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CYTOLOGICAL ANALYSIS OF *Elaeis guineensis* AND *Elaeis oleifera* CHROMOSOMES

Keywords: *Elaeis guineensis, Elaeis oleifera,* karyotypes, chromosomes, cytogenetics

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Cytological analysis performed on metaphase chromosome spreads of two oil palm species, E. guineensis (tenera) *and* E. oleifera, *showed that both species have 2n=32 chromosomes. Paired t-tests showed no significant difference between paired homologues of* E. oleifera *whereas for* E. guineensis, *pair 7 showed a significant difference between the homologues. For both species, based on chromosome length, pair 1 was assigned to Group I, pairs 2-9 to group II and pairs 10-16 to group III. For* E. guineensis *and* E. oleifera, *Group I consists of the longest chromosome (10.98% and 10.69% of total haploid chromosome length respectively), Group II of medium length chromosomes(5.86%-8.79% and 6.05%-8.49% of total haploid chromosome length respectively) and Group III of medium short chromosomes (3.22%-5.47% and 3.01%-5.69% of total haploid chromosome length respectively). Paired t-tests performed for homologue chromosome pairs of* E. oleifera *and* E. guineensis *showed no significant difference in chromosome lengths between them. This is expected due to the fact that the two species can be crossed.*

INTRODUCTION

Elaeis guineensis and *Elaeis oleifera* (two species of oil palm, subfamily *Cocoineae*) belong to the family *Palmae* which contains over 225 genera and 2600 species (Purseglove, 1975). *E. guineensis* originates from the tropical lowlands of West Africa, from Cape Verde down to Angola but is now also grown commercially in South East Asia and South and Central America. *E. oleifera* species, on the other hand,

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originates from Central and South America. The chromosome numbers of 111 genera and approximately 250 species of the *Palmae* family, including *E. guineensis*, have been reported (Palomino *et al.*, 1992). However, there have been few karyotype studies. Research on the cytogenetics of *Palmae* have been conducted by Darlington *et al.* (1945), Ventakusubban (1945), Sato (1946), Sharma and Sarkar (1956) and Maria *et al.* (1995). The studies were mainly on *E. guineensis*.

Elaeis guineensis has 2n=32 chromosomes (Poerk, 1943; Sato, 1946; Darlington and La Cour 1966; Tan, 1976 and Maria *et al.*, 1995) which Sato (1946) categorized into two groups by length (that is 2n=8A+24C) – four long pairs and 12 short pairs with either submedian or subterminal constrictions. Sharma and Sarkar (1956), however, found three groups of chromosomes - three long, four medium and nine short pairs. Maria *et al.* (1995) found one long chromosome pair (10.83% of total haploid chromosome length) which they assigned to Group I, eight medium length chromosome pairs (6.21%-8.42% of total haploid chromosome length) assigned to Group II, and seven medium short chromosome pairs (3.17%-5.37% of total haploid chromosome length) assigned to Group III.

According to Sharma and Sarkar (1956), the chromosomes vary from 1.15μm-2.97μm in length while Maria *et al.* (1995) reported a range of 1.00μm-3.89μm. The amount of DNA in the diploid nucleus of *E. guineensis* was estimated to be 2 pg (Jones *et al.*, 1982) giving, by calculation, a genome size of approximately 1.8 x 10^9 base pairs. The work of Maria *et al.* (1995) was carried out to karyotype both *E. guineensis* and *E. oleifera* and to compare the karyotypes of these two closely related species.

MATERIALS AND METHODS

Obtaining Metaphase Spreads

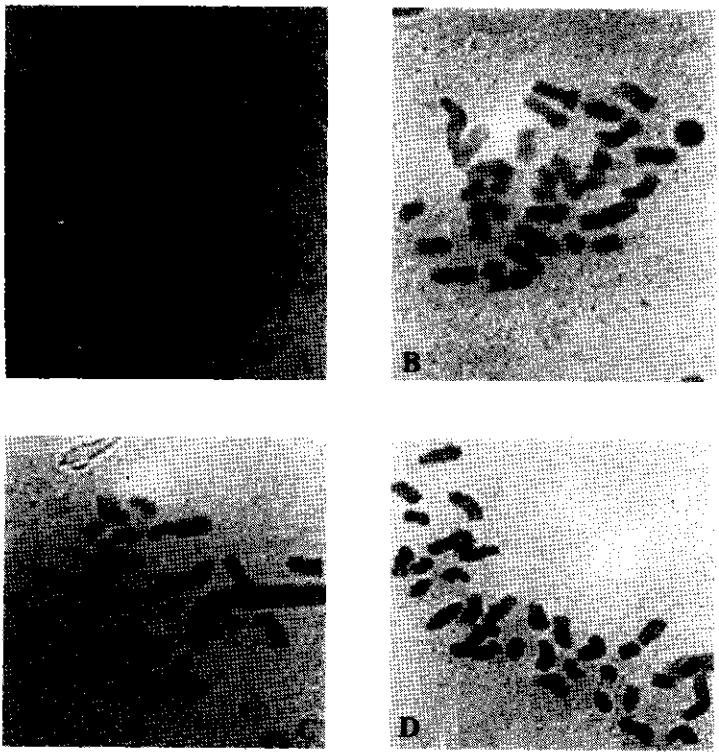
Metaphase spreads were obtained using a protoplast technique modified from the methods of Ambros *et al.* (1986) and Schwarzacher *et al.* (1989). The rest of the procedure followed that of Maria *et al.* (1995) except that the slides were viewed under bright field through a Carl Zeiss Axioplan microscope.

