

CHAPTER 4

RESULTS

4.1 Phenotypic Distribution of All Traits

A general idea of the variation in 358 palms for all the traits in Senegal can be obtained by examining the phenotypic distribution using frequency histograms. The mean, range of values and coefficient variation of all 35 traits are presented in Table 4 and the frequency distributions of the 35 traits are given in Figures 2 - 36.

4.1.1 Yield Components

Trial mean for fresh fruit bunch (FFB) was 80.61 kg/p/yr, ranging from 8.59 kg/p/yr to 160.93 kg/p/yr. The distribution of FFB yield is approximately symmetric because many palms had low and high yields (Figure 2). Mean for bunch number (BNO) was 19.05 no./p/yr and the distribution of BNO is slightly negatively skewed because many palms had low BNO (Figure 3). Mean for average bunch weight (ABW) was 4.15 kg/p/yr and the distribution of ABW is nearly normal (Figure 4).

Table 4: Means, Range of Values and Coefficient of Variation for All Traits

No.	Traits	n	Mean	Range of Values		Coefficient of Variation (%)
				Minimum	Maximum	
1	FFB (kg/p/yr)	358	80.61	8.59	160.93	39.79
2	BNO (no./p/yr)	358	19.05	4.13	31.50	28.41
3	ABW (kg/p/yr)	358	4.15	1.74	6.46	23.87
4	BWT (kg)	358	3.62	0.90	8.17	30.25
5	MFW (g)	358	2.41	1.34	6.20	23.63
6	MNW (g)	358	1.56	0.91	3.80	22.71
7	M/F (%)	358	34.78	24.34	52.58	11.38
8	K/F (%)	358	15.64	6.83	24.06	17.43
9	S/F (%)	358	49.57	35.45	59.49	7.67
10	O/DM (%)	358	70.13	52.93	80.06	6.59
11	O/WM (%)	358	41.22	18.34	55.36	15.04
12	F/B (%)	358	57.53	35.36	77.09	10.30
13	O/B (%)	358	8.36	2.84	16.69	25.30
14	K/B (%)	358	8.97	4.29	13.97	19.24
15	OY (kg/p/yr)	358	6.61	0.69	19.99	43.60
16	KY (kg/p/yr)	358	7.21	0.69	16.75	43.16
17	TEP (kg/p/yr)	358	10.94	1.25	25.28	40.37
18	FP (no./p/yr)	355	31.30	21.00	44.00	11.53
19	PCS (cm ²)	355	16.01	7.77	35.20	27.38
20	RL (m)	355	3.85	2.00	4.94	11.09
21	LL (cm)	355	85.73	58.42	108.8	11.02
22	LW (cm)	355	3.93	2.42	5.60	12.68
23	LN (no./p/yr)	355	123.09	82.0	186.0	11.46
24	HT (m)	355	2.81	1.20	4.50	22.34
25	LA (m ²)	355	4.73	1.95	8.53	21.35
26	LAI	355	2.80	1.15	5.05	21.35
27	DIA (m)	355	0.67	0.46	0.95	12.17
28	<i>f</i>	355	0.68	0.33	0.89	12.69
29	LAR	355	12.91	6.49	23.28	21.62
30	BDM (t/ha/yr)	355	6.33	0.67	12.62	39.62
31	VDM (t/ha/yr)	355	11.71	5.21	22.29	23.76
32	TDM (t/ha/yr)	355	18.03	7.93	29.01	20.76
33	BI	355	0.35	0.05	0.56	30.23
34	<i>e</i> (g/MJ)	355	0.86	0.48	1.47	20.02
35	NAR	355	12.72	6.68	24.37	23.72

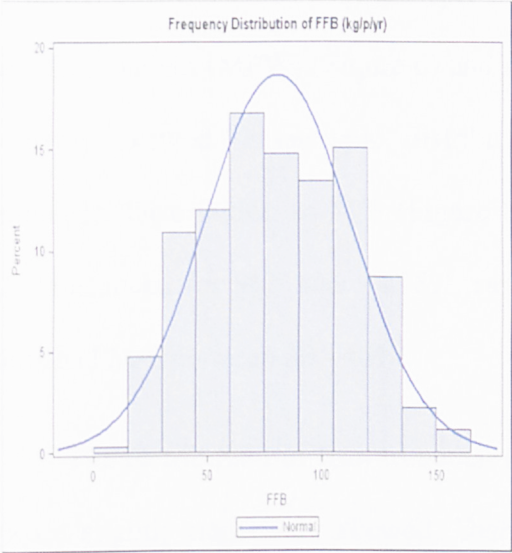


Figure 2: Frequency Distribution of Fresh Fruit Bunch

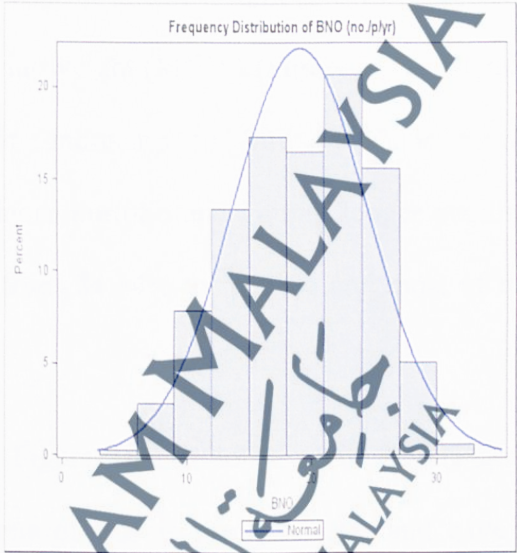


Figure 3: Frequency Distribution of Bunch Number

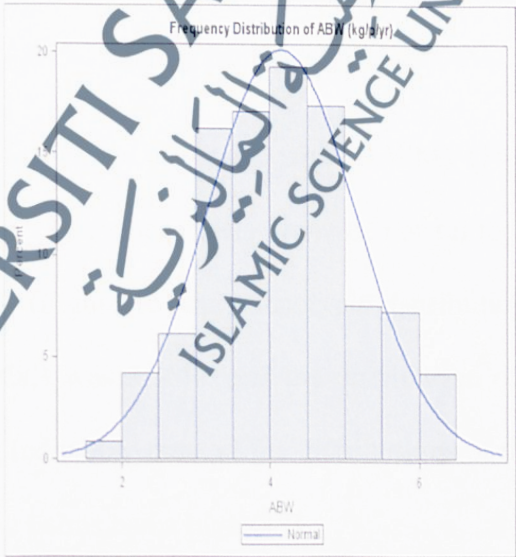


Figure 4: Frequency Distribution of Average Bunch Weight

4.1.2 Bunch Quality Traits

For bunch quality traits, the phenotypic distribution for bunch weight (BWT) (Figure 5), mean fruit weight (MFW) (Figure 6) and mean nut weight (MNW) (Figure 7) are slightly positively skewed. Phenotypic distribution for mesocarp to fruit (M/F) is nearly symmetric. Distribution of M/F (Figure 8) is more kurtotic and having longer positive tail. Trial mean for M/F was 34.78%, ranging from 24.34% to 52.58% and most of the palms had M/F between 30 - 40%.

The distribution of fruit to bunch (F/B) (Figure 9) and shell to fruit (S/F) (Figure 10) are slightly negatively skewed. Distributions of F/B is more kurtotic and have a longer negative tail indicating that some of the palms have a low F/B, but most of the distributions of the palms were more than the trial mean, 57.53%. Trial mean for S/F was high 49.57% and the range was from 34.45% to 59.49%. Most of the palms in Senegal had S/F more than 45%. Distribution of kernel to fruit (K/F) (Figure 11) is nearly normal. Trial mean for K/F was 14.64%, ranging from 6.83% to 24.06%.

The distribution for oil to wet mesocarp (O/WM) (Figure 12) and oil to dry mesocarp (O/DM) (Figure 13) are negatively skewed. For oil to bunch (O/B) (Figure 14) and kernel to bunch (K/B) (Figure 15) the phenotypic distributions are slightly positively skewed. Trial mean for O/B was 8.36%, and the distribution of the palms is positively skewed with a longer tail indicating most of the distributions of the palms were more than trial mean and some of the palms had a high O/B.

The distribution of oil yield (OY) (Figure 16) is positively skewed with a longer tail, many palms had yields between 3 to 10 kg/p/yr and some of the palms had yield

more than 15 kg/p/yr. The trial mean for OY was 6.61 kg/p/yr, ranging from 0.99 kg/p/yr to 19.99 kg/p/yr. The distribution of KY (Figure 17) and TEP (Figure 18) is nearly normal. Trial mean for KY was 7.21 kg/p/yr. Trial mean for total economic product (TEP) was 10.94 kg/p/yr, ranging from 1.25 kg/p/yr to 25.28 kg/p/yr.

