bunches palm^{-1} yr^{-1})	12.43	14.79	13.00	13.85	13.09	12.18	13.29	13.16	12.47	10.17
9 Average bunch weight (kg bunch^{-1})	14.31	12.57	13.50	13.02	12.98	13.01	13.43	13.01	14.59	14.56
Bunch Quality Components										
Number of palms (N)	28	54	28	26	30	30	31	28	40	35
10 Mean fruit weight (g)	11.57	12.25	11.74	12.38	13.53	11.42	8.25	13.43	13.62	11.46
11 Mesocarp to fruit (%)	83.78	85.82	84.84	88.38	86.97	83.60	83.43	87.51	85.13	84.38
12 Kernel to fruit (%)	7.13	6.47	7.29	5.77	5.72	8.01	6.50	4.89	6.03	6.92
13 Shell to fruit (%)	9.11	7.70	8.03	5.85	7.32	8.37	10.07	7.60	8.84	8.69
14 Oil to dry mesocarp (%)	78.60	79.14	77.89	79.34	77.75	78.22	77.16	75.32	77.25	76.45
15 Oil to wet mesocarp (%)	52.42	53.42	51.66	54.13	52.40	49.57	50.34	49.10	48.42	48.62
16 Fruit to bunch (%)	64.59	67.02	65.09	64.83	64.55	67.44	65.61	65.86	65.32	62.10
17 Oil to bunch (%)	28.41	30.76	28.48	30.96	29.47	27.93	27.58	28.27	26.92	25.43
18 Kernel to bunch (%)	4.61	4.35	4.76	3.75	3.70	5.44	4.27	3.20	3.94	4.30
19 Oil yield (t ha^{-1} yr^{-1})	6.91	7.68	6.91	7.69	6.70	6.46	6.98	6.75	6.92	5.36
20 Kernel yield (t ha^{-1} yr^{-1})	1.12	1.09	1.17	0.93	0.84	1.22	1.08	0.76	1.02	0.90
Vegetative and Physiological Traits										
Number of palms (N)	26	26	09	30	30	27	28	27	31	26
21 Frond production (No. palm^{-1} yr^{-1})	28.12	28.42	28.86	26.21	27.17	27.42	22.78	24.57	23.53	26.70
22 Petiole cross section (cm^2)	30.42	38.61	35.70	48.94	44.66	32.70	42.31	47.40	48.97	42.08
23 Rachis length (m)	5.71	6.32	6.08	6.66	6.57	5.60	7.15	6.49	6.79	6.46
24 Leaflet length (cm)	85.70	100.30	91.70	97.81	97.02	87.31	99.91	94. 1	111.32	95.14
25 Leaflet width (cm)	6.39	6.05	5.91	5.92	6.17	5.49	6.92	6.46	6.36	6.37
26 Leaflet number (No. palm^{-1} yr^{-1})	166.92	168.81	172.83	178.21	175.05	165.42	174.97	179.57	174.69	182.59
27 Palm height (m)	4.69	4.54	3.66	4.33	4.48	4.13	2.97	4.48	3.41	4.00
28 Leaf area (cm^2)	10.50	11.68	10.70	11.79	11.93	9.09	13.78	12.47	14.11	12.61
29 Leaf area index	5.67	6.31	5.78	6.37	6.44	4.91	7.44	6.73	7.62	6.81
30 Diameter (m)	0.54	0.54	0.52	0.58	0.57	0.50	0.58	0.50	0.55	0.49
31 Leaf dry weight (kg)	4.78	4.16	3.86	5.21	4.78	3.55	4.54	5.06	5.22	4.51
32 Trunk dry weight (kg)	24.58	22.29	17.21	24.25	24.58	17.43	16.74	18.63	17.24	16.37
33 Frond dry weight (kg)	129.86	118.00	111.37	136.01	129.86	97.56	103.25	124.22	122.92	119.54
34 Leaf area ratio	15.58	17.61	17.90	14.21	15.58	16.23	19.48	15.85	17.55	18.51
35 Vegetative dry matter (kg palm^{-1} yr^{-1})	21.00	19.08	17.49	21.79	21.00	15.64	16.32	19.43	19.06	18.48
36 Bunch dry matter (kg palm^{-1} yr^{-1})	12.79	11.71	12.76	12.64	12.79	10.73	12.36	11.67	13.58	10.29
37 Total dry matter (kg palm^{-1} yr^{-1})	33.80	30.79	30.25	34.43	33.80	26.37	28.68	31.10	32.65	28.77
38 Bunch index	0.38	0.38	0.42	0.37	0.38	0.41	0.43	0.38	0.42	0.36
39 Net assimilation rate	50.52	46.99	50.42	52.24	50.52	51.54	36.95	44.70	41.34	40.95