Selecting and Processing Metaphase Spreads

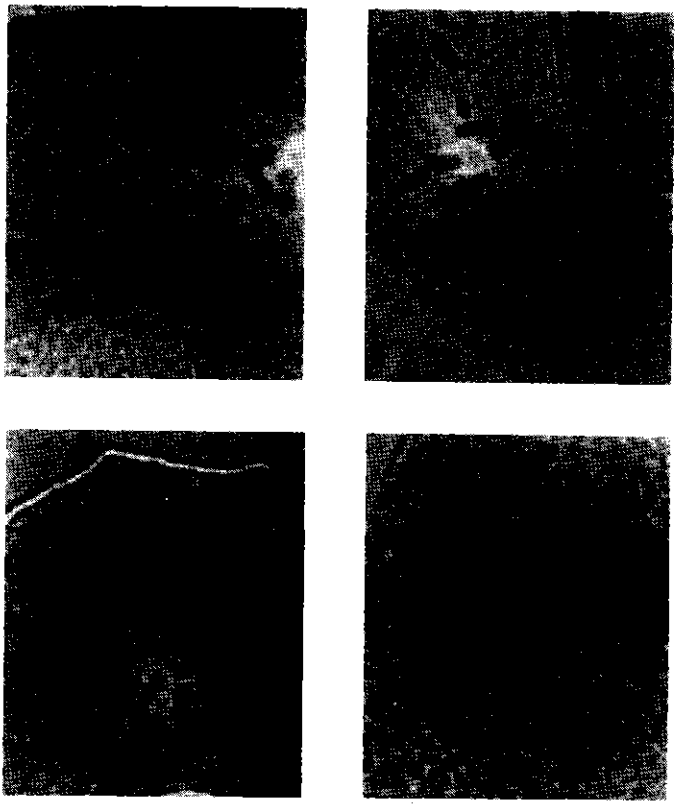
Metaphase spreads were considered good if they clearly showed 32 well-spaced chromosomes. Such spreads were photographed at 315x magnification using an automatic Carl Zeiss MC 80 camera with black and white Kodak Technical Plus X Pan film. *Figures 1a-1j* and *2a-2j* show selected metaphase spreads of *E. guineensis* and *E. oleifera*, respectively. The images of metaphase spreads on film were scanned into Adobe Photoshop 3.0 programme using a Polascan 35 negative scanner. Images were stored in both hard disk and diskettes. Measurements of chromosomes were done using Kontron Elektronik (KS Lite V 2.0) software. The length of each chromosome was measured three times and averaged. Statistical analysis of the data was performed using Microsoft Excel programme. Finally, the chromosomes were karyotyped by morphology, banding pattern and length. The manipulations were done using Adobe Photoshop 3.0 software in which contrast optimization and image size were the only functions changed. The karyograms were printed on sublimation dye paper using a NEC SuperScript Color 3000 printer. *Figures 3a-3j* and *4a-4j* show the karyograms of *E. guineensis* and *E. oleifera* respectively. For *E. guineensis*, the lengths of the chromosome arms (p and q) were not measured because the centromeric locations were unclear. However, the arms were measured in the second chromosome spread of *E. oleifera* (*Table 5*). This gave information on the centromeric locations in *E. oleifera* chromosomes. Statistical analyses, however, were only done on the absolute lengths of chromosomes for both species.

RESULTS

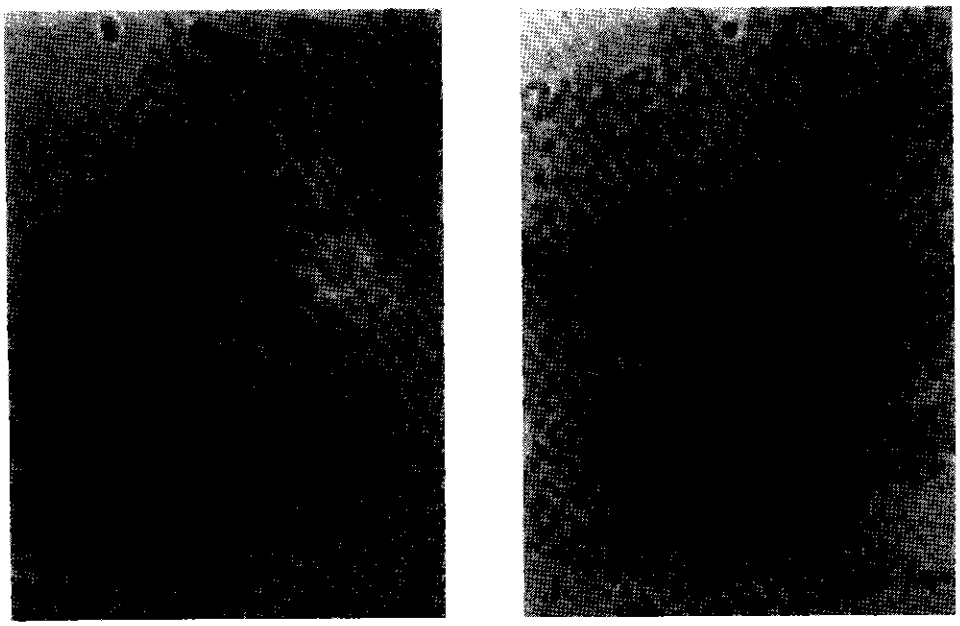
Cytological analysis on 10 metaphase spreads of *E. guineensis* and *E. oleifera* confirmed that both species have 2n=32 chromosomes. Paired t-tests (5% significance level) were carried out to ascertain the homology of pairings for both species. *Tables 1* and *2* show the t-values computed and the results of H_0 for