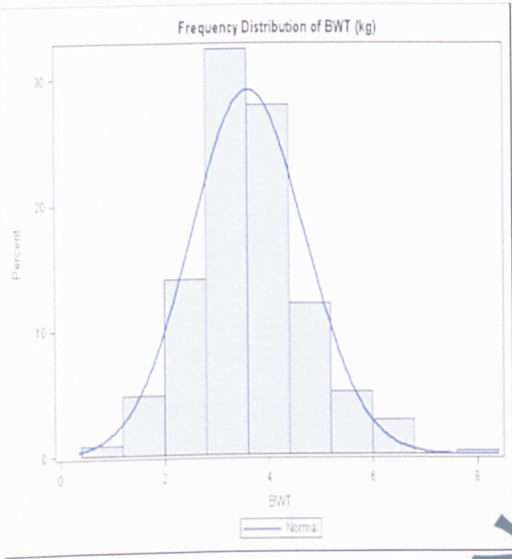


Figure 5: Frequency Distribution of Bunch Weight

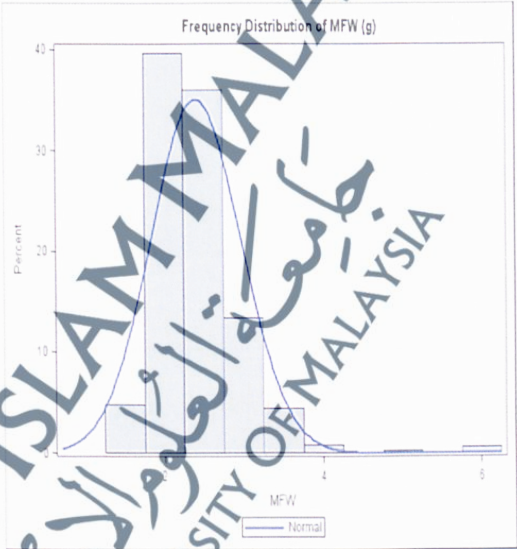


Figure 6: Frequency Distribution of Mean Fruit Weight

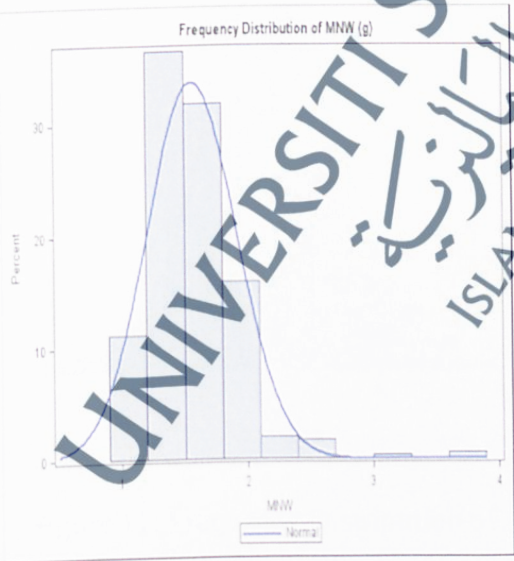


Figure 7: Frequency Distribution of Mean Nut Weight

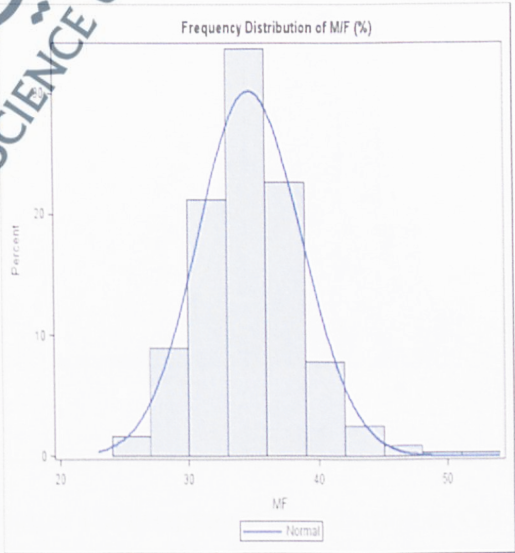


Figure 8: Frequency Distribution of Mesocarp to Fruit

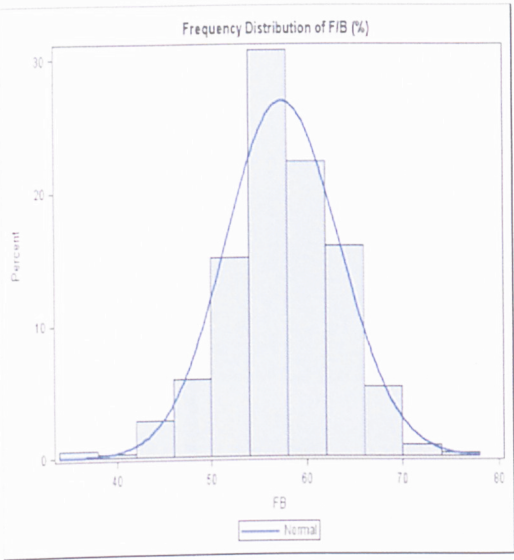


Figure 9: Frequency Distribution of Fruit to Bunch

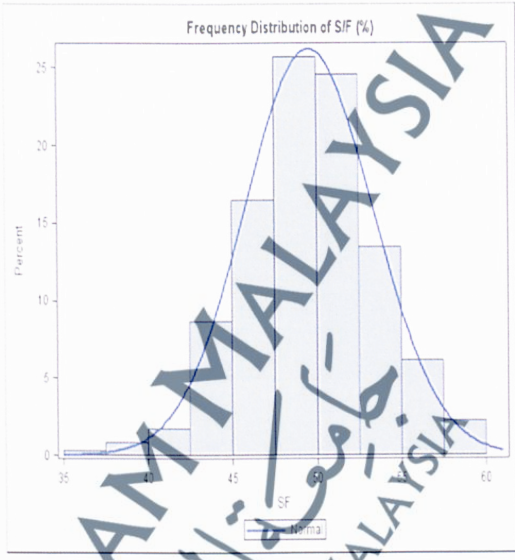


Figure 10: Frequency Distribution of Shell to Fruit

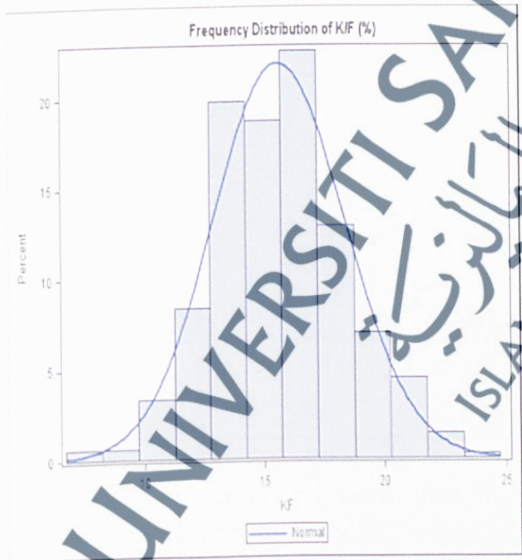


Figure 11: Frequency Distribution of Kernel to Fruit

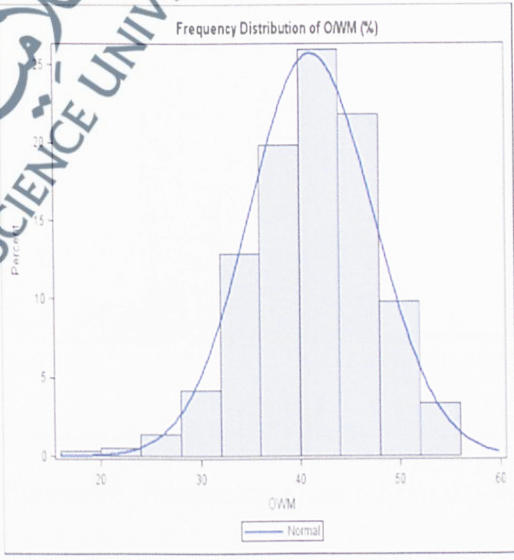


Figure 12: Frequency Distribution of Oil to Wet Mesocarp

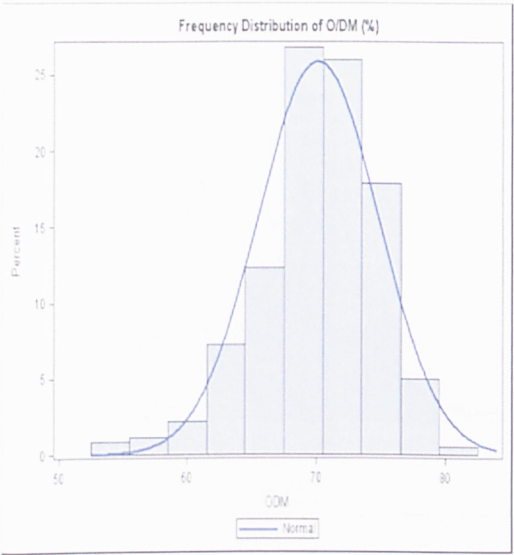


Figure 13: Frequency Distribution of Oil to Dry Mesocarp

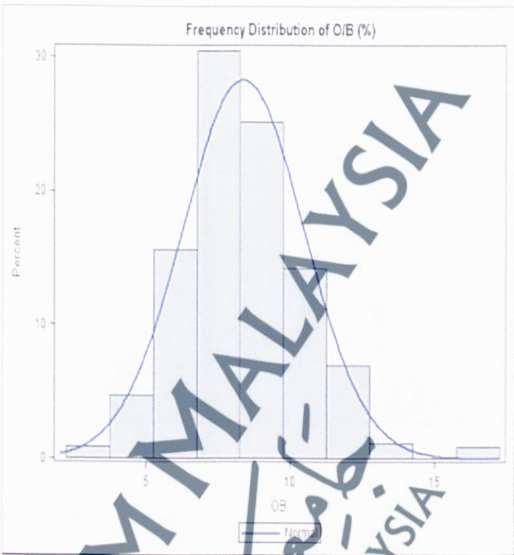


Figure 14: Frequency Distribution of Oil to Bunch

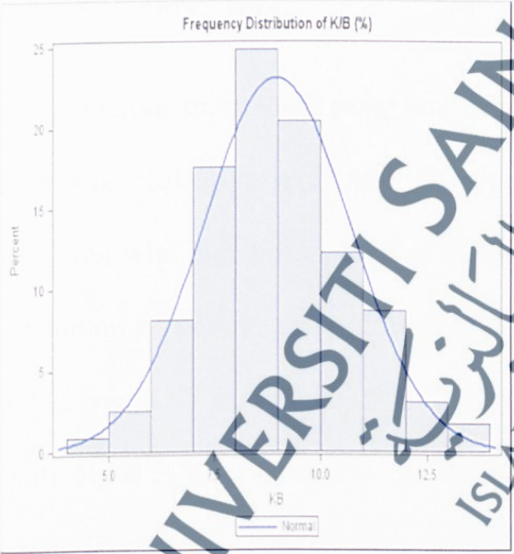


Figure 15: Frequency Distribution of Kernel to Bunch

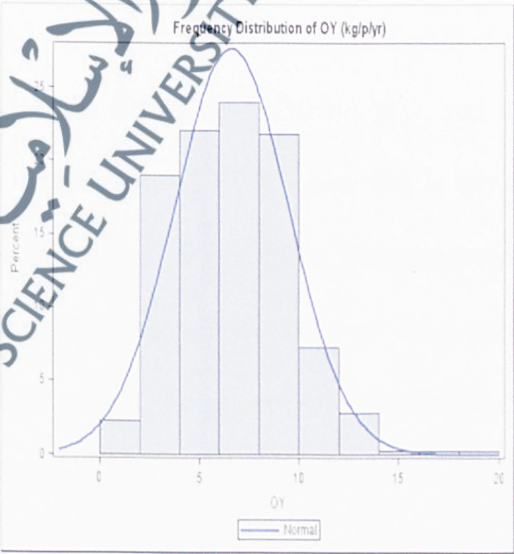


Figure 16: Frequency Distribution of Oil Yield

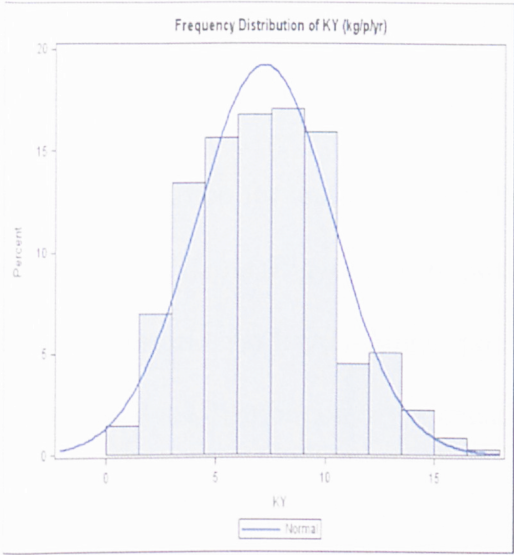


Figure 17: Frequency Distribution of Kernel Yield

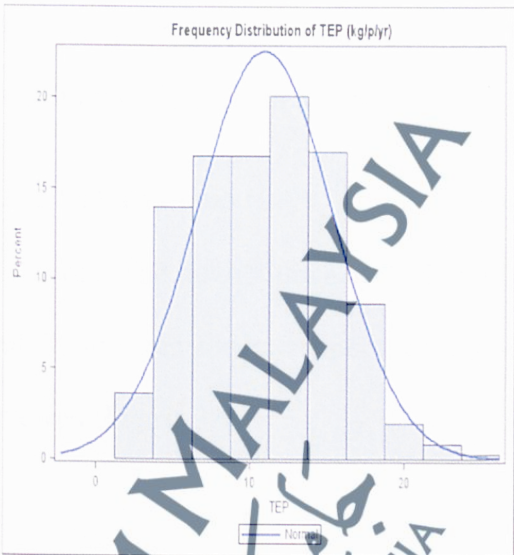


Figure 18: Frequency Distribution of Total Economic Product

4.1.3 Vegetative Traits

For vegetative traits, trial mean for frond production (FP) was 31.30 no./p/yr and the range was 21.0 no./p/yr to 44.0 no./p/yr. The distribution of FP (Figure 19) is nearly symmetric with high peaks, most of the palms had FP of 30 – 33 no./p/yr. The phenotypic distribution of petiole cross-section (PCS) (Figure 20) is positively skewed. Trial mean for RL was 3.85 m, ranging from 2.00 m to 4.94 m and the phenotypic distribution is negatively skewed (Figure 21). As for leaflet number (LN), the distribution is positively skewed (Figure 22).

Phenotypic distribution is nearly symmetric for leaflet width (LW) (Figure 23), leaflet length (LL) (Figure 24), palm height (HT) (Figure 25) and trunk diameter (DIA)

(Figure 26). Generally, most of the palms in Senegal population were tall with trial mean of 2.81 m, ranging from the shortest palm at 1.20 m to the tallest palm at 4.50 m.

Distribution for leaf area (LA) (Figure 27), leaf area ratio (LAR) (Figure 28) and leaf area index (LAI) (Figure 29) are positively skewed. The distributions of PCS and LN are more kurtotic and have a longer positive tail. Trial mean for interception of light (f) was 0.68 and the distribution of f is negatively skewed (Figure 30).