TABLE 4. PROGENY MEANS FOR YIELD, BUNCH QUALITY, VEGETATIVE AND PHYSIOLOGY TRAITS IN *TENERA* POPULATIONS (continued)

Pisifera group	AVROS					Combined progenies		
Character/progeny	**DA33**	**DA43**	**DA50**	**DA56**	**DA66**	**Mean**	**CV (%)**	**LSD (p≤0.05)**
Bunch Yield Components								
Number of palms (N)	78	76	79	78	78	1900	-	-
a. *Young mature period (1st to 3rd year of harvest)*								
1 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	137.40	107.46	119.04	130.00	140.39	128.71	25.80	9.97
2 Bunch number (bunches palm^{-1} yr^{-1})	13.63	10.72	12.40	13.55	14.77	14.87	26.10	1.09
3 Average bunch weight (kg bunch^{-1})	10.11	10.12	9.69	9.62	9.57	8.79	17.72	0.43
b. *Mature period (4th to 6th year of harvest)*								
4 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	214.12	178.13	200.64	216.53	216.28	212.73	21.72	13.76
5 Bunch number (bunches palm^{-1} yr^{-1})	11.73	10.26	11.71	12.16	13.60	13.58	23.45	0.86
6 Average bunch weight (kg bunch^{-1})	11.73	10.26	11.71	17.88	15.94	15.88	14.40	0.62
c. *8-year mean (2001 to 2008)*								
7 Fresh fruit bunch yield (kg palm^{-1} yr^{-1})	175.80	145.57	159.49	171.96	180.59	172.54	17.91	12.17
8 Bunch number (bunches palm^{-1} yr^{-1})	11.47	9.61	10.89	11.58	12.78	12.80	19.93	0.92
9 Average bunch weight (kg bunch^{-1})	15.38	15.23	14.74	14.87	14.17	13.64	12.30	0.57
Bunch Quality Components								
Number of palms (N)	33	26	28	38	32	875	-	-
10 Mean fruit weight (g)	14.17	11.85	12.19	13.89	12.37	11.87	23.49	1.23
11 Mesocarp to fruit (%)	80.03	81.85	86.70	84.62	82.47	84.46	5.21	1.89
12 Kernel to fruit (%)	8.74	8.42	6.54	7.23	7.77	7.02	30.00	0.91
13 Shell-to-fruit (%)	11.24	9.72	6.75	8.15	9.12	8.50	31.28	1.13
14 Oil to dry mesocarp (%)	78.18	78.38	78.88	77.89	78.13	78.46	3.10	1.08
15 Oil to wet mesocarp (%)	48.27	50.31	50.52	50.60	50.56	51.87	8.46	1.96
16 Fruit to bunch (%)	65.81	63.17	65.02	63.76	63.78	65.50	6.24	1.93
17 Oil to bunch (%)	25.34	26.08	28.52	27.28	26.77	28.72	12.04	1.54
18 Kernel to bunch (%)	5.67	5.32	4.23	4.56	5.00	4.60	31.44	0.63
19 Oil yield (t ha^{-1} yr^{-1})	6.34	5.04	6.44	6.41	6.61	6.95	21.36	0.66
20 Kernel yield (t ha^{-1} yr^{-1})	1.42	1.03	0.95	1.06	1.24	1.11	35.50	0.17
Vegetative and Physiological Traits								
Number of palms (N)	31	30	30	30	31	724	-	-
21 Frond production (No. palm^{-1} yr^{-1})	25.19	25.73	24.03	25.20	27.16	26.26	10.45	1.16
22 Petiole cross-section (cm^2)	42.14	44.31	51.13	47.43	39.55	41.49	20.70	3.53
23 Rachis length (m)	6.49	6.50	6.69	6.38	5.86	6.38	8.76	0.23
24 Leaflet length (cm)	100.61	97.02	103.13	93.75	83.82	9.66	9.72	0.38
25 Leaflet width (cm)	6.65	6.11	6.62	6.71	6.49	6.30	10.25	0.27
26 Leaflet number (No. palm^{-1} yr^{-1})	174.16	174.07	175.07	178.32	170.61	173.95	5.98	9.98
27 Palm height (m)	3.88	3.70	4.20	4.07	4.56	4.11	17.74	0.31
28 Leaf area (cm^2)	13.30	11.79	13.61	12.78	10.57	12.10	16.45	0.16
29 Leaf area index	7.18	6.37	7.35	6.90	5.71	6.53	16.45	0.09
30 Diameter (m)	0.52	0.54	0.58	0.55	0.51	0.54	10.37	0.03
31 Leaf dry weight (kg)	4.52	4.74	5.44	5.06	4.25	4.45	19.74	0.36
32 Trunk dry weight (kg)	17.84	18.00	24.04	21.16	20.12	20.47	28.10	2.67
33 Frond dry weight (kg)	113.14	121.83	131.25	127.79	115.61	116.13	19.51	10.55
34 Leaf area ratio	18.95	16.05	15.71	16.09	15.76	17.29	16.34	0.24
35 Vegetative dry matter (kg palm^{-1} yr^{-1})	17.81	19.02	21.12	20.26	18.46	18.58	18.40	1.59
36 Bunch dry matter (kg palm^{-1} yr^{-1})	12.74	10.55	11.26	12.67	12.08	12.39	17.57	1.01
37 Total dry matter (kg palm^{-1} yr^{-1})	30.55	29.57	32.38	32.93	30.54	30.97	13.67	2.02
38 Bunch index	0.42	0.36	0.35	0.38	0.40	0.40	14.57	0.03
39 Net assimilation rate	41.07	45.16	42.54	45.70	51.82	46.13	17.39	3.44