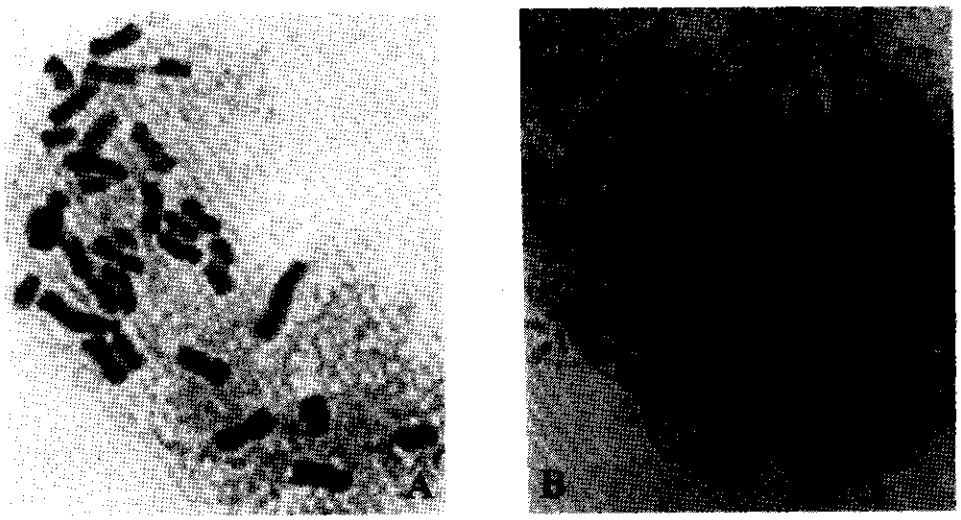
Figures 1A-1D. First (6920x), second (5478x), third (6420x) and fourth (5284x) metaphase spreads of E. guineensis.



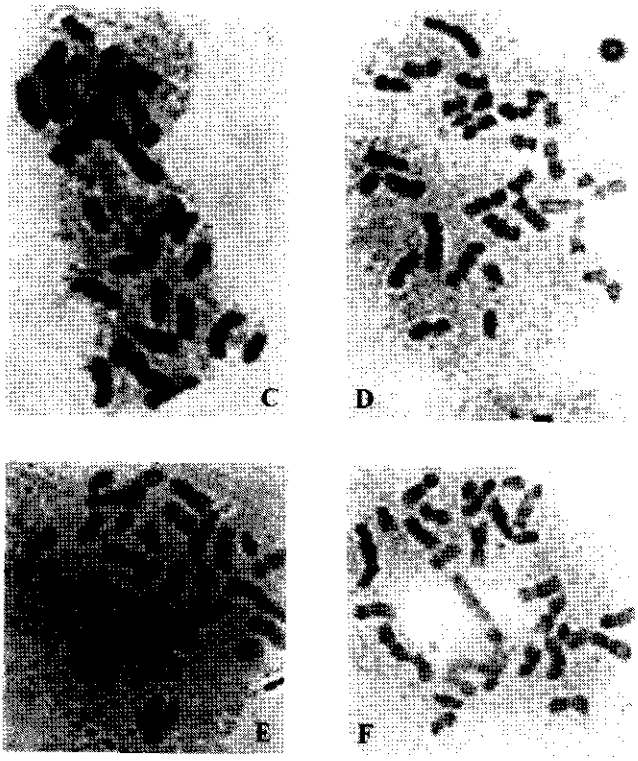
Figures 1E-1H. Fifth (7372x), sixth (5625x), seventh (6718x) and eighth (7203x) metaphase spreads of E. guineensis.



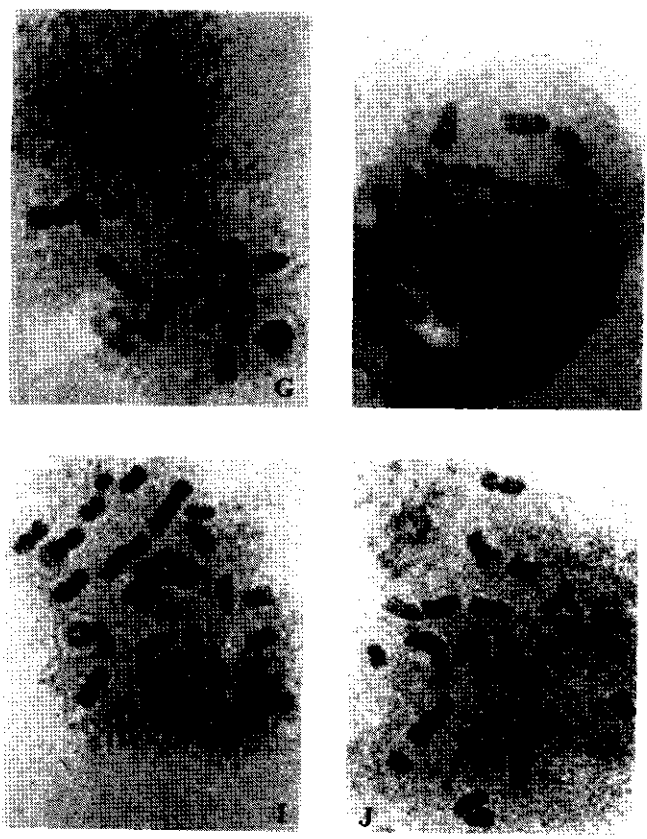
Figures 1I and 1J. Ninth (6837x) and tenth (7128x) metaphase spreads of E. guineensis.



Figures 2A and 2B. First (6510x) and second (4913x) metaphase spreads of E. oleifera.



Figures 2C-2F. Third (7380x), fourth (6675x), fifth (6435x) and sixth (7966x) metaphase spreads of E. oleifera.



Figures 2G-2J. Seventh (9240x), eighth (8175x), ninth (7808x) and tenth (7035x) metaphase spreads of E. oleifera.