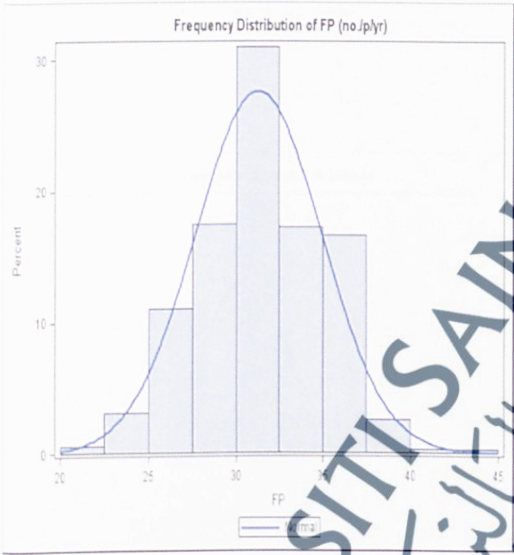


Figure 19: Frequency Distribution of Frond Production

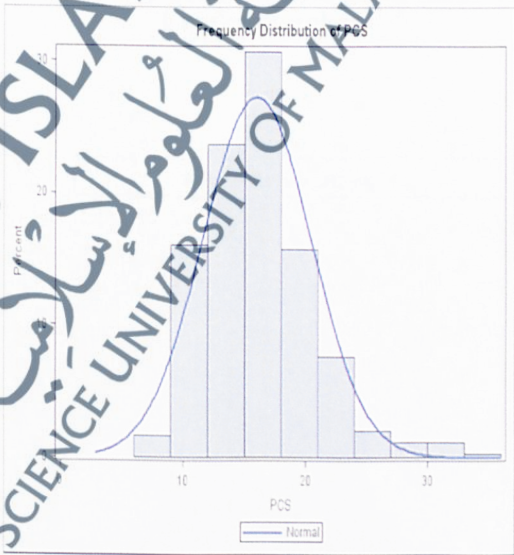


Figure 20: Frequency Distribution of Petiole Cross-Section

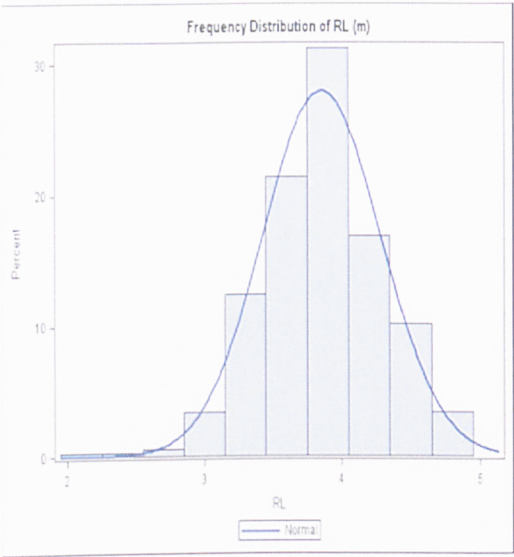


Figure 21: Frequency Distribution of Rachis Length

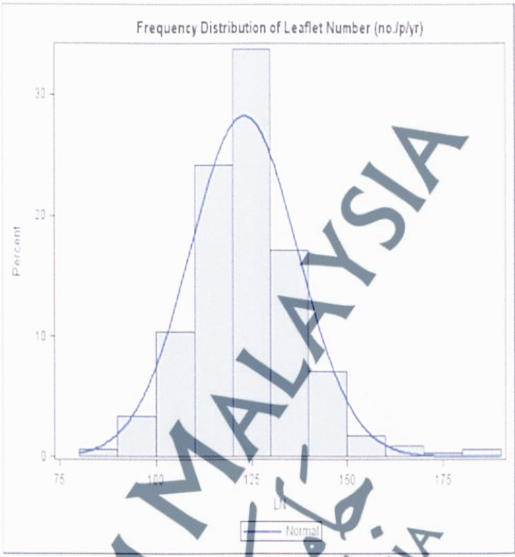


Figure 22: Frequency Distribution of Leaflet Number

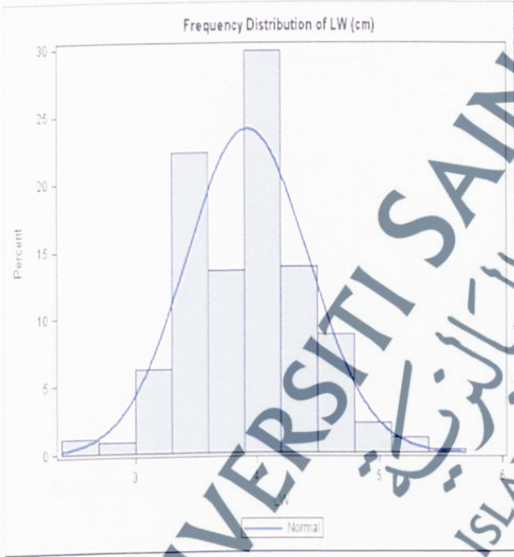


Figure 23: Frequency Distribution of Leaflet Width

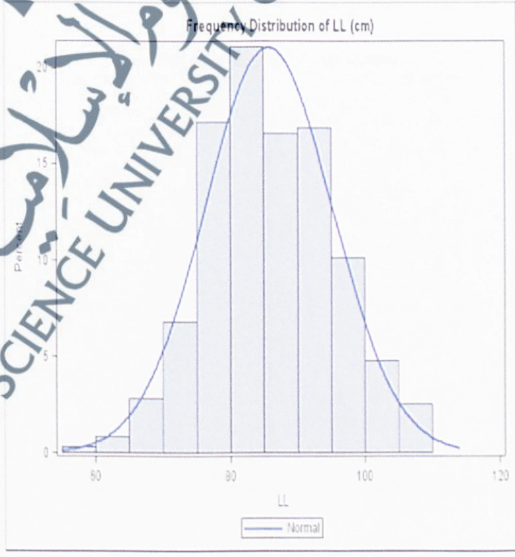


Figure 24: Frequency Distribution of Leaflet Length

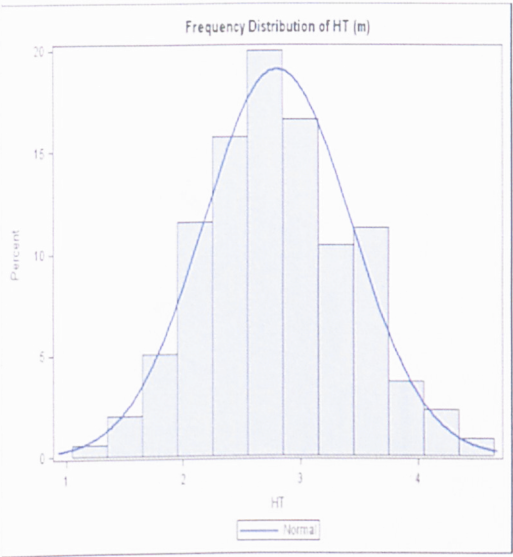


Figure 25: Frequency Distribution of Palm Height

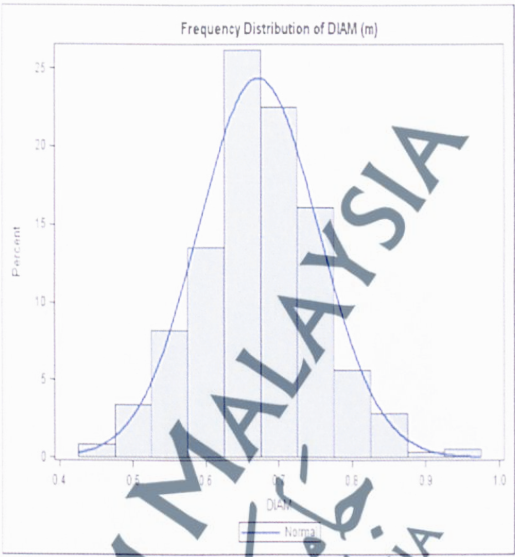


Figure 26: Frequency Distribution of Trunk Diameter

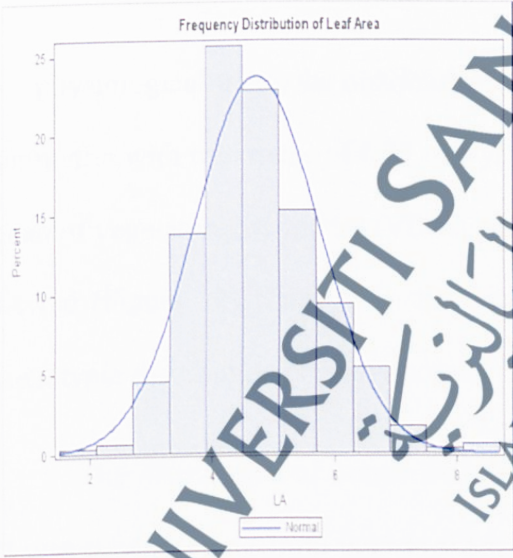


Figure 27: Frequency Distribution of Leaf Area

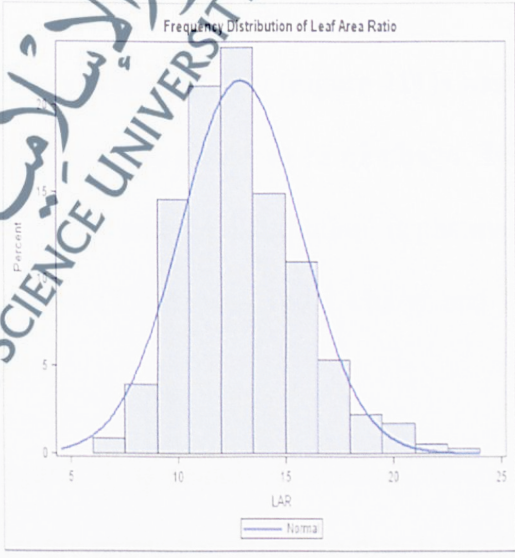


Figure 28: Frequency Distribution of Leaf Area Ratio

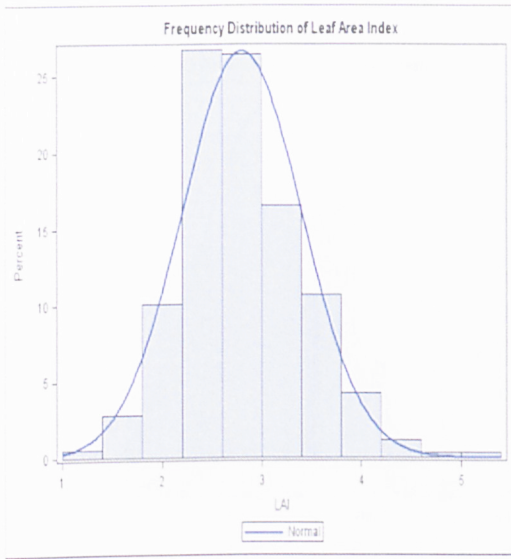


Figure 29: Frequency Distribution of Leaf Area Index

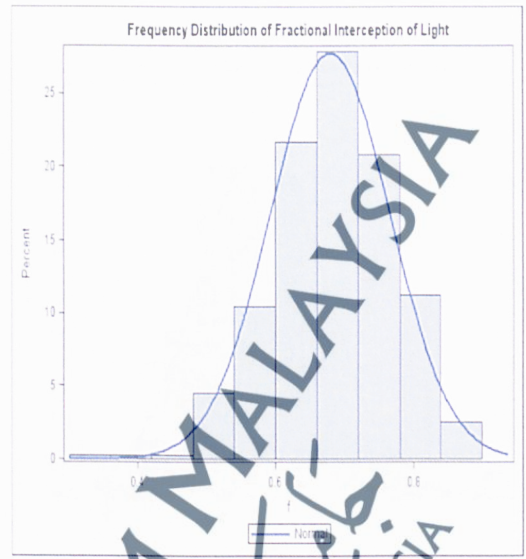


Figure 30: Frequency Distribution of Interception of Light

4.1.4 Physiological Traits

For physiological traits, the distribution of bunch dry matter (BDM) (Figure 31) is nearly symmetric with trial mean of 6.33 t/ha/yr, ranging from 0.66 t/ha/yr to 12.62 t/ha/yr. Trial mean of vegetative dry matter (VDM) was 11.71 t/ha/yr and the distribution is positively skewed (Figure 32). Trial mean for total dry matter (TDM) was 18.03 t/ha/yr and the phenotypic distribution is nearly normal (Figure 33).

The distribution of bunch index (BI) (Figure 34) is negatively skewed. Mean for BI was 0.34, ranging from 0.05 to 0.56. Most of the palms had BI more than 0.30. The phenotypic distribution for conversion efficiency rate (e) (Figure 35) and net assimilation rate (NAR) (Figure 36) are positively skewed and have a longer tail. Trial mean for e was 0.86 g/MJ, ranging from 0.48 g/MJ to 1.47 g/MJ and mean for NAR was 12.72, ranging from 6.68 to 24.37.

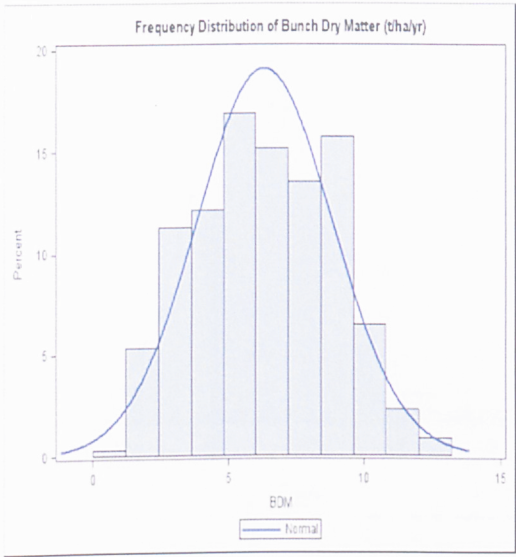


Figure 31: Frequency Distribution of Bunch Dry Matter

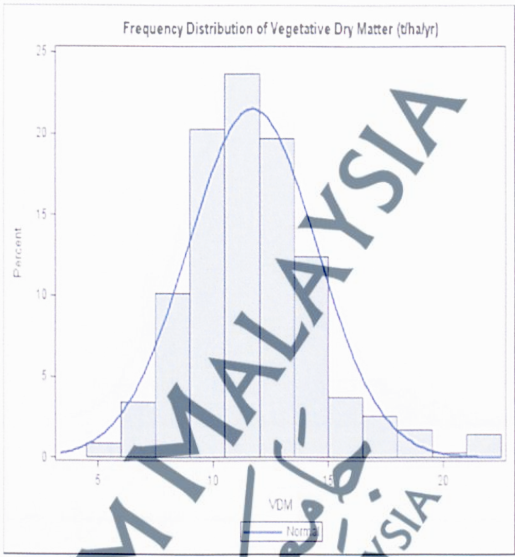


Figure 32: Frequency Distribution of Vegetative Dry Matter

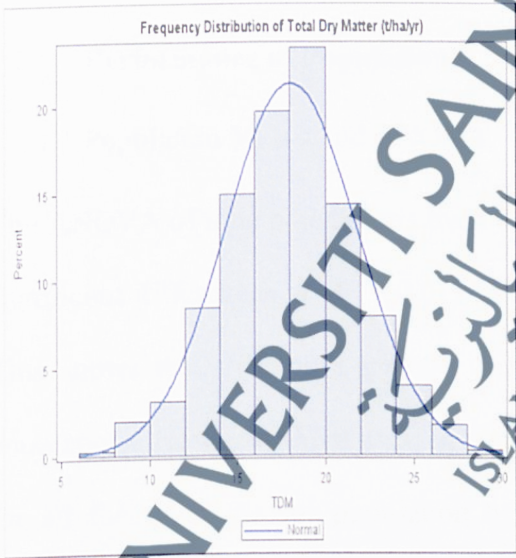


Figure 33: Frequency Distribution of Total Dry Matter

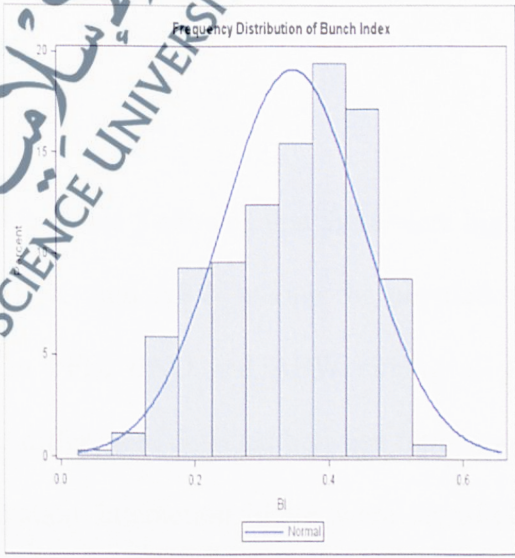


Figure 34: Frequency Distribution of Bunch Index

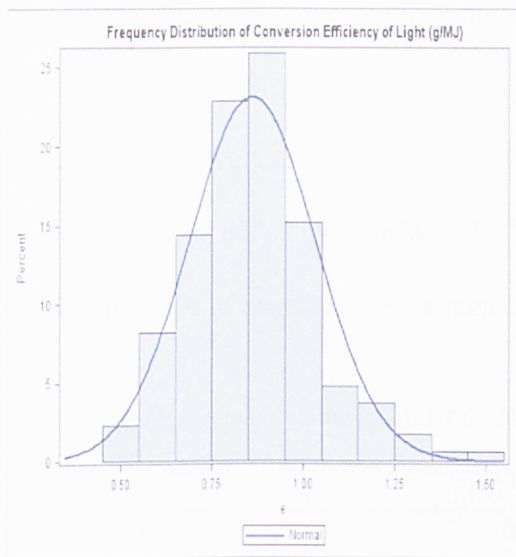


Figure 35: Frequency Distribution of Light Conversion Efficiency

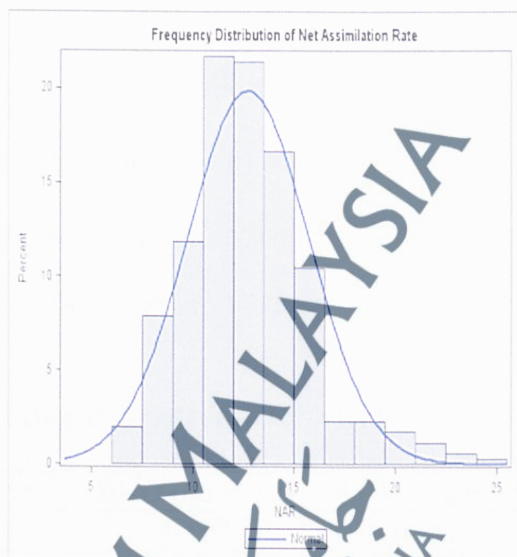


Figure 36: Frequency Distribution of Net Assimilation Rate

4.2 Yield Components

4.2.1 Performance of Populations

4.2.1.1 Population Means and ANOVA

The ANOVA of nine populations from Senegal in Table 5 showed that there were highly significant differences at ($P \leq 0.01$) for FFB, BNO and ABW among the populations. This shows that there is a genetic variation in FFB, BNO and ABW among all the populations. However, there were no significant differences detected between replications for all the traits. As for population by replication interaction, there were significant differences at ($P \leq 0.05$) detected in FFB and BNO but not significant in ABW.

Estimated variance components of Senegal populations for each trait showed in Table 5 indicated that within palms (σ^2_w) were generally high for FFB (79.35%), BNO (87.63%) and ABW (75.84%). However, the variance components estimated for the three

traits in the population $\times$ replication interaction (σ^2_{pr}) were low, 4.39% for FFB, 4.55% for BNO and 0.00 for ABW since the population $\times$ replication interaction was not significant. Variance components estimated for populations (σ^2_p) were also low, FFB (16.24%), BNO (7.81%) and ABW (17.7%). The level σ^2_p (%) provides information on the differentiation of population in Senegal ranging from 7.8% to 17.7%.

Table 5: ANOVA and Variance Components of Senegal Populations for Yield

Source	df	FFB (kg/p/yr)	BNO (no./p/yr)	ABW (kg/p/yr)
Replications (R)	1	0.05 ^{ns}	4.71 ^{ns}	0.24 ^{ns}
Populations (P)	8	7121.63 ^{**}	118.85 ^{**}	7.26 ^{**}
P $\times$ R	8	1690.07 [*]	53.89 [*]	0.96 ^{ns}
Within seedlings	316	818.16	25.28	0.79
σ^2_p		166.91 (16.24)	2.25 (7.81)	0.17 (0.18)
σ^2_{pr}		45.15 (4.39)	1.31 (4.55)	0.00 (0.00)
σ^2_w		815.38 (79.55)	25.22 (87.63)	0.79 (75.84)
Total		1027.45	28.78	0.96
σ^2_p (%)		16%	7.8%	17.7%

^{*},^{**},^{ns} : Significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively

The mean performance for Senegal populations is presented in Table 6. The mean performance for Senegal populations for FFB, BNO and ABW were 82.14 kg/p/yr, 19.27 no./p/yr and 4.19 kg/p/yr respectively. The highest mean performance in all three traits with 95.66 kg/p/yr for FFB, 21.02 no/p/yr for BNO and 4.76 kg/p/yr for ABW was from population SEN 05. However, Duncan New Multiple Range Test (DNMRT) showed that SEN 05 was not significantly different from SEN 06, SEN 07, SEN 02 and SEN 04 for FFB. The lowest mean performance for FFB was from SEN 12 with 53.44 kg/p/yr and DNMRT showed that SEN 12 was not significantly different from SEN 03 and SEN 10.

For BNO, SEN 05 was significantly different from SEN 10 and SEN 12 but not significantly different from the other populations. SEN 12 showed the lowest mean performance with 15.15 no./p/yr. For ABW, SEN 05 was not significantly different from SEN 02 but was significantly different from the other populations. SEN 12 and SEN 03 showed the lowest mean performance with 3.44 kg/p/yr and 3.53 kg/p/yr. DNMRT showed that SEN 03, SEN 10 and SEN 12 were not significantly different from each other.

Table 6: Mean Values of Senegal Populations for Yield

Populations	n	Traits		
		FFB (kg/p/yr)	BNO (no./p/yr)	ABW (kg/p/yr)
SEN 01	12	79.73bcd	19.02ab	4.17bc
SEN 02	63	93.12ab	21.02a	4.35ab
SEN 03	30	67.46cde	18.99ab	3.53d
SEN 04	29	81.84abc	18.98ab	4.26b
SEN 05	76	95.66a	20.19a	4.76a
SEN 06	21	83.82ab	20.07a	4.13bc
SEN 07	41	85.28ab	19.65ab	4.30b
SEN 10	29	66.37de	17.33bc	3.73cd
SEN 12	33	53.44e	15.15c	3.44d
	334	$\bar{X}$ 82.14	19.27	4.19

Means with the same letter in the same column are not significantly different at $P \leq 0.05$ by DNMRT

4.2.2 Performance of Progenies

4.2.2.1 Progeny Means and ANOVA

The ANOVA of 14 progenies in Table 7 showed highly significant differences ($P \leq 0.01$) for FFB, BNO and ABW among the progenies. This indicates that there was a significant amount of genetic variability among all the progenies for the three traits. The progeny $\times$ replicate interaction item showed no significant differences for FFB and ABW. However, progeny $\times$ replicate interaction for BNO was highly significant.