Note: VDM = vegetative dry matter; TDM = total dry matter; FFB = fresh fruit bunches.

Figure 1. Dry matter production trend versus leaf area index.

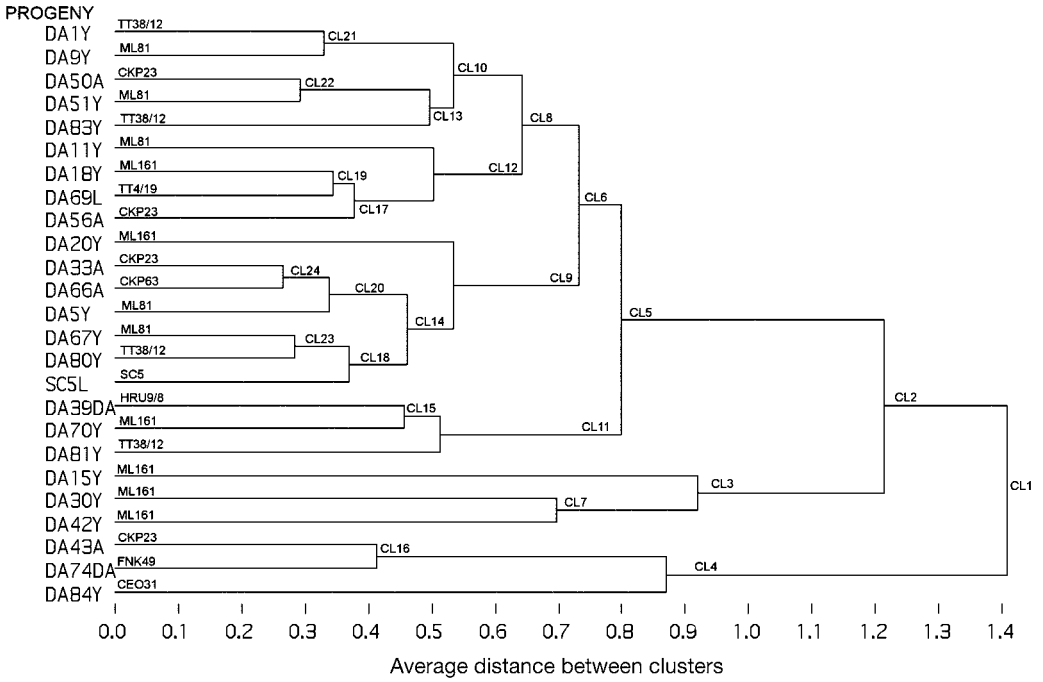


Figure 2. Dendrogram of 25 progenies based on Anderberg's (1973) average distance.