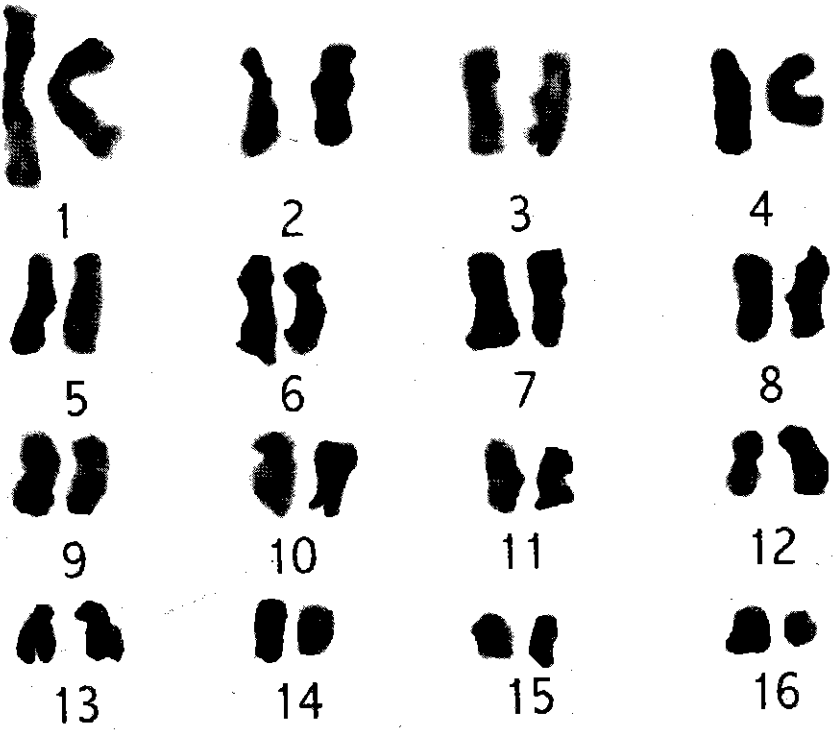


Figure 3a. Karyogram of E. guineensis *first metaphase spread*

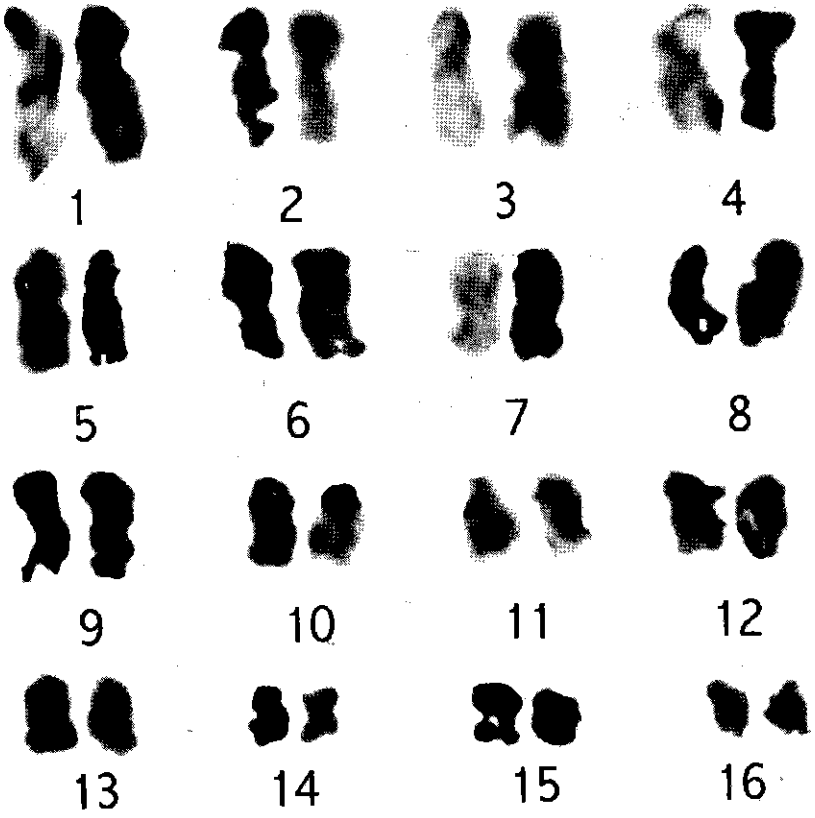


Figure 3b. Karyogram of E. guineensis *second metaphase spread*

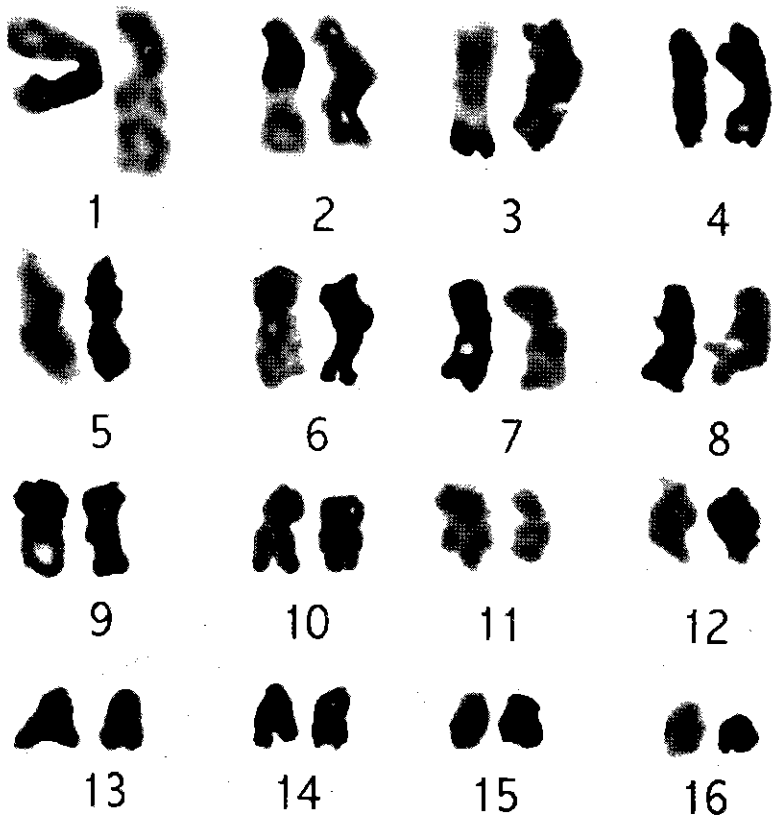


Figure 3c. Karyogram of E. guineensis *third metaphase spread*