Table 7: ANOVA, Variance Components and Heritability Estimated of Senegal Progenies for Yield

Source	df	FFB (kg/p/yr)	BNO (no./p/yr)	ABW (kg/p/yr)
Replications (R)	1	0.03 ^{ns}	6.31 ^{ns}	0.25 ^{ns}
Progenies (G)	13	5374.40 ^{**}	136.64 ^{**}	4.67 ^{**}
G×R	13	1034.08 ^{ns}	43.58 ^{**}	0.18 ^{ns}
Within palms	196	694.53	19.59	0.75
σ^2_g		280.06	6.06	0.26
		(27.6)	(21.3)	(26.8)
σ^2_{gr}		42.16	2.79	0.00
		(4.16)	(9.81)	(0.00)
σ^2_w		690.86	19.59	0.71
		(68.19)	(68.88)	(73.19)
Total		1013.08	28.44	0.97
h^2_B		0.56	0.42	0.52

* **,ns : Significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively
 h^2_B : broad-sense heritability
FFB: fresh fruit bunch, BNO: bunch numbers, ABW: average bunch weight

The mean performances of FFB, BNO and ABW for all progenies are presented in Table 8. Mean FFB yield for all 14 progenies was 83.06 kg/p/yr. Progeny SEN 05.03 outperformed the others for FFB yield (109.92 kg/p/yr). However, DNMRT showed that progeny SEN 05.03 was not significantly different from SEN 02.06, SEN 02.09, SEN 04.03 and SEN 05.08. Progeny SEN 12.03 had the lowest mean for FFB yield with 51.58 kg/p/yr and was not significantly different from progeny SEN 03.07, SEN 04.01 and SEN 10.03.

Trial mean for BNO was 19.30 no./p/yr. Progeny SEN 02.06, SEN 05.03 and SEN 05.08 outperformed the others and were significantly different from the other progenies except for SEN 02.09, SEN 04.03, SEN 06.08 and SEN 10.05. Progeny SEN 12.03 had the lowest mean for BNO with 13.82 no./p/yr and was not significantly different from SEN 04.01, SEN 05.01 and SEN 10.03. Trial mean for ABW was 4.25 kg/p/yr. Progeny

SEN 05.01 had the highest mean of 5.02 kg/p/yr and was significantly different from all progenies except for progeny SEN 04.03, SEN 05.03, SEN 05.08 and SEN 07.03.

Table 8: Mean Values of Senegal Progenies for Yield

Progenies	n	Traits		
		FFB (kg/p/yr)	BNO (no./p/yr)	ABW (kg/p/yr)
SEN 01.03	11	77.34ef	18.84bc	4.09cde
SEN 02.06	20	99.29abcd	22.45a	4.29bcd
SEN 02.09	19	92.07abcde	21.12ab	4.37bcd
SEN 03.07	19	63.29fg	18.98bc	3.33f
SEN 04.01	13	65.85fg	16.57cd	3.86def
SEN 04.03	12	100.45abc	21.20ab	4.84ab
SEN 05.01	20	81.45def	16.43cd	5.02a
SEN 05.03	18	109.92a	23.00a	4.83ab
SEN 05.08	18	104.27ab	22.50a	4.58abc
SEN 06.08	14	80.92def	20.22ab	3.93def
SEN 07.03	17	87.72bcde	18.39bc	4.85ab
SEN 10.03	17	53.35g	14.71d	3.52ef
SEN 10.05	12	84.81cde	21.4ab	4.03cde
SEN 12.03	14	51.58g	13.82d	3.63ef
	224	$\bar{X}$ 83.06	19.30	4.25

Means with the same letter in the same column are not significantly different at $P \leq 0.05$

by DNMRT

4.2.2.2 Heritability Estimates for Yield Components

Estimation of variance components for FFB, BNO and ABW is shown in Table 7.

Variance component within palms (σ^2_w) was more than 65% for all three traits. For FFB, the genetic variance for progenies (σ^2_g) was low with only 27.6% and 4.16% detected in genotype $\times$ replication (σ^2_{gr}) and high variation was detected in σ^2_w with 68.19%. For BNO, σ^2_g was 21.3%, σ^2_{rg} was 9.81% and σ^2_w was 68.88%. For ABW, σ^2_w was the highest with 73.19% followed by σ^2_g (26.8%) and no significant differences was detected for σ^2_{gr} . Broad-sense heritability (h^2_B) estimated based on variance component for FFB,

BNO and ABW are summarized in Table 7. The h^2_B for FFB (56%) and ABW (52%) was high but moderate for BNO (42%).

4.3 Bunch Quality Traits

4.3.1 Performances of Populations

4.3.1.1 Population Means and ANOVA

The ANOVA of Senegal populations for bunch quality traits is presented in Table 9. The populations (σ^2_p) showed highly significant differences ($P \leq 0.01$) for all the traits except for M/F and F/B which were significant at $P \leq 0.05$ and no significant differences detected for K/F and K/B. The replications item showed no significant differences for all the traits except for M/F at $P \leq 0.05$. Population $\times$ replication item was not significant in all the traits indicating that the performance of all the traits in all populations across the two replicates was consistent in their ranking.

Estimated variance components of Senegal populations are also shown in Table 9. Variance components for populations (σ^2_p) were low for all the traits, less than 20% with the highest value for BWT (13.22%), OY (15.26) and KY (13.49%). No variation was detected at population (σ^2_p) level for K/F and K/B. No variation was detected for replication $\times$ population interaction (σ^2_{rp}) except for K/F (3.51%), O/DM (1.31%), O/WM (0.43%), O/B (1.95%), OY (1.66%) and KY (2.69%). Variance components for within the palms (σ^2_w) were quite high, more than 85% for all the traits. Estimates of σ^2_p were very low, less than 15% for all the traits except for OY (15.3%).

Table 9: ANOVA and Variance Components of Senegal Populations for Bunch Quality Traits

Source	df	BWT (kg)	MFW (g)	MNW (g)	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/WM (%)
Replications (R)	1	0.20 ^{ns}	0.53 ^{ns}	0.02 ^{ns}	96.93 [*]	18.01 ^{ns}	31.46 ^{ns}	44.34 ^{ns}	48.18 ^{ns}
Populations (P)	8	6.34 ^{**}	1.40 ^{**}	0.51 ^{**}	44.87 [*]	3.29 ^{ns}	59.63 ^{**}	100.17 ^{**}	171.88 ^{**}
P×R	8	0.56 ^{ns}	0.49 ^{ns}	0.09 ^{ns}	16.46 ^{ns}	9.54 ^{ns}	12.42 ^{ns}	32.25 ^{ns}	55.11 ^{ns}
Within seedlings	316	1.06	0.29	0.12	14.91	6.93	13.27	19.10	36.05
σ^2_p		0.16	0.03	0.013	0.60	0.00	1.30	1.79	2.78
		(3.22)	(9.09)	(10.0)	(3.86)	(0.00)	(8.92)	(8.38)	(7.07)
σ^2_{pr}		0.00	0.01	0.00	0.00	0.25	0.00	0.28	0.17
		(0.00)	(3.03)	(0.00)	(0.00)	(3.51)	(0.00)	(1.31)	(0.43)
σ^2_w		1.05	0.29	0.12	14.94	6.87	13.28	19.28	36.36
		(86.77)	(87.88)	(92.3)	(96.14)	(96.49)	(91.08)	(90.30)	(92.5)
Total		1.21	0.33	0.13	15.54	7.12	14.58	21.35	39.31
σ^2_p (%)		13.20%	9%	10%	3.8%	0%	8.9%	8.3%	7%

Source	df	F/B (%)	O/B (%)	K/B (%)	OY (kg/p/yr)	KY (kg/p/yr)	TEP (kg/p/yr)
Replications (R)	1	0.00 ^{ns}	15.42 ^{ns}	6.11 ^{ns}	7.66 ^{ns}	2.78 ^{ns}	3.14 ^{ns}
Populations (P)	8	69.91 ^{**}	1736 ^{**}	1.85 ^{ns}	46.22 ^{**}	53.15 ^{**}	118.22 ^{**}
P×R	8	23.79 ^{ns}	7.66 ^{ns}	2.53 ^{ns}	11.76 ^{ns}	12.96 ^{ns}	25.06 ^{ns}
Within Seedlings	316	34.88	4.18	2.93	6.96	8.12	15.84
σ^2_p		2.67	0.08	0.00	1.29	1.30	3.33
		(7.18)	(6.09)	(0.00)	(15.26)	(13.49)	(17.03)
σ^2_{pr}		0.00	0.09	0.00	0.14	0.26	0.36
		(0.00)	(1.95)	(0.00)	(1.66)	(2.69)	(1.84)
σ^2_w		34.52	4.23	2.88	7.02	8.08	15.86
		(92.82)	(91.95)	(100.0)	(83.07)	(83.82)	(81.13)
Total		37.19	4.60	2.88	8.45	9.64	19.55
σ^2_p (%)		7.2%	6%	0%	15.3%	13.5%	17%

*, **, ns: Significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively

BWT: bunch weight, MFW: mean fruit weight, MNW: mesocarp to fruit, K/F: kernel to fruit, S/F: shell to fruit, O/DM: oil to dry mesocarp, O/WM : oil to wet mesocarp, F/B: fruit to bunch, O/B: oil to bunch, K/B : kernel to bunch, OY: oil yield, KY: kernel yield, TEP: total economic product

The mean performance of bunch quality components in Senegal populations is presented in Table 10. Trial mean for BWT was 3.66 kg. The highest mean performance of 4.10 kg was from SEN 05 and DNMRT showed SEN 05 was significantly different from all the population except for SEN 01, SEN 02, SEN 04 and SEN 07. Trial mean for MFW and MNW was 2.39 g and 1.55 g respectively. SEN 12 scored the lowest mean for MFW and MNW and was significantly different from all population except for SEN 04.

The mean for M/F ranged from 34.06% to 36.56% with overall mean of 34.85% and populations showed slightly different in each other. K/F ranged from 14.97% to 17.01% and overall mean of 15.73%. Populations (σ^2_p) showed no significant differences. The mean for S/F in Senegal population was high ranging from 47.41% to 51.13% with overall mean of 49.43%. SEN 01 and SEN 10 had the highest S/F while SEN 06 and SEN 07 had the lowest S/F.

Trial mean for O/DM and O/WM was 70.21% and 41.33% respectively. For both traits, SEN 03 scored the lowest mean of 67.34% and 39.08% and was significantly different from others except for SEN 01 and SEN 02. The fruit to bunch (F/B) of Senegal populations was fairly uniform, ranged from 54.04% to 59.97%. Even though SEN 06 (59.97%) and SEN 01 (59.59%) had the highest mean, they were not significantly different from the others except for SEN 12 which had the lowest F/B (54.04%). However, SEN 12 showed no significant differences from SEN 04 and SEN 05.

Mean oil to bunch ratios (O/B) were low, 8.41% ranging from 7.85% to 9.59%. SEN 07 had the highest O/B and SEN 02 had the lowest mean. DNMRT showed that SEN 07 was significantly different from the others except for SEN 06 and SEN 10. Trial

mean for kernel to bunch (K/B) was 9.02% ranging from 8.54% to 9.54%. However, ANOVA and DNMR showed no significant differences between all the populations for K/B.

The oil yield (OY) ranged from 4.23 kg/p/yr to 7.88 kg/p/yr with trial mean of 6.77 kg/p/yr. SEN 05, SEN 06 and SEN 07 had the highest OY with 7.63 kg/p/yr, 7.83 kg/p/yr and 7.88 kg/p/yr respectively while SEN 12 had the lowest OY with 4.23 kg/p/yr. However, SEN 01, SEN 02 and SEN 04 showed no significant differences from SEN 05, SEN 06 and SEN 07. Trial mean for kernel yield (KY) was 7.37 kg/p/yr and ranged from 4.80 kg/p/yr to 8.25 kg/p/yr with SEN 04 scored the highest KY and SEN 12 scored the lowest KY. SEN 12 was significantly different from the others except for SEN 03 and SEN 10.

As for total economic product (TEP), trial mean was 11.18 kg/p/yr ranging from 7.12 kg/p/yr to 12.73 kg/p/yr. The best performer was from SEN 06 (12.73 kg/p/yr), however DNMR showed SEN 06 was not significantly different from SEN 01, SEN 02, SEN 04, SEN 05 and SEN 07. SEN 10 and SEN 12 scored the lowest TEP and were significantly different from each other. The lowest performer was SEN 12 with 7.12 kg/p/yr and DNMR showed SEN 12 was significantly different from the other populations except for SEN 03.

Table 10: Mean Values of Senegal Population for Bunch Quality Traits

Populations	n	Traits							
		BWT (kg)	MFW (g)	MNW (g)	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/WM (%)
SEN 01	12	3.71abc	2.44ab	1.61ab	34.38ab	14.48b	51.13a	69.11bc	39.22c
SEN 02	63	3.78ab	2.31ab	1.52abc	34.26ab	15.39b	50.34ab	69.09bc	39.32bc
SEN 03	30	2.95d	2.59a	1.63ab	35.31ab	15.60ab	49.09abcd	67.34c	39.08c
SEN 04	29	3.95ab	2.16bc	1.39cd	35.33ab	15.85ab	48.81bcd	70.92ab	41.06abc
SEN 05	76	4.10a	2.59a	1.70a	34.06b	15.81ab	50.12abc	70.03ab	41.09abc
SEN 06	21	3.46bcd	2.60a	1.64ab	36.56a	16.02ab	47.41d	70.39ab	41.66abc
SEN 07	41	3.88ab	2.43ab	1.54abc	36.38ab	15.79ab	48.82d	72.12a	43.81a
SEN 10	29	3.15cd	2.31ab	1.49bc	34.05b	14.97b	50.96a	72.07a	44.44a
SEN 12	33	3.05d	2.00c	1.31d	34.78ab	17.01a	48.20cd	70.98ab	42.79ab
	334	$\bar{X}$ 3.66	$\bar{X}$ 2.39	$\bar{X}$ 1.55	34.85	15.73	49.43	70.21	41.33

Populations	n	Traits							
		F/B (%)	O/B (%)	K/B (%)	OY (kg/p/yr)	KY (kg/p/yr)	TEP (kg/p/yr)		
SEN 01	12	59.59a	8.23bc	8.56a	6.43abc	6.79abc	10.52ab		
SEN 02	63	57.78ab	7.85c	8.86a	7.11ab	8.25a	12.06a		
SEN 03	30	58.70ab	8.01bc	9.17a	5.39cd	6.29bcd	9.17bc		
SEN 04	29	55.78bc	8.16bc	8.87a	6.61abc	7.19abc	10.93ab		
SEN 05	76	56.47abc	8.05bc	8.93a	7.63a	8.41a	12.68a		
SEN 06	21	59.97a	9.24ab	9.54a	7.83a	8.15a	12.73a		
SEN 07	41	58.88ab	9.59a	9.26a	7.88a	7.84ab	12.58a		
SEN 10	29	59.44ab	9.13ab	8.92a	5.97bc	5.92cd	9.53b		
SEN 12	33	54.04c	8.09bc	9.10a	4.23d	4.80d	7.12c		
	334	$\bar{X}$ 57.53	$\bar{X}$ 8.41	$\bar{X}$ 9.02	$\bar{X}$ 6.77	$\bar{X}$ 7.37	$\bar{X}$ 11.18		

Means with the same letter in the same column are not significantly different at $P \leq 0.05$ by DNMRT

4.3.2 Performance of Progenies

4.3.2.1 Progeny Means and ANOVA

ANOVA in Table 11 showed highly significant differences ($P \leq 0.01$) among progenies (σ^2_g) for all traits BWT, MFW, MNW, S/F, O/DM, O/WM, F/B, K/B, OY and KY except for M/F and K/F which showed significant difference at ($P \leq 0.05$). For progeny $\times$ replication (σ^2_{gr}) interaction the result was not significant for all traits indicating that the performance of all the traits across the two replicates was consistent in ranking.