Phenotypic Cluster

Twenty-three clusters were obtained from the cluster analysis, and are presented in the form of a dendrogram in *Figure 2*. Analysis revealed that, in general, the progenies were grouped according to their *pisifera* sources except for progenies DA51 of D×P (Yangambi) origin and DA50 of D×P (AVROS) origin. However, it was noted that these progenies shared the same *dura* parental line which contributed to the similarity in their performance. Two elite progenies (DA30 and DA42) derived from crosses between Deli *dura* and *pisifera* Yangambi formed a single group as cluster 7 (CL7) which connected later with progeny DA15 in cluster 3 (CL3). The root mean square distances between the observations were recorded at less than 1, except for cluster 1 and cluster 2 at 1.4 and 1.2, respectively.

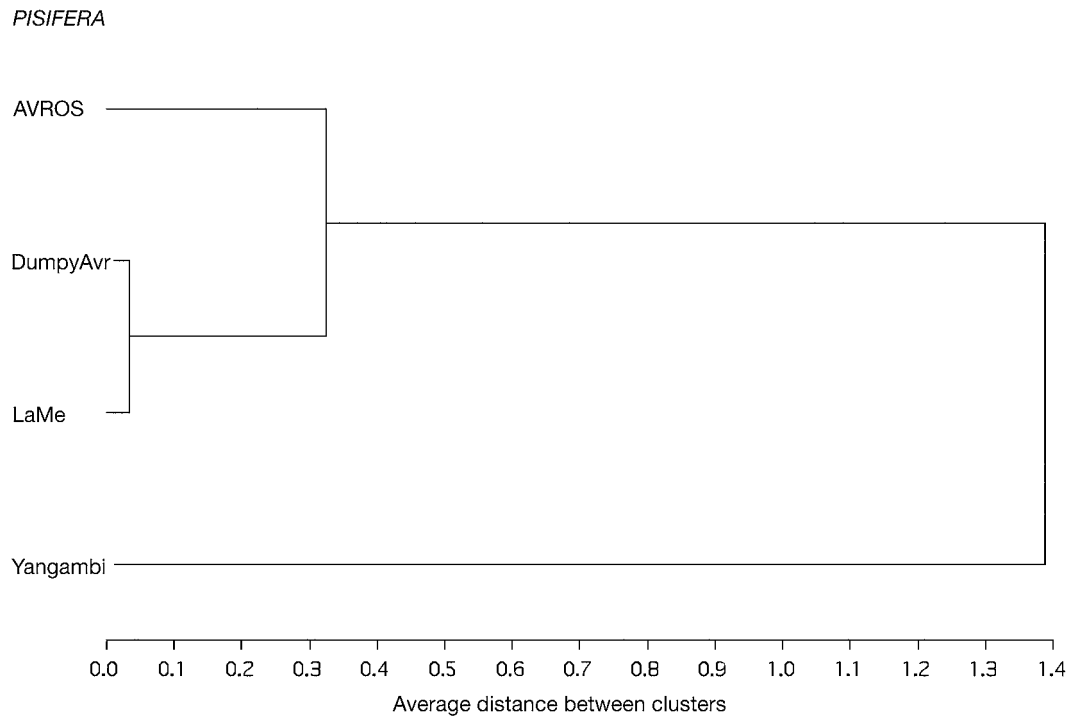


Figure 3. Dendrogram of four pisifera *groups based on Anderberg's (1973) average distance.*

The relationship between the *pisifera* sources is illustrated by the dendogram in *Figure 3*. The first pair is composed of *pisifera* Dumpy AVROS and La Me connected by a vertical line or root mean square distance of 0.035, followed by *pisifera* AVROS at 0.325 and *pisifera* Yangambi at 1.39. These results indicate that *pisifera* Dumpy AVROS and La Me in this study were closely related populations while *pisifera* Yangambi was the most distantly related *pisifera* population.

CONCLUSION

The analysis of 25 D×P progenies derived from crosses between Deli *dura* with *pisifera* from different sources, tested on inland soil, indicated that the performance of progenies was generally grouped according to the *pisifera* sources. The highly significant differences among the progenies shown by ANOVA for bunch yield, bunch quality, vegetative and physiological traits showed the existence of variability among those traits, implying that these can be improved further. The Yangambi *pisifera* was found to differ from the other *pisifera* sources. The superior progenies of D×P (Yangambi) were clustered together, indicating a close relationship among these progenies.

ACKNOWLEDGEMENT

The authors are grateful to FELDA Agricultural Services Sdn Bhd and Universiti Putra Malaysia for permission to publish this article.

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