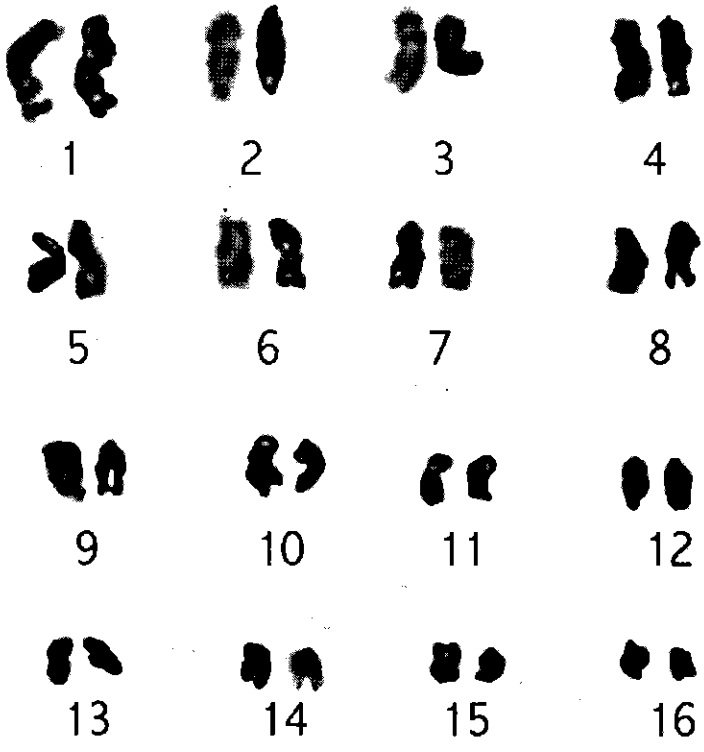


Figure 3d. Karyogram of E. guineensis *fourth metaphase spread*

Figure 3e. Karyogram of E. guineensis *fifth metaphase spread*

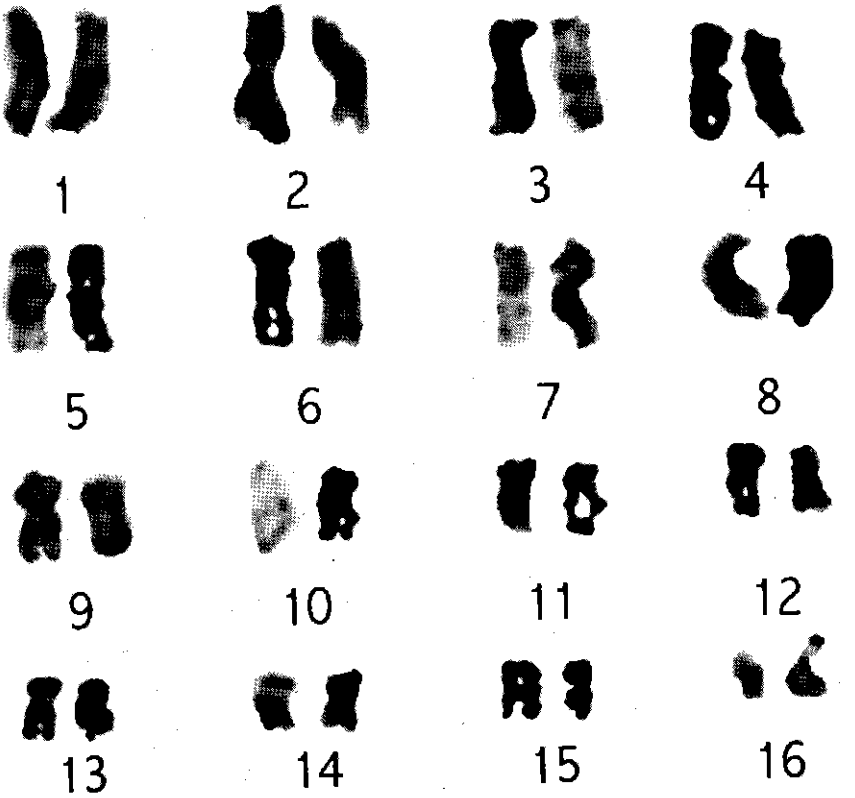


Figure 3f. Karyogram of E. guineensis *sixth metaphase spread*