The mean performance of bunch quality traits in Senegal progenies is presented in Table 12. The BWT for Senegal progenies was low with overall mean of 3.66 kg ranging from 2.66 kg to 4.54 kg. Progeny SEN 07.03 scored the highest mean for BWT with 4.54 kg. DNMRT showed that SEN 07.03 was significantly different from other progenies except for SEN 04.03, SEN 05.01, SEN 05.03 and SEN 05.08. Trial mean for MFW was 2.39 g, the highest mean of 2.81 g was from progeny SEN 06.08 and the lowest mean of 1.95 g was from progeny SEN 12.03. As for MNW, the overall mean for the progenies was 1.54 g with the highest mean of 1.78 g from progeny SEN 05.01 and the lowest mean of 1.24 g from progeny SEN 12.03.

Trial mean for M/F was 35.02%. The highest mean with 37.58% was from progeny SEN 06.08 and the lowest mean with 33.23% was from progeny SEN 10.05. DNMRT showed that SEN 06.08 was not significantly different from the other progenies except for progeny SEN 02.06 and SEN 10.05 which scored the lowest mean for M/F. The overall means for S/F and K/F was 49.32% and 15.65% respectively. Progeny SEN 07.03 had the lowest mean for S/F but scored the highest mean performance for K/F.

Trial mean for O/DM and O/WM were 70.46% and 41.74% respectively. Progeny SEN 07.03 had the highest mean for O/DM with 73.44% and SEN 03.07 had the lowest mean with 65.50%. DNMRT showed that SEN 03.07 was significantly different from other progenies except for SEN 02.06 and SEN 02.09. As for O/WM, SEN 05.01 scored the highest mean of 45.73% and was significantly different from other progenies except for SEN 04.03, SEN 07.03, SEN 10.03, SEN 10.05 and SEN 12.03.

Fruit to bunch (F/B) is an estimate of the fertile fruits in an oil palm bunch. The overall mean for F/B was 57.68% with the highest mean of 60.97% from progeny SEN 03.07 and the lowest mean of 53.45% from progeny SEN 12.03. DNMRT showed that SEN 03.07 was not significantly different from other progenies except for SEN 04.01, SEN 04.03, SEN 05.03, SEN 05.08 and SEN 12.03.

Trial mean for O/B was 8.54%. Progeny SEN 07.03 scored the highest mean of 10.22% and DNMRT showed that SEN 07.03 was significantly different from others except for SEN 05.01, SEN 06.08 and SEN 10.03. Progeny SEN 02.06 scored the lowest mean for O/B with 7.26%. As for K/B, overall mean was 9.02%, with the highest mean of 9.96% from progeny SEN 07.03 and the lowest mean of 7.61% from SEN 05.08.

Oil yield (OY) of Senegal progenies was low with the mean of 6.95 kg/p/yr. Among the progenies, SEN 07.03 scored the highest mean with 8.69 kg/p/yr and SEN 12.03 had the lowest mean of 4.46 kg/p/yr. DNMRT showed that SEN 12.03 was significantly different from the others except for SEN 03.07, SEN 04.01 and SEN 10.03. Overall mean for KY was 7.45kg/p/yr with the highest mean of 9.58 kg/p/yr from progeny SEN 05.03 and the lowest mean of 4.47 kg/p/yr from progeny SEN 12.03.

Table 11: ANOVA, Variance Components and Heritability Estimates of Senegal Progenies for Bunch Quality Traits

Source	df	BWT (kg)	MFW (g)	MNW (g)	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/WM (%)
Replications(R)	1	0.07 ^{ns}	0.32 ^{ns}	0.04 ^{ns}	25.77 ^{ns}	35.99*	0.84 ^{ns}	5.38 ^{ns}	0.33 ^{ns}
Progeny (G)	13	4.27**	0.89**	0.29**	33.31*	11.67*	46.21**	100.66**	157.28**
G×R	13	0.44 ^{ns}	0.29 ^{ns}	0.07 ^{ns}	12.36 ^{ns}	4.24 ^{ns}	9.93 ^{ns}	19.28 ^{ns}	40.62 ^{ns}
Within Palms	196	1.03	0.20	0.08	15.36	6.20	12.81	15.29	27.27
σ^2_g		0.22	0.04	0.02	0.76	0.50	2.15	4.89	7.08
		(18.18)	(16.0)	(19.98)	(4.78)	(7.59)	(14.59)	(23.89)	(19.82)
σ^2_{gr}		0.00	0.01	0.0001	0.00	0.00	0.00	0.23	1.38
		(0.00)	(4.0)	(0.009)	(0.00)	(0.00)	(0.00)	(1.12)	(3.86)
σ^2_w		0.99	0.20	0.08	15.18	6.09	12.58	15.35	27.27
		(81.82)	(80.0)	(79.92)	(95.23)	(92.41)	(85.41)	(74.98)	(76.32)
Total		191	0.25	0.1001	15.94	6.59	14.73	20.47	35.73
h^2_B		0.36	0.31	0.32	0.10	0.15	0.30	0.48	0.40

Source	df	F/B (%)	O/B (%)	K/B (%)	OY (kg/p/yr)	KY (kg/p/yr)	TEP (kg/p/yr)
Replications (R)	1	0.15 ^{ns}	1.88 ^{ns}	11.73*	0.98 ^{ns}	5.36 ^{ns}	0.15 ^{ns}
Progeny (G)	13	90.10**	13.79*	7.55*	35.5**	39.73**	87.6**
G×R	13	34.60 ^{ns}	4.66 ^{ns}	1.18 ^{ns}	8.85 ^{ns}	8.44 ^{ns}	19.03 ^{ns}
Within Palms	196	26.39	3.54	2.48	5.93	7.16	13.18
σ^2_g		4.06	0.53	0.29	1.84	2.00	4.74
		(12.95)	(12.86)	(10.78)	(22.80)	(21.51)	(25.64)
σ^2_{gr}		1.01	0.01	0.00	0.27	0.15	0.54
		(3.22)	(0.24)	(0.00)	(3.34)	(1.62)	(2.92)
σ^2_w		26.29	3.58	2.40	5.96	7.15	13.21
		(83.83)	(86.89)	(89.22)	(73.85)	(76.38)	(71.44)
Total		31.36	4.12	2.69	8.07	9.30	18.49
h^2_B		0.26	0.26	0.22	0.46	0.44	0.52

*, **, ns: Significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively h^2_B : broad-sense heritability
BWT: bunch weight, MFW: mean fruit weight, MNW: mean nut weight, M/F: mesocarp to fruit, K/F: kernel to fruit, S/F: shell to fruit, O/DM: oil to dry mesocarp, O/WM: oil to wet mesocarp, F/B: fruit to bunch, O/B: oil to bunch, K/B: kernel to bunch, OY: oil yield, KY: kernel yield, TEP: total economic product

Table 12: Mean Values of Senegal Progenies for Bunch Quality Traits

Progenies	n	Traits							
		BWT (kg)	MFW (g)	MNW (g)	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/WM (%)
SEN 01.03	11	3.69bcd	2.43bcd	1.58abc	34.95abcd	14.59def	50.45ab	69.78cdef	39.88def
SEN 02.06	20	3.70bcd	2.19efg	1.47cd	32.78d	16.30abcd	50.92ab	68.18efg	38.26ef
SEN 02.09	19	3.75bcd	2.29ef	1.49cd	34.97abcd	14.73cdef	50.30ab	67.72fg	37.92ef
SEN 03.07	19	2.66f	2.68abc	1.65abc	35.15abcd	16.06abcde	48.78bcd	65.50g	37.25f
SEN 04.01	13	3.68bcd	2.08fg	1.35de	35.37abcd	15.69abcde	48.93bcd	70.13cdef	39.81def
SEN 04.03	12	4.28ab	2.27ef	1.47cd	35.42abcd	16.83ab	47.74cde	72.37abc	43.00abcd
SEN 05.01	20	4.18ab	2.72ab	1.78a	34.89abcd	16.40abc	48.71bcd	73.44a	45.73a
SEN 05.03	18	3.97abcd	2.32def	1.53cd	33.97cd	15.91abcde	50.11abc	70.08cdef	41.42bcde
SEN 05.08	18	3.98abc	2.42bcde	1.56bc	34.90abcd	14.04f	51.05ab	70.61bcde	41.59bcde
SEN 06.08	14	3.34cdef	2.581a	1.76ab	37.58a	15.10bcdef	47.31de	69.34def	40.57cdef
SEN 07.03	17	4.54a	2.61abcd	1.64abc	36.98ab	16.92a	46.09e	73.86a	45.86a
SEN 10.03	17	2.95ef	2.28ef	1.49cd	34.64bcd	15.37abcde	49.98abc	72.39abc	44.93ab
SEN 10.05	12	3.44cde	2.35cdef	1.50cd	33.23d	14.41ef	52.36a	71.62abcd	43.76abc
SEN 12.03	14	3.16def	1.95g	1.24e	36.23abc	16.38abc	47.38de	73.08ab	45.68a
	224	3.66	2.39	1.54	35.02	15.65	49.32	70.46	41.74

Progenies	n	Traits							
		O/B (%)	K/B (%)	OY (kg/p/yr)	KY (kg/p/yr)	TEP (kg/p/yr)			
SEN 01.03	11	60.35ab	8.57bcd	6.58bc	6.76def	10.64de			
SEN 02.06	20	57.45abcd	7.16c	6.83b	9.13ab	12.31abcd			
SEN 02.09	19	57.78abcd	7.75de	7.07ab	7.69abcd	11.69cd			
SEN 03.07	19	60.97a	8.97cde	4.88d	6.38def	8.65ef			
SEN 04.01	13	54.89cde	7.16c	4.90cd	5.63efg	8.34ef			
SEN 04.03	12	56.92bcde	8.73bcd	8.65a	9.39a	14.29ab			
SEN 05.01	20	58.41abc	9.39abc	7.72ab	7.81abcd	12.41abcd			
SEN 05.03	18	54.77cde	7.86de	8.58a	9.58a	14.34a			
SEN 05.08	18	54.29de	7.91de	8.30ab	7.87abcd	13.01abcd			
SEN 06.08	14	60.61a	9.40abc	7.76ab	7.42bcde	12.21abcd			
SEN 07.03	17	59.19ab	10.22a	8.69a	8.79abc	13.98abc			
SEN 10.03	17	60.32ab	9.51ab	4.94cd	5.07fg	7.98f			
SEN 10.05	12	58.21abc	8.59bcde	7.44ab	7.13cde	11.71bcd			
SEN 12.03	14	53.45e	8.87bcd	4.46d	4.47g	7.14f			
	224	57.68	8.54	6.95	7.45	11.41			

Means with the same letter in the same column are not significantly different at $P \leq 0.05$ by DNMRT

4.3.2.2 Heritability Estimates for Bunch Quality Traits

Variance components estimated for all the bunch traits are shown in Table 11. Variance components of the progenies (σ^2_g) was low, ranging from 0.91% to 25.64% and variance components within the palms (σ^2_w) was high, ranging from 71.44% to 95.23%. σ^2_{gr} was not significant. Variance components of M/F, K/F and S/F for σ^2_g were 4.78%, 7.59% and 14.59% respectively. σ^2_w was high for M/F, K/F and S/F with 95.23%, 92.41% and 85.41% respectively. σ^2_w for O/B, K/B and F/B were 83.83%, 86.89% and 89.22%. For OY and KY, the σ^2_w was 73.85% and 76.88% respectively.

Broad-sense heritability (h^2_B) estimated from the variance components for M/F (10%), K/F (15%), S/F (30%), O/B (26%), K/B (26%) and F/B (22%) were very low. However the h^2_B for O/DM (48%), O/WM (40%), OY (46%) and KY (44%) were quite moderate.

4.4 Vegetative Traits Components

4.4.1 Performances of Populations

4.4.1.1 Population Means and ANOVA

The ANOVA for Senegal populations are presented in Table 13. Highly significant difference ($P \leq 0.01$) was detected among all the traits except for FP and LW which were significant at $P \leq 0.05$ and no significant different detected in LAR. The replications item (σ^2_r) showed no significant difference in all traits except for LN, LA, LAI, f and LAR which was significant at $P \leq 0.01$. However, population $\times$ replication item was not

significant in all the traits indicating that the performances of all the traits across the two replicates were consistent in ranking.

Variance components estimated are also presented in Table 13. Variance component for population (σ^2_p) was low, ranging from 3.23% to 26.32%. PCS, RL and HT had the highest σ^2_p estimated with 20.32%, 26.32% and 21.95% respectively. The lowest σ^2_p estimated was from LW (3.23%) and FP (5.52%). Very low variation was detected in σ^2_{pr} for FP (1.01%), PCS (1.55%), HT (2.44%), DIAM (2.91%) and f (0.27%). Variance component σ^2_w was high, ranging from 75.61% to 96.77%. FP, LW, LA, LAI and f had the highest σ^2_w estimated with 93.45%, 96.77%, 93.14%, 93.01% and 92.62% respectively.

Mean performances of Senegal populations are presented in Table 14. Trial mean for FP was 31.34 no./p/yr. Population SEN 10 outperformed the other population with the highest mean of 33.42 no./p/yr whereas SEN 12 scored the lowest mean of 29.58 no./p/yr. DNMRT showed that SEN10 was not significantly different from SEN 01, SEN 05, SEN 06 and SEN 07. Despite having the lowest mean for FP, DNMRT showed that SEN 12 was not significantly different from the other population which performed moderately.

Trial mean for PCS was 15.87 cm². SEN 12 had the highest PCS of 20.38 cm² and SEN 03 had the lowest PCS of 13.24 cm². DNMRT showed that SEN 12 was significantly different from all the populations for this trait. SEN 03 was not significantly different from SEN 05 and SEN 10.