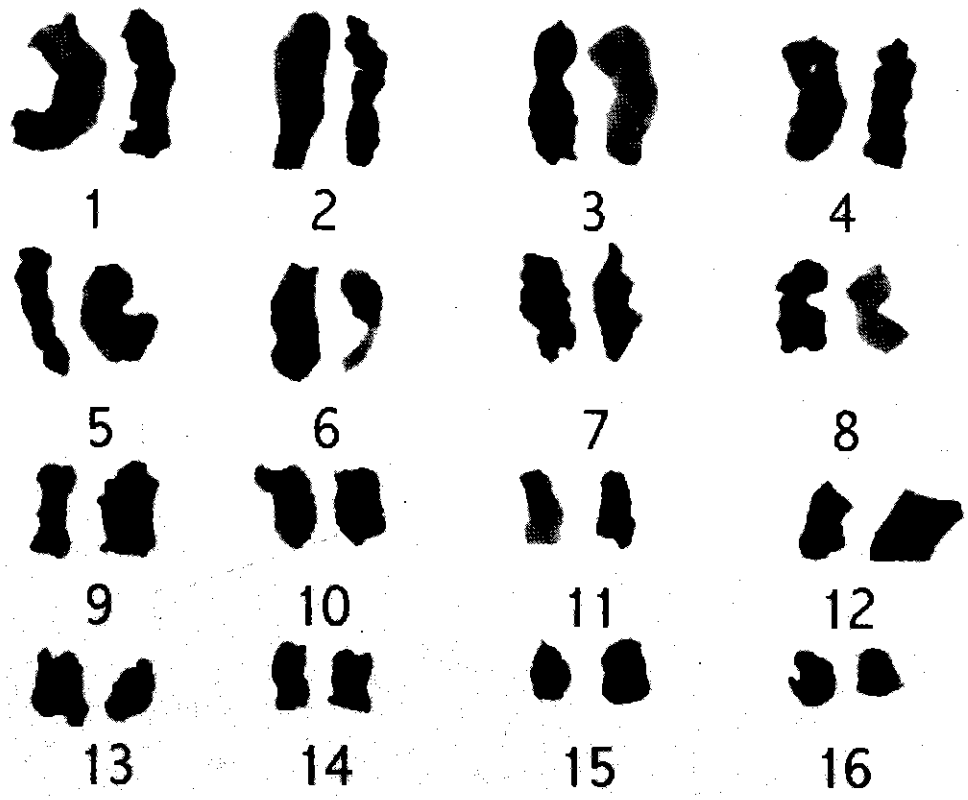


Figure 3g. Karyogram of E. guineensis *seventh metaphase spread*

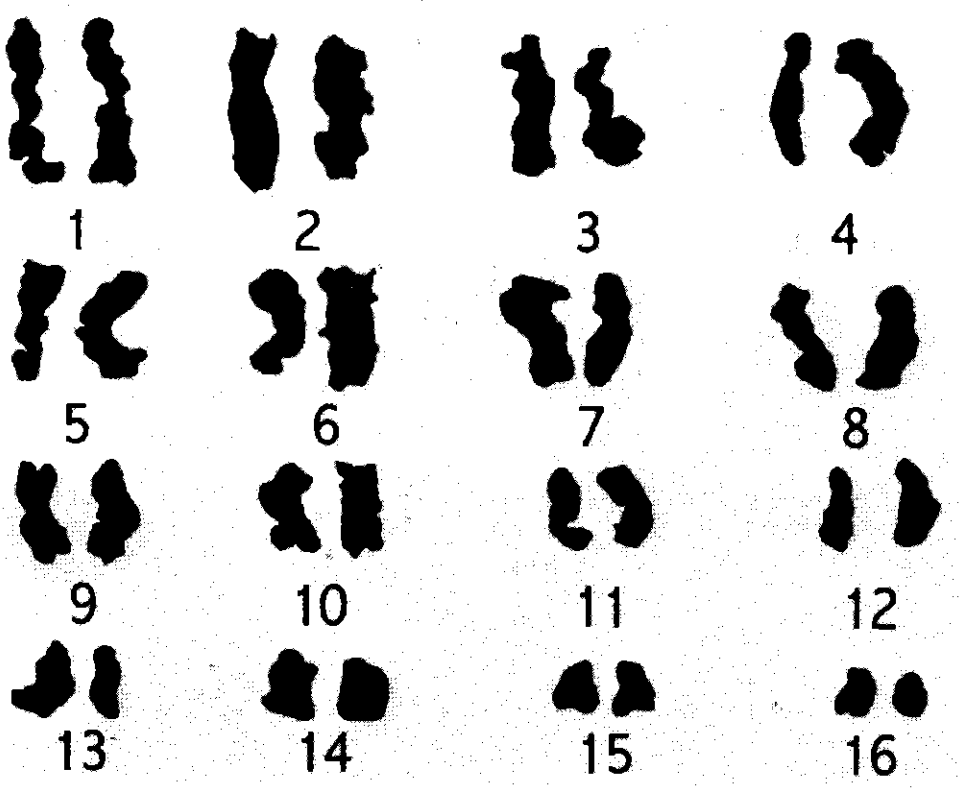


Figure 3h. Karyogram of E. guineensis *eighth metaphase spread*

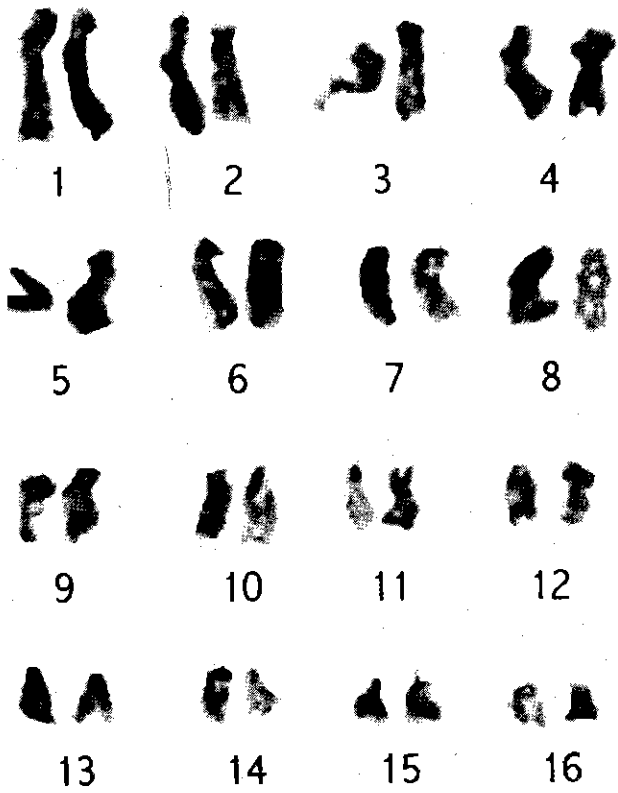


Figure 3i. Karyogram of E. guineensis *ninth metaphase spread*

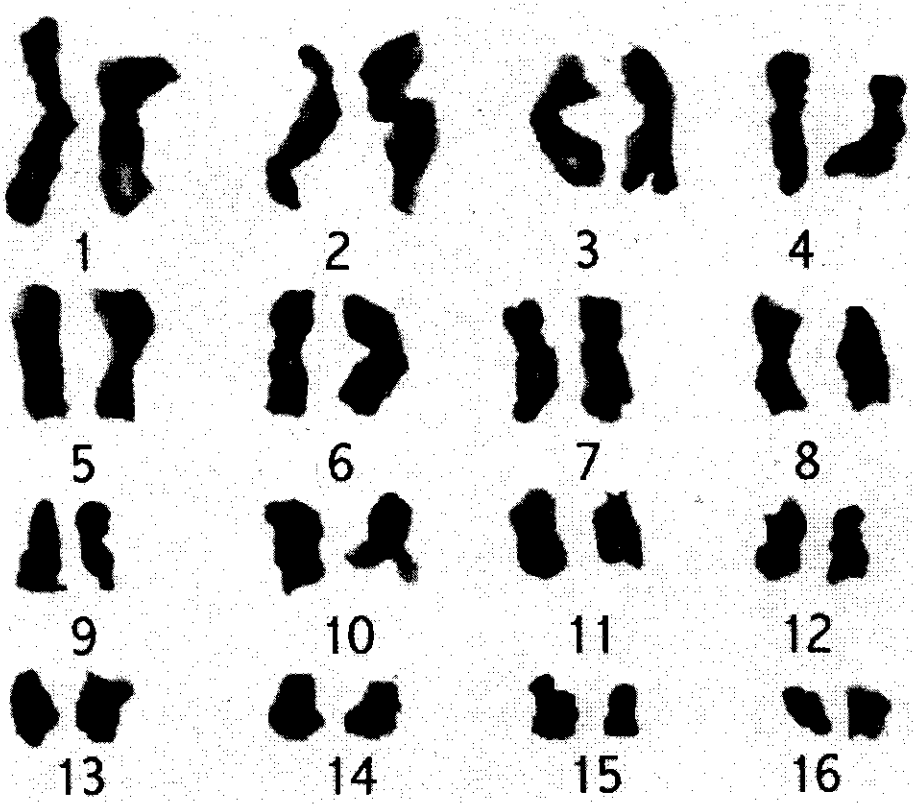


Figure 3j. Karyogram of E. guineensis *tenth metaphase spread*

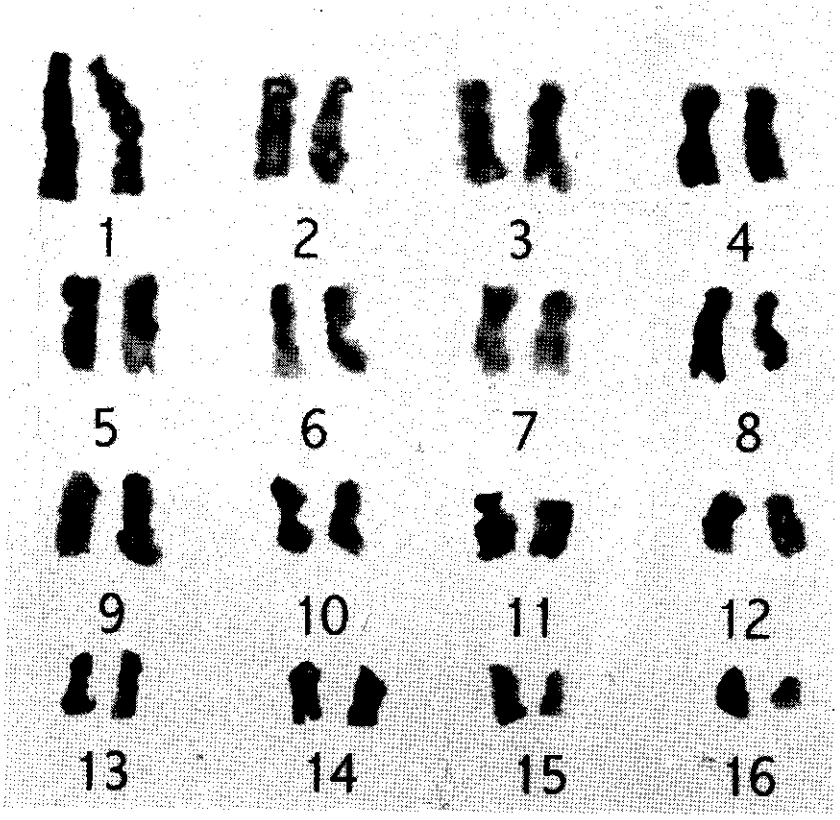


Figure 4a. Karyogram of E. oleifera *first metaphase spread*

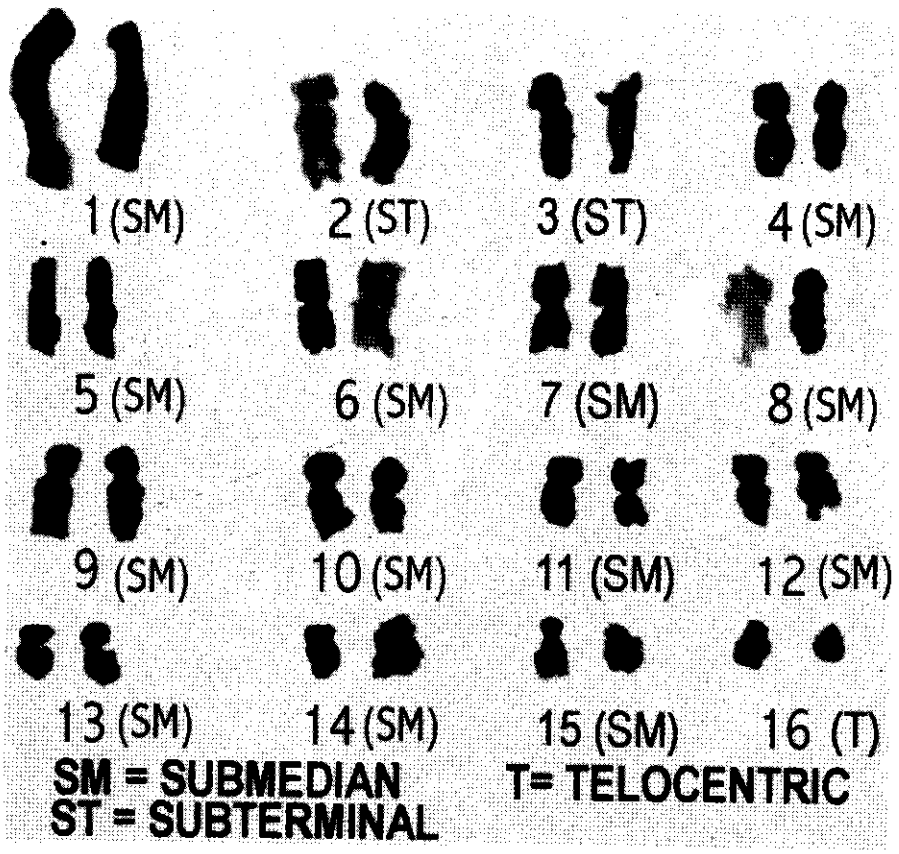


Figure 4b. Karyogram of E. oleifera *second metaphase spread*