Table 13: ANOVA and Variance Components of Senegal Populations for Vegetative Traits

Source	df	FP (no./p/yr)	PCS (cm ²)	RL (m)	LL (cm)	LW (cm)	LN (no./p/yr)
Replications (R)	1	0.16 ^{ns}	1.44 ^{ns}	0.11 ^{ns}	19.28 ^{ns}	1.09 ^{ns}	1444.58 [*]
Population (P)	8	26.67 [*]	106.32 ^{**}	1.25 ^{**}	516.73 ^{**}	0.64 [*]	860.03 ^{**}
P×R	8	12.17 ^{ns}	23.95 ^{ns}	0.13 ^{ns}	136.75 ^{ns}	0.21 ^{ns}	193.25 ^{ns}
Within Seedlings	313	12.06	14.57	0.14	77.34	0.24	170.93
σ ² p		0.71	3.81	0.05	14.27	0.008	24.61
		(5.52)	(20.32)	(26.32)	(15.37)	(3.23)	(12.56)
σ ² pr		0.13	0.29	0.00	0.00	0.00	0.00
		(1.01)	(1.55)	(0.00)	(0.00)	(0.00)	(0.00)
σ ² w		12.02	14.65	0.14	78.58	0.24	171.35
		(93.45)	(78.13)	(73.68)	(84.63)	(96.77)	(87.44)
Total		12.86	18.75	0.19	92.85	0.248	195.96
σ ² p (%)		5.5%	20.3%	26%	15.3%	3.3%	12.5%

Source	df	HT (m)	LA (m ²)	LAI	DIA (m)	f	LAR
Replications (R)	1	0.17 ^{ns}	8.41 ^{**}	2.84 ^{**}	0.002 ^{ns}	0.07 ^{**}	51.48 ^{**}
Population (P)	8	2.35 ^{**}	2.99 ^{**}	1.05 ^{**}	0.03 ^{**}	0.02 ^{**}	13.43 ^{ns}
P×R	8	0.42 ^{ns}	1.58 ^{ns}	0.55 ^{ns}	0.009 ^{ns}	0.01 ^{ns}	1.54 ^{ns}
Within Seedlings	313	0.31	0.93	0.33	0.006	0.007	7.50
σ ² p		0.09	0.07	0.025	0.00075	0.00053	0.41
		(21.95)	(6.86)	(6.96)	(11.47)	(7.15)	(5.28)
σ ² pr		0.01	0.00	0.00	0.00019	0.00002	0.00
		(2.44)	(0.00)	(0.00)	(2.91)	(0.27)	(0.00)
σ ² w		0.31	0.95	0.334	0.0056	0.0069	7.36
		(75.61)	(93.14)	(93.04)	(85.62)	(92.62)	(94.72)
Total		0.41	1.02	0.359	0.00654	0.00745	7.77
σ ² p (%)		21.9%	6.9%	6.9%	11.4%	7.1%	5.2%

*, **, ns: Significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively

FP: frond production, PCS: petiole cross-section, RL: rachis length, LL: leaflet length, LW: leaflet width, LN: leaflet number

HT: palm height, LA: leaflet area, LAI: leaflet area index, DIA: trunk diameter, f: fractional interception of light, LAR : leaflet area ratio

Table 14: Mean Values of Senegal Populations for Vegetative Traits

Populations	n	Traits					
		FP (no./p/yr)	PCS (cm ²)	RL (m)	LL (cm)	LW (cm)	LN (no./p/yr)
SEN 01	12	31.83ab	17.86b	4.02a	88.39a	3.97a	125.08bc
SEN 02	62	31.05bc	16.51bc	4.03a	88.86a	3.88a	119.63cd
SEN 03	30	30.06bc	13.24c	3.67bc	91.19a	3.57b	114.43d
SEN 04	29	31.34bc	15.93bcd	4.02a	87.84a	3.92a	127.86ab
SEN 05	76	31.76ab	14.75cde	3.78b	82.89b	3.95a	120.92bcd
SEN 06	21	31.52abc	15.71bcd	3.56c	83.17b	4.00a	123.62bc
SEN 07	41	31.72ab	15.86bcd	3.79b	82.78b	3.94a	126.78bc
SEN 10	28	33.42a	14.22de	3.54c	79.78b	4.01a	120.71bcd
SEN 12	33	29.58c	20.38a	4.21a	90.73a	3.90a	134.39a
	332	$\bar{X}$ 31.34	15.87	3.86	85.92	3.91	123.05

Populations	n	Traits					
		HT (m)	LA (m ²)	LAI	DIA (m)	f	LAR
SEN 01	12	3.42a	3.07ab	3.00ab	0.68bc	0.70abc	11.94c
SEN 02	62	2.88bd	4.71bcd	2.78bcd	0.68bc	0.68bcd	12.34bc
SEN 03	30	2.58cde	4.32d	2.56d	0.62d	0.63d	13.80ab
SEN 04	29	2.41e	4.96abc	2.94abc	0.65cd	0.70ab	14.34a
SEN 05	76	2.53de	4.53bcd	2.68bcd	0.67bcd	0.66bcd	13.31abc
SEN 06	21	3.15ab	4.76bcd	2.78bcd	0.65cd	0.68bcd	12.91abc
SEN 07	41	3.25a	4.74bcd	2.81bcd	0.64cd	0.68bcd	12.79abc
SEN 10	28	2.80cd	4.42cd	2.61cd	0.71ab	0.65cd	12.94abc
SEN 12	33	2.69cde	5.42a	3.21a	0.72a	0.73a	11.92c
	332	$\bar{X}$ 2.79	4.72	2.79	0.67	0.68	12.96

Means with the same letter in the same column are not significantly different at P < 0.05 by DNMR.T

Trial mean for RL was 3.86 m. SEN 12 had the longest mean of 4.21 m for RL and DNMRT showed that SEN 12 was not significantly different from SEN 01 and SEN 02. The shortest mean for RL was from SEN 10 (3.54 m). DNMRT showed that SEN 10 was significantly different from other population except for population SEN 06 and SEN 03. However, SEN 03 was not significantly different from SEN 04 and SEN 07.

Trial mean for leaflet length (LL) and leaflet width (LW) were 85.92 cm and 3.91 cm respectively. For LL, DNMRT showed that SEN 01, SEN 02, SEN 03 and SEN 12 were not significant from each other but significantly different from SEN 05, SEN 06, SEN 07 and SEN 10. For LW, DNMRT showed all the populations were not significantly different from each other except for population SEN 03. Overall mean for leaflet number (LN) was 123.05 no./p/yr with the lowest mean of 114.43 no./p/yr from SEN 03 to the highest mean of 134.39 no./p/yr from SEN 12. DNMRT showed that SEN 12 was not significantly different from SEN 04.

Trunk height (HT) in Senegal population was quite tall with mean of 2.79 m, the shortest mean of 2.41 m from SEN 04 and the tallest mean of 3.42 m from SEN 01. DNMRT showed that SEN 04 was not significantly different from SEN 03 (2.58 m), SEN 05 (2.53 m) and SEN 12 (2.69 m). The mean for trunk diameter (DIA) was 0.67 m. SEN 12 had the highest mean of 0.72 m for DIA. DNMRT tested showed that SEN 12 was significantly different from all the population except for SEN 10.

The mean for leaf area (LA) of Senegal populations was 4.72 cm². SEN 12 had the highest mean of 5.42 cm² and SEN 03 had the lowest mean of 4.32 cm². DNMRT showed that SEN 12 was not significantly different from SEN 01 and SEN 04 but was

significantly different from the others. SEN 03 and SEN 10 had the lowest mean for DIA and were not significantly different from each other.

Trial mean for LAI was 2.79. SEN 12 scored the highest mean of 3.21 and DNMRT showed that SEN 12 was significantly different from all population except for SEN 01 and SEN 04. Trial mean for f was 0.68. SEN 12 scored the highest mean 0.73 and was significantly different from the others except for SEN 01 and SEN 04.

4.4.2 Performance of Progenies

4.4.2.1 Progeny Means and ANOVA

The ANOVA for Senegal progenies is presented in Table 15. All the vegetative traits were highly significant at $P \leq 0.01$ except for FP which was significant at $P \leq 0.05$. For progeny $\times$ replication (σ^2_{gr}), the result was not significant for all traits. In terms of replication, leaflet number (LN), leaflet area (LA), leaf area index (LAI), fractional of light interception (f) and leaflet area ratio (LAR) showed there were highly significant difference among the two replicates.

The mean performance of the progenies for vegetative traits is presented in Table 16. The mean for FP was 31.32 no./p/yr, the highest mean of 34.33 no./p/yr was from SEN 10.05 and the lowest mean of 29.37 no./p/yr was from SEN 03.07. DNMRT showed that SEN 10.03 were not significantly different from SEN 10.05 and SEN 01.03. Trial mean for PCS was 15.55 cm². Progeny SEN 12.03 had the highest mean of 20.77 cm² and was significantly different from all progeny. SEN 03.07 had the lowest mean of 11.94 cm².

Trial mean for rachis length (RL) was 3.86 m. Progeny SEN 12.03 had the longest mean for RL (4.29 m) whereas progeny SEN 10.03 had the shortest mean for RL 3.49 m. With shorter RL, more palms can be planted in a unit area to increase planting density. DNMRT showed no significant differences between progenies SEN 03.07, SEN 06.08 and SEN 10.03 who scored the shortest RL among all the progenies.

Trial mean for LL and LW were 85.41 cm and 3.89 cm respectively. For LL, progeny SEN 12.03 had the longest mean of 94.33 cm while progeny SEN 05.08 had the shortest mean of 74.55 cm. DNMRT showed that SEN 12.03 was significantly different from all progeny except for SEN 02.09, SEN 03.07 and SEN 04.01. For LW, progeny SEN 04.03 had the widest mean of 4.20 cm and SEN 03.07 had the shortest width of 3.36 cm.

The mean for leaflet number (LN) was 122.84 no./p/yr, with the highest mean of 139.29 no.p/yr from SEN 12.03 and the lowest mean of 110.63 no./p/yr from SEN 03.07. DNMRT showed that progeny SEN 12.03 was significantly different from all progeny.

Trunk height (HT) is an important factor in determining the economic life of oil palm plantation due to difficulties in harvesting tall palms. Senegal progenies palms were quite tall, with trial mean of 2.76 m. The shortest mean of 2.14 m was from progeny SEN 05.01. DNMRT showed that SEN 03.07, SEN 04.01 and SEN 04.03 showed no significant differences between SEN 05.01, SEN 05.03 and SEN 05.08 of having a short height. For trunk diameter (DIA), trial mean was 0.67 m, with the widest mean of 0.73 m from progeny SEN 12.03 and the smallest mean of 0.59 m from progeny SEN 03.07.

Table 15: ANOVA, Variance Components and Heritability Estimates of Senegal Progenies for Vegetative Traits

Source	df	FP (no./p/yr)	PCS (cm ²)	RL (m)	LL (cm)	LW (cm)	LN (no./p/yr)
Replications (R)	1	0.43 ^{ns}	12.41 ^{ns}	0.19 ^{ns}	3.31 ^{ns}	0.53 ^{ns}	2541.65 ^{**}
Progeny (G)	13	24.58 [*]	67.54 ^{**}	0.99 ^{**}	412.86 ^{**}	0.69 ^{**}	678.84 ^{**}
G×R	13	13.97 ^{ns}	17.76 ^{ns}	0.08 ^{ns}	99.06 ^{ns}	0.12 ^{ns}	94.83 ^{ns}
Within Palms	194	11.37	12.28	0.13	72.03	0.23	170.65
σ^2_g		0.79	3.61	0.06	23.06	0.03	34.7
		(6.35)	(22.18)	(31.57)	(23.75)	(12.0)	(17.3)
σ^2_{gr}		0.32	0.19	0.00	1.06	0.00	0.00
		(2.57)	(1.16)	(0.00)	(1.09)	(0.00)	(0.00)
σ^2_w		11.32	12.47	0.13	72.95	0.22	165.81
		(91.01)	(76.64)	(68.42)	(75.15)	(88.0)	(82.7)
Total		12.43	16.27	0.19	97.07	0.25	200.51
h^2_B		0.12	0.44	0.66	0.48	0.24	0.34

Source	df	HT (m)	LA (m ²)	LAI	DIA (m)	f	LAR
Replications (R)	1	0.04 ^{ns}	7.14	2.50 [*]	0.005 ^{ns}	0.05 ^{**}	87.75 ^{**}
Progeny (G)	13	0.89 ^{**}	3.84 ^{**}	1.35 ^{**}	0.019 ^{**}	0.03 ^{**}	11.88 ^{**}
G×R	13	0.19 ^{ns}	0.56 ^{ns}	0.19 ^{ns}	0.007 ^{ns}	0.005 ^{ns}	4.80 ^{ns}
Within Palms	194	0.22	0.88	0.51	0.006	0.006	7.54
σ^2_g		0.14	0.19	0.07	0.0007	0.001	0.46
		(32.55)	(18.09)	(18.92)	(10.15)	(14.29)	(5.87)
σ^2_{gr}		0.00	0.00	0.00	0.0002	0.00	0.00
		(0.00)	(0.00)	(0.00)	(2.89)	(0.00)	(0.00)
σ^2_w		0.29	0.86	0.30	0.006	0.006	7.38
		(67.44)	(81.9)	(81.08)	(86.95)	(85.71)	(94.13)
Total		0.43	1.05	0.37	0.0069	0.007	7.84
h^2_B		0.64	0.36	0.86	0.22	0.34	0.12

* **, ns: Significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively

h^2_B : broad-sense heritability

FP: frond production, PCS: petiole cross-section, RL: rachis length, LL: leaflet length, LW: leaflet width, LN: leaflet number

HT: palm height, LA: leaflet area, LAI: leaflet area index, DIA: trunk diameter, f: fractional interception of light, LAR: leaflet area ratio

Table 16: Mean Values of Senegal Progenies for Vegetative Traits

Progenies	n	Traits					
		FP (no./p/yr)	PCS (cm ²)	RL (m)	LL (cm)	LW (cm)	LN (no./p/yr)
SEN 01.03	11	32.00abc	16.8bcd	3.98bcd	86.68bcd	3.92abc	124.09bcd
SEN 02.06	19	30.74bcd	17.99b	4.06abcd	85.57bcd	3.98abc	122.21bcd
SEN 02.09	19	31.37bcd	15.17cd	4.18ab	91.49ab	3.77bc	116.79de
SEN 03.07	19	29.37d	11.94g	3.52g	89.87abcd	3.36d	110.63e
SEN 04.01	13	30.00cd	16.99bc	4.15abc	90.79abc	3.69cd	129.54bc
SEN 04.03	12	31.92bc	15.19cd	4.00bcd	84.03def	4.20a	128.50bc
SEN 05.01	20	30.10cd	14.81cd	3.91cde	86.42bcd	4.00abc	118.05de
SEN 05.03	18	31.78bc	15.95bcd	3.85def	85.35cde	4.04abc	125.33bcd
SEN 05.08	18	32.85ab	14.02fg	3.65efg	74.55g	3.75bc	120.33cd
SEN 06.08	14	31.60bcd	14.47def	3.49g	82.12ef	4.09ab	122.79bcd
SEN 07.03	17	30.82bcd	16.57bcd	3.93bcd	84.62de	3.96abc	129.77b
SEN 10.03	16	32.75ab	14.24efg	3.49g	80.75ef	3.99abc	122.25bcd
SEN 10.05	12	30.33d	14.20efg	3.61fg	78.47fg	4.05ab	118.67de
SEN 12.03	14	30.43bcd	20.77a	4.29a	94.33a	3.85bc	139.29a
$\bar{X}$	222	31.32	15.55	3.86	85.41	3.89	122.84

Progenies	n	Traits					
		HF (m)	LA (m ²)	DIA (m)	<i>f</i>	LAR	
SEN 01.03	11	3.42a	4.87bc	2.87bc	0.67abcde	0.69bc	11.91bc
SEN 02.06	19	2.98bcd	4.75bc	2.82bc	0.69abc	0.68bc	11.38c
SEN 02.09	19	2.99bcd	4.59bc	2.72bc	0.67abcde	0.67bc	12.62bc
SEN 03.07	19	2.56efg	3.82d	2.27d	0.59f	0.59d	13.46b
SEN 04.01	13	2.24gh	4.85bc	2.87bc	0.66bcde	0.69abc	13.47b
SEN 04.03	12	2.45fgh	5.19ab	3.07ab	0.63ef	0.72ab	15.65a
SEN 05.01	20	2.14h	4.66bc	2.76bc	0.68abcd	0.68bc	13.79ab
SEN 05.03	18	2.47fgh	4.94b	2.93b	0.70abc	0.69abc	13.62b
SEN 05.08	18	2.56efg	3.84d	2.27d	0.66cde	0.59d	11.98bc
SEN 06.08	14	3.31ab	4.73bc	2.80bc	0.66cde	0.67bc	13.32bc
SEN 07.03	17	3.21abc	4.97b	2.95bc	0.64def	0.70abc	12.89bc
SEN 10.03	16	2.67def	4.54bc	2.69bc	0.72ab	0.66bc	13.03bc
SEN 10.05	12	2.98bcd	4.26cd	2.53cd	0.69abcd	0.64cd	12.84bc
SEN 12.03	14	2.90cde	5.80a	3.44a	0.73a	0.75a	12.37bc
$\bar{X}$	222	2.76	4.68	2.76	0.67	0.67	12.98

Means with the same letter in the same column are not significantly different at $P \leq 0.05$ by DNMRT

The trial mean for leaf area (LA) and leaf area index (LAI) was 4.68 m² and 2.76 respectively. Mean for interception of light (f) was 0.67. SEN 12.03 scored the highest mean for LA (5.80 m²), LAI (3.44) and f (0.75). DNMRT showed SEN 12.03 was significantly different from all the progenies except from progeny SEN 04.03 for all these three traits.

4.4.2.2 Heritability Estimates for Vegetative Traits

Variance components estimated for all the traits in vegetative components are shown in Table 15. Variance components for progeny (σ^2_g) were low for all the vegetative traits, varied from 6.35% to 32.55%. HT and RL had the highest σ^2_g of 32.55% and 31.57% respectively. FP and LAR had the lowest σ^2_g of 6.35% and 5.87%. Variance components for progeny $\times$ replication (σ^2_{gr}) showed no variation was detected except for FP (2.57%), PCS (1.16%), and LL (1.09%). Variance components for within the palms (σ^2_w) were high ranging from 67.44% to 94.13%.

Broad-sense heritability (h^2_B) estimated for the traits were low to moderate ranging from 12% to 66%. The lowest h^2_B estimated was from FP with only 12%. RL and HT had a high h^2_B of 66% and 64% respectively. The h^2_B for PCS (44%), LL (48%), LW (24%), LN (34%) and LA (36%) were moderate.

4.5 Physiological Traits Components

4.5.1 Performances of Populations

4.5.1.1 Population Means and ANOVA

ANOVA for physiological traits of Senegal population are presented in Table 17. ANOVA showed all the traits were highly significant at ($P \leq 0.01$). The population $\times$ replication (σ^2_{pr}) interaction item was not significant in all the traits but highly significant at ($P \leq 0.05$) for BDM. As for replication (σ^2_r), all the traits showed no significant differences except for e and NAR which were highly significant at ($P \leq 0.01$).

Variance components estimated for physiological traits is also presented in Table 17. Variance components for population (σ^2_p) components were low varied from 8.53% to 19.42%. Variance components for population $\times$ replication interaction (σ^2_{pr}) were very low, 4.47% in BDM, 1.94% in TDM and 2.91% in BI. Variance component for within the palms (σ^2_w) were high ranging from 79% to 92%. Value for σ^2_p estimated for all the traits in physiological parameters were low, 16% (BDM), 16.6% (VDM), 11% (TDM), 20.7% (BI), 9.87% (e) and 8.5% (NAR).

Mean performance for physiological traits in Senegal population is presented in Table 18. Trial mean for BDM was 6.44 t/ha/yr. Population SEN 05 had the highest mean of 7.50 t/ha/yr followed by SEN 02 (7.25 t/ha/yr) and SEN 07 (6.78 t/ha/yr). DNMR showed SEN 01, SEN 02, SEN 05 and SEN 07 were not significantly different from each other but showed significant differences from population SEN 03, SEN 06, SEN 10 and SEN 12. SEN 12 scored the lowest mean of 4.19 t/ha/yr for BDM.

Table 17: ANOVA and Variance Components of Senegal Populations for Physiological Traits

Source	df	BDM (t/ha/yr)	VDM (t/ha/yr)	TDM (t/ha/yr)	BI	e (g/MJ)	NAR
Replications (R)	1	0.001 ^{ns}	0.17 ^{ns}	0.21 ^{ns}	0.00003 ^{ns}	0.11 [*]	63.69 ^{**}
Populations (P)	8	42.76 ^{**}	43.43 ^{**}	75.94 ^{**}	0.07 ^{**}	0.13 ^{**}	34.98 ^{**}
P×R	8	10.55 [*]	9.21 ^{ns}	21.31 ^{ns}	0.014 ^{ns}	0.03 ^{ns}	8.52 ^{ns}
Within Seedlings	813	4.98	6.34	12.52	0.008	0.03	8.48
σ ² p		1.01	1.28	1.61	0.002	0.003	0.79
		(6.13)	(16.69)	(11.14)	(19.42)	(10.0)	(8.53)
σ ² pr		0.28	0.00	0.28	0.0003	0.00	0.00
		(4.47)	(0.00)	(1.94)	(2.91)	(0.00)	(0.00)
σ ² w		4.97	6.39	12.56	0.008	0.027	8.47
		(79.39)	(83.31)	(86.92)	(77.67)	(90.0)	(91.47)
Total		6.26	7.67	14.45	0.0103	0.03	9.26
σ ² p (%)		16%	16.6%	11%	20.7%	9.87%	8.5%

*, **, ns: Significant at P ≤ 0.05, P ≤ 0.01 and non-significant respectively.
BDM: bunch dry matter, VDM: vegetative dry matter, TDM: total dry matter, BI: bunch index, e: conversion efficiency, NAR: net assimilation rate

Table 18: Mean Values of Senegal Populations for Physiological Traits

Populations	n	Traits				
		BDM (t/ha/yr)	VDM (t/ha/yr)	TDM (t/ha/yr)	BI	e (g/MJ)
SEN 01	12	6.25a	13.48a	19.74a	0.32bc	0.92a
SEN 02	62	7.25a	12.08b	19.33ab	0.37ab	0.91a
SEN 03	30	5.29bc	9.58c	14.88d	0.35abc	0.75d
SEN 04	29	6.42ab	11.06b	17.48bc	0.36ab	0.80bcd
SEN 05	76	7.50a	10.86bc	18.36abc	0.40a	0.90a
SEN 06	21	5.29bc	11.91b	18.48abc	0.35ab	0.88ab
SEN 07	41	6.78a	11.93b	18.71abc	0.35ab	0.89ab
SEN 10	28	5.24bc	11.75b	16.99c	0.30c	0.85abc
SEN 12	33	4.19c	13.62a	17.81abc	0.23d	0.78cd
	332	$\bar{X}$ 6.44	11.63	18.08	0.35	0.86

Means with the same letter in the same column are not significantly different at P ≤ 0.05 by DNMRT

The mean for VDM was 11.63 t/ha/yr. Despite having the lowest mean for BDM, SEN 12 had the highest mean of 13.62 t/ha/yr for VDM. DNMRT showed that SEN 12 was significantly different from all populations except for population SEN 01. SEN 03 had the lowest VDM (9.58 t/ha/yr) and showed significant differences from the others except for SEN 05.

Trial mean for TDM was 18.08 t/ha/yr. SEN 01 had the highest mean of 19.33 t/ha/yr and SEN 10 had the lowest mean of 16.99 t/ha/yr. DNMRT showed no significant differences between SEN 01 and the others except for SEN 03, SEN 04 and SEN 10.

For BI, the trial mean was 0.35 with the highest mean of 0.40 from SEN 05 and the lowest mean of 0.23 from SEN 12. DNMRT showed SEN 05 was not significantly different from the others except for SEN 01, SEN 10 and SEN 12. SEN 12 was significantly different from all population. Mean for e was 0.86 g/MJ. The lowest mean for e was 0.75 g/MJ from SEN 03 and the highest mean was 0.92 g/MJ from SEN 01. DNMRT showed all the populations were not significantly different from each other except for SEN 03, SEN 04 and SEN 12.

For net assimilation rate (NAR), the mean was 12.81. Population SEN 05 and SEN 02 outperformed the other populations having the highest mean performance of 13.61 and 13.58 respectively. DNMRT showed that SEN 05 was significantly different from all populations except from SEN 01, SEN 02, SEN 06 and SEN 07. The lowest mean was SEN 12 with 10.94 and DNMRT showed SEN 12 was significantly different from all population except for population SEN 03 and SEN 04.

4.5.2 Performance of Progenies

4.5.2.1 Progeny Means and ANOVA

The ANOVA for physiological traits in Senegal progenies are presented in Table 19. ANOVA showed all the physiological traits were highly significant at $P \leq 0.01$. The replication (σ^2_r) effects showed no significant differences among all the traits except for conversion efficiency (e) and NAR which showed significant differences at $P \leq 0.01$. Progeny $\times$ replication (σ^2_{gr}) interaction showed that no significant differences were detected in all traits except for bunch index at $P \leq 0.05$.

Mean performances of the Senegal progenies are presented in Table 20. Trial mean for BDM was 6.57 t/ha/yr. DNMRT showed that SEN 05.03 scored the highest mean, 8.62 t/ha/yr but was not significantly different from SEN 02.06, SEN 02.09, SEN 04.03 and SEN 05.08. Progenies SEN 10.03 and SEN 12.03 scored the lowest mean of 4.18 t/ha/yr and 4.05 t/ha/yr respectively. DNMRT showed that they were not significantly different from SEN 03.07 and SEN 04.01.

Trial mean for VDM was 11.46 t/ha/yr. SEN 12.03 had the highest mean of 14.39 t/ha/yr and DNMRT showed that SEN 12.03 was significantly different from all progeny except from SEN 01.03 and SEN 02.06. Progeny SEN 03.07 had the lowest mean of 8.49 t/ha/yr and DNMRT showed that SEN 03.07 was significantly different from all progeny. Mean for TDM was 17.97 t/ha/yr with the highest mean of 20.53 t/ha/yr from progeny SEN 02.06 and the lowest mean of 13.46 t/ha/yr from progeny SEN 03.07. DNMRT showed that SEN 03.07 was significantly different from other progeny except from SEN 10.03.

Table 19: ANOVA, Variance Components and Heritability Estimates of Senegal Progenies for Physiological Traits

Source	df	BDM (t/ha/yr)	VDM (t/ha/yr)	TDM (t/ha/yr)	BI	e (g/MJ)	NAR
Replications (R)	1	0.04 ^{ns}	5.74 ^{ns}	6.72 ^{ns}	0.0009 ^{ns}	0.18 ^{**}	84.92 ^{**}
Progenies (G)	13	31.78 ^{**}	32.28 ^{**}	64.68 ^{**}	0.05 ^{**}	0.14 ^{**}	41.13 ^{**}
G×R	13	6.93 ^{ns}	7.85 ^{ns}	11.89 ^{ns}	0.012 [*]	0.03 ^{ns}	10.46 ^{ns}
Within Palms	194	4.23	5.28	11.22	0.006	0.02	7.64
σ^2_g		1.65	1.58	3.00	0.003	0.006	1.91
		(26.66)	(22.51)	(21.08)	(30.92)	(22.73)	(19.6)
σ^2_{gr}		0.23	0.07	0.06	0.0007	0.0004	0.05
		(5.33)	(1.00)	(0.42)	(7.22)	(1.52)	(0.51)
σ^2_w		4.21	5.37	11.17	0.006	0.02	7.78
		(68.01)	(76.49)	(78.50)	(61.86)	(75.75)	(79.88)
Total		6.19	7.02	14.23	0.0097	0.0264	9.74
h^2_B (%)		54%	44%	42%	56%	44%	40%

* **, ns: Significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively

h^2_B (%): broad-sense heritability

BDM: bunch dry matter, VDM: vegetative dry matter, TDM: total dry matter, BI: bunch index, e: conversion efficiency, NAR: net assimilation rate

Mean for BI in Senegal progenies was 0.36. DNMRT showed that progeny SEN 05.03 had the highest mean, 0.43 and significantly different from other progeny except from progeny SEN 04.03, SEN 05.01 and SEN 05.08. Progeny SEN 12.03 had the lowest mean of 0.22 and DNMRT showed SEN 12.03 was significantly different from all progeny except for SEN 10.03.

Mean for light conversion efficiency (e) was 0.86 g/MJ. SEN 05.08 had the highest mean of 1.02 g/MJ and SEN 03.07 had the lowest mean of 0.73 g/MJ. DNMRT showed that SEN 05.08 was significantly different from all progeny except for progeny SEN 01.03, SEN 02.06, SEN 05.03 and SEN 10.05.

For NAR, the mean was 12.88. Progeny SEN 05.08 outperformed the other progenies having the highest mean of 16.18. DNMRT showed that SEN 05.08 was significantly different from all progenies except for SEN 02.06 and SEN 10.05. The lowest mean 10.67 was from progeny SEN 12.03.

4.5.2.2 Heritability Estimates for Physiological Traits

Estimation of variance components for physiological traits is presented in Table 19. Variance components for progeny (σ^2_g) were low varied from 19.6% to 30.92% and variance components for within palms (σ^2_w) were high, 60% to 80%. Variance components for progeny $\times$ replication (σ^2_{gr}) interaction were low, less than 5%. Broad-sense heritability (h^2_B) estimated for all the traits were average, BDM (54%), VDM (44%), TDM (42%), BI (56%), e (44%) and NAR (40%).

Table 20: Mean Values of Senegal Progenies for Physiological Traits

Progenies	n	Traits				
		BDM (t/ha/yr)	VDM (t/ha/yr)	TDM (t/ha/yr)	BI	e (g/MJ)
SEN 01.03	11	6.07ef	13.04ab	19.10ab	0.32c	0.91abcd
SEN 02.06	19	7.64abcd	12.89ab	20.53a	0.36bc	0.97ab
SEN 02.09	19	7.22abcde	11.59bcd	18.81abc	0.38bc	0.91bcd
SEN 03.07	19	4.96fg	8.49e	13.46f	0.36bc	0.73g
SEN 04.01	13	5.16fg	11.12cd	16.28de	0.31cd	0.75fg
SEN 04.03	12	7.88abc	10.72cd	18.59abcd	0.42a	0.84defg
SEN 05.01	20	6.39def	10.20d	16.59cde	0.38ab	0.79efg
SEN 05.03	18	8.62a	11.57bcd	20.19ab	0.43a	0.95abc
SEN 05.08	18	8.18ab	10.74cd	18.92abc	0.42a	1.02a
SEN 06.08	14	6.33def	11.55bcd	17.89bcde	0.36bc	0.85cdef
SEN 07.03	17	6.88bcde	12.00bc	18.88abc	0.36bc	0.88bcde
SEN 10.03	16	4.18g	11.53bcd	13.71ef	0.26de	0.77efg
SEN 10.05	12	6.65cde	12.05bc	18.70abc	0.36bc	0.95abcd
SEN 12.03	14	4.05g	14.39a	18.43abcd	0.22e	0.79efg
	222	$\bar{X}$ 6.57	11.46	17.97	0.36	0.86

Means with the same letter in the same column are not significantly different at $P \leq 0.05$ by DNMRT

4.6 Correlation Among Traits in Senegal

The phenotypic correlations among all the traits are presented in Table 21. Phenotypically, FFB correlated significantly with BNO and ABW. The correlation coefficient (r) of FFB with BNO and ABW were $r = 0.82^{**}$ and $r = 0.72^{**}$ respectively. BNO and ABW was also positively correlated with each other with $r = 0.21^{**}$. This deviates from the usual findings where negative correlation is found between BNO and ABW (Hardon et al, 1985). Correlations between FFB and bunch quality traits were not significant except for OY, KY and TEP where $r = 0.52^{**}$, 0.53^{**} and 0.58^{**} respectively. However, FFB was not significantly correlated with vegetative traits except for RL ($r = 0.21^{**}$), LA ($r = 0.14^{*}$), LAI ($r = 0.14^{*}$) and f ($r = 0.17^{**}$). As for physiological traits, FFB correlated positively and significantly with all the traits.

In bunch quality traits, M/F correlated significantly with O/DM ($r = 0.42^{**}$), O/WM ($r = 0.35^{**}$), O/B ($r = 0.71^{**}$) and OY ($r = 0.28^{**}$) but negatively significantly correlated with S/F ($r = -0.78^{**}$), K/F ($r = -0.39^{**}$), K/B ($r = -0.33^{**}$) and KY ($r = 0.29^{**}$). Oil palm breeding emphasized low S/F and high M/F for high oil yield (OY). In this study, very strong negative correlation ($r = -0.78^{**}$) was observed between M/F and S/F. S/F was found to be negatively correlated to O/WM ($r = -0.22^{**}$), O/B ($r = -0.54^{**}$) and OY ($r = -0.21^{**}$).

O/B is the product of F/B, M/F and O/WM. O/B was positively correlated with MFW ($r = 0.27^{**}$), F/B ($r = 0.42^{**}$), M/F ($r = 0.71^{**}$), O/DM ($r = 0.73^{**}$), O/WM ($r = 0.78^{**}$) but negatively significantly correlated with S/F ($r = -0.54^{**}$) and K/F ($r = -$

0.28**). Oil yield (OY) was positively correlated to M/F ($r = 0.28^{**}$), O/DM ($r = 0.37^{**}$), O/WM ($r = 0.33^{**}$), O/B ($r = 0.36^{**}$) and KY ($r = 0.66^{**}$).

For vegetative traits, FP was positively correlated with O/DM ($r = 0.14^{**}$), HT ($r = 0.14^{**}$), VDM ($r = 0.33^{**}$), TDM ($r = 0.28^{**}$), e ($r = 0.42^{**}$) and NAR ($r = 0.41^{**}$), however was negatively significantly correlated with RL ($r = -0.19^{**}$) and LL ($r = -0.24^{**}$). PCS was found to be positively correlated with all the vegetative characters except for LAR ($r = -0.32^{**}$).

Strong positive relationship was observed between LA and its component LL and LW with $r = 0.54^{**}$ and $r = 0.63^{**}$ respectively. LA was also positively correlated with PCS, RL, LN, DIAM, VDM and TDM. LAI was strongly positively correlated with f with $r = 0.97^{**}$. HT was found to be not significant with all the traits in this study except for FP ($r = 0.14^{**}$), PCS ($r = 0.37^{**}$), VDM ($r = 0.48^{**}$), TDM ($r = 0.35^{**}$), e ($r = 0.33^{**}$) and NAR ($r = 0.26^{**}$) which was positively correlated.

Interception of light (f) was found to be positively correlated to FFB ($r = 0.17^{**}$), ABW ($r = 0.35^{**}$) and all the vegetative traits except for FP, HT and DIA. f was negatively correlated to physiological traits, VDM ($r = -0.42^{**}$), TDM ($r = -0.25^{**}$), e ($r = -0.58^{**}$) and NAR ($r = -0.66^{**}$).

For physiological traits, BDM was positively correlated with FFB ($r = 1.00^{**}$), BNO ($r = 0.81^{**}$), ABW ($r = 0.71^{**}$), OY ($r = 0.52^{**}$), KY ($r = 0.53^{**}$), TDM ($r = 0.72^{**}$), BI ($r = 0.85^{**}$), e ($r = 0.63^{**}$) and NAR ($r = 0.50^{**}$). VDM was positively correlated with all vegetative characters except for LAR which was negatively

significantly correlated at $r = -0.42^{**}$. BI was positively correlated to FFB ($r = 0.85^{**}$), BNO ($r = 0.78^{**}$), ABW ($r = 0.55^{**}$), LAR ($r = 0.28^{**}$), e ($r = 0.32^{**}$), BDM ($r = 0.85^{**}$), TDM ($r = 0.27^{**}$) and NAR ($r = 0.28^{**}$) however negatively correlated with VDM ($r = -0.43^{**}$). Conversion efficiency (e) was found to be positively correlated with all vegetative traits and physiological traits except for LL ($r = -0.27^{**}$), LA ($r = -0.24^{**}$) and LAR ($r = -0.58^{**}$) and f ($r = -0.23^{**}$) which was negatively correlated.

Table 21: Phenotypic Correlation Coefficients among Traits in Senegal

Traits	n	FFB	BNO	ABW	BWT	MFW	MNW	M/F	K/F	S/F	O/DM	O/WM	F/B	O/B	K/B	O/Y	K/Y	TEP
FFB	222		0.82**	0.72**	0.21ns	0.006ns	0.03ns	-0.05ns	-0.06ns	0.09ns	-0.01ns	-0.03ns	0.02ns	-0.03ns	-0.05ns	0.52**	0.53**	0.58**
BNO	222			0.21**	0.10ns	-0.01ns	0.01ns	-0.16*	-0.06ns	0.21**	-0.04ns	-0.14*	0.02ns	-0.16*	-0.04ns	0.42**	0.45**	0.46**
ABW	222				0.33*	0.06ns	0.08ns	-0.02ns	-0.01ns	0.03ns	0.13*	0.06ns	0.01ns	0.03ns	-0.01ns	0.40**	0.37**	0.42**
BWT	222					0.12ns	0.10ns	0.02ns	0.11	-0.13*	0.26**	0.21**	-0.23**	0.03ns	0.01ns	0.45**	0.40**	0.47**
MFW	222						0.85**	0.20*	-0.001ns	-0.18*	0.04ns	0.05ns	0.32**	0.27**	0.13ns	0.11	0.13ns	0.08ns
MNW	222							-0.22**	0.12*	0.15	-0.08ns	-0.05ns	0.32**	0.02ns	0.29**	0.91	0.14**	0.06ns
M/F	222								-0.39**	-0.78**	0.42**	0.35**	0.04ns	0.71**	-0.33**	0.28**	-0.29**	0.06ns
K/F	222									-0.26**	-0.14*	-0.11ns	-0.09ns	-0.28**	0.86**	-0.10ns	0.43**	0.10ns
S/F	222										-0.34**	-0.22**	-0.03ns	-0.54**	-0.22**	-0.21**	-0.04ns	-0.13**
O/DM	222											0.91**	0.07ns	0.73**	-0.15*	0.37**	-0.07ns	0.18**
O/WM	222												0.08ns	0.78**	-0.12ns	0.33**	-0.17**	0.18**
F/B	222													0.44**	0.44**	0.06ns	0.00ns	0.14*
O/B	222														-0.47ns	0.36**	-0.25**	-0.03ns
K/B	222															-0.11ns	0.37**	0.12ns
O/Y	222																0.66**	0.95**
K/Y	222																	0.87**
TEP	222																	
FP	222																	
PCS	222																	
RL	222																	
LL	222																	
LW	222																	
LN	222																	
HT	222																	
LA	222																	
LAI	222																	
DIA	222																	
f	222																	
LAR	222																	
BDM	222																	
VDM	222																	
TDM	222																	
BI	222																	
e	222																	
NAR	222																	

Traits	n	FP	PCS	RL	LL	LW	LN	HT	LA	LAI	DIA	f	LAR	BDM	VDM	TDM	BI	e	NAR
FFB	222	0.07ns	0.12ns	0.21**	0.06ns	0.09ns	0.04ns	0.00ns	0.14**	0.14**	-0.05ns	0.17**	0.10ns	1.00**	0.03ns	0.72**	0.85**	0.63**	0.48**
BNO	222	0.12ns	-0.08ns	-0.04ns	-0.03ns	-0.06ns	-0.06ns	0.06ns	-0.08ns	-0.07ns	-0.08ns	-0.06ns	0.05ns	0.81**	-0.06ns	0.52**	0.78**	0.57**	0.51**
ABW	222	0.06ns	0.27**	0.34**	0.29**	0.29**	0.16*	-0.05ns	0.31**	0.31**	-0.00ns	0.35**	0.13**	0.71**	0.11ns	0.58**	0.55**	0.37**	0.21**
BWT	222	0.10ns	-0.01ns	0.06ns	-0.02ns	0.01ns	0.05ns	0.05ns	0.02ns	0.02ns	0.00ns	0.04ns	0.03ns	0.20**	0.08**	0.19**	0.15**	0.16**	0.11**
MFW	222	0.07ns	-0.21**	-0.17ns	-0.04ns	-0.00ns	-0.15**	0.04ns	-0.09ns	-0.09ns	-0.07ns	-0.10ns	0.08ns	0.00ns	-0.16*	-0.15	0.07ns	-0.03ns	0.00ns
MNW	222	0.05ns	-0.17**	-0.07ns	-0.04ns	0.01ns	-0.14*	0.01ns	-0.08ns	-0.08ns	0.03ns	-0.08ns	0.08ns	0.03ns	-0.17*	-0.07ns	0.11ns	-0.02ns	0.00ns
M/F	222	0.03ns	-0.02ns	-0.03ns	-0.02ns	-0.00ns	0.01ns	0.09ns	-0.00ns	-0.00ns	0.03ns	-0.00ns	-0.02ns	-0.04ns	0.01ns	-0.01ns	-0.01ns	-0.01ns	-0.01ns
K/F	222	-0.06ns	0.00ns	0.06ns	0.01ns	0.05ns	0.07ns	0.00ns	0.07ns	0.06ns	0.02ns	0.06ns	0.04ns	-0.06ns	-0.00ns	-0.04ns	-0.04ns	-0.09ns	-0.10ns
S/F	222	-0.01ns	0.02ns	0.02ns	0.01ns	-0.02ns	-0.06ns	-0.09ns	-0.04ns	-0.04ns	-0.05ns	-0.04ns	-0.00ns	0.16*	-0.01ns	0.05ns	0.17**	0.07ns	0.08ns
O/D/M	222	0.14*	0.08ns	0.01ns	-0.06ns	0.07ns	0.08ns	-0.00ns	0.04ns	0.04ns	0.15ns	0.07ns	-0.03ns	0.01ns	0.13ns	0.10ns	-0.04ns	0.08ns	0.06ns
O/W/M	222	0.10ns	0.05ns	-0.03ns	-0.07ns	0.03ns	0.09ns	-0.03ns	0.02ns	0.02ns	0.13ns	0.03ns	-0.02ns	-0.03ns	0.08ns	0.04ns	0.06ns	0.04ns	0.03ns
F/B	222	0.05ns	-0.03ns	-0.09ns	-0.02ns	0.12*	0.07ns	0.06ns	0.00ns	0.00ns	-0.03ns	0.03ns	0.05ns	0.01ns	-0.00ns	0.01ns	-0.05ns	-0.01ns	-0.02ns
O/B	222	0.10ns	-0.00ns	-0.08ns	-0.07ns	0.06ns	0.04ns	0.06ns	0.01ns	0.01ns	0.07ns	0.02ns	0.00ns	-0.03ns	0.05ns	0.01ns	-0.14*	-0.14*	0.00ns
K/B	222	-0.02ns	-0.01ns	-0.06ns	-0.00ns	0.10ns	0.03ns	0.03ns	0.05ns	0.05ns	-0.00ns	0.06ns	0.06ns	-0.04ns	-0.00ns	-0.03ns	-0.01ns	-0.08ns	-0.09ns
O/Y	222	0.17ns	-0.00ns	0.00ns	-0.06ns	0.06ns	0.00ns	0.02ns	0.00ns	0.00ns	-0.01ns	0.02ns	0.01ns	0.52**	0.05ns	0.38**	0.43**	0.36**	0.32**
K/Y	222	0.11ns	-0.01ns	0.01ns	-0.01ns	0.07ns	0.00ns	0.01ns	0.03ns	0.03ns	-0.05ns	0.05ns	0.06ns	0.53**	0.02ns	0.36**	0.48**	0.30**	0.21**
TEP	222	0.15ns	-0.01ns	0.00ns	0.05ns	0.07ns	0.00ns	0.02ns	0.01ns	0.01ns	-0.03ns	0.03ns	0.03ns	0.57**	0.04ns	0.42**	0.48**	0.37**	0.29**
FP	222		-0.09ns	-0.19**	0.14**	0.00ns	-0.22ns	0.14*	-0.10ns	-0.10ns	0.03ns	0.10ns	0.05ns	0.10ns	0.33**	0.28**	-0.04ns	0.42**	0.41**
PCS	222			0.62**	0.34**	0.34**	0.37**	0.17**	0.55**	0.55**	0.29**	0.55**	-0.32**	0.02ns	0.82**	0.65**	-0.29**	0.31**	0.06ns
RL	222				0.51**	0.21**	0.29**	0.03ns	0.32**	0.32**	0.17**	0.53**	-0.02ns	0.13ns	0.42**	0.43**	-0.06ns	0.03ns	-0.15**
LL	222				0.11ns	0.01ns	0.06ns	-0.12ns	0.54**	0.54**	0.08ns	0.55**	0.29**	0.05ns	0.13**	0.14**	-0.06ns	-0.27**	-0.43**
LW	222				0.14**	0.09ns	0.09ns	0.14**	0.63**	0.63**	0.21**	0.65**	0.31**	0.16*	0.33**	0.35**	-0.08ns	-0.08ns	-0.27**
LN	222				0.01ns	0.01ns	0.01ns	0.01ns	0.64**	0.64**	0.13ns	0.63**	0.32**	0.04ns	0.28**	0.22**	-0.10ns	-0.14ns	-0.30**
HT	222								0.06ns	0.06ns	0.08ns	0.06ns	-0.37**	0.00ns	0.48**	0.35**	-0.19ns	0.33**	0.26**
LA	222								0.99**	0.99**	0.21**	0.98**	0.49**	0.10ns	0.41**	0.36**	-0.11ns	-0.24**	-0.53**
LAI	222								0.21**	0.21**	0.21**	0.98**	0.49**	0.10ns	0.41**	0.36**	-0.11ns	-0.24**	-0.53**
DIA	222								0.24**	0.24**	0.24**	0.24**	0.31**	-0.04ns	0.53**	0.36**	-0.25**	0.23**	0.12ns
f	222								0.49**	0.49**	0.49**	0.49**	0.49**	0.13ns	0.42**	0.41**	-0.08ns	-0.23**	-0.52**
LAR	222													0.10ns	-0.42**	-0.25**	0.28**	-0.58**	-0.66**
BDM	222														0.03ns	0.72**	0.85**	0.63**	0.50**
VDM	222															0.76**	-0.40**	0.51**	0.29**
TDM	222																0.27**	0.79**	0.54**
BI	222																	0.32**	0.31**
e	222																		0.94**
NAR	222																		

*, **, ns: Significant at $P \leq 0.01$, $P \leq 0.05$ and non-significant respectively

FFB: fresh fruit bunch, BNO: bunch number, ABW: average bunch wt., BWT: bunch weight, MNW: mean nut weight, MNW: mesocarp to fruit, K/F: kernel to fruit, S/F: shell to fruit, O/D/M: oil to dry mesocarp, O/W/M : oil to wet mesocarp, F/B: fruit to bunch, O/B: oil yield, K/Y: kernel yield, TEP: total economic product, FP: frond production, PCS: petiole cross-section, RL: rachis length, LL: leaflet length, LW: leaflet width, LN: leaflet number, HT: palm height, LA: leaflet area, LAI: leaflet area index, DIA: trunk diameter, f: fractional interception of light, LAR : leaflet area ratio, BDM: bunch dry matter, VDM: vegetative dry matter, TDM: total dry matter, BI: bunch index, e: conversion efficiency, NAR: net assimilation rate