Figure 4c. Karyogram of E. oleifera *third metaphase spread*

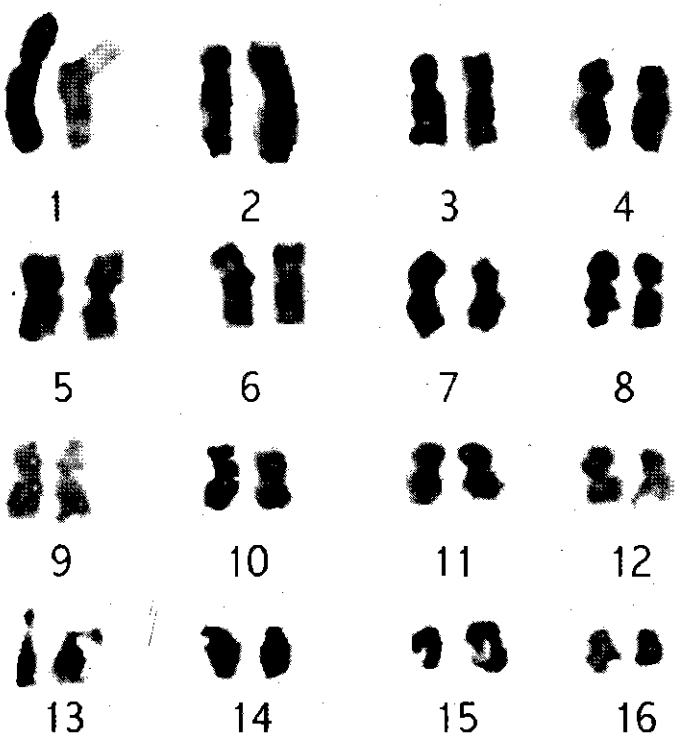


Figure 4d. Karyogram of E. oleifera *fourth metaphase spread*

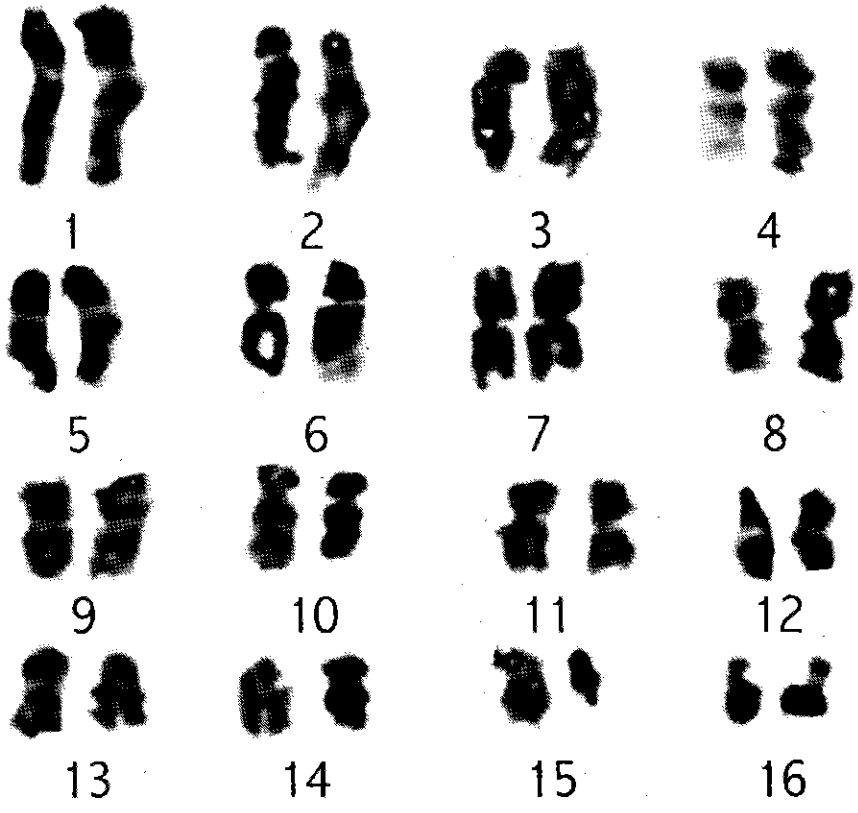


Figure 4e. Karyogram of E. oleifera *fifth metaphase spread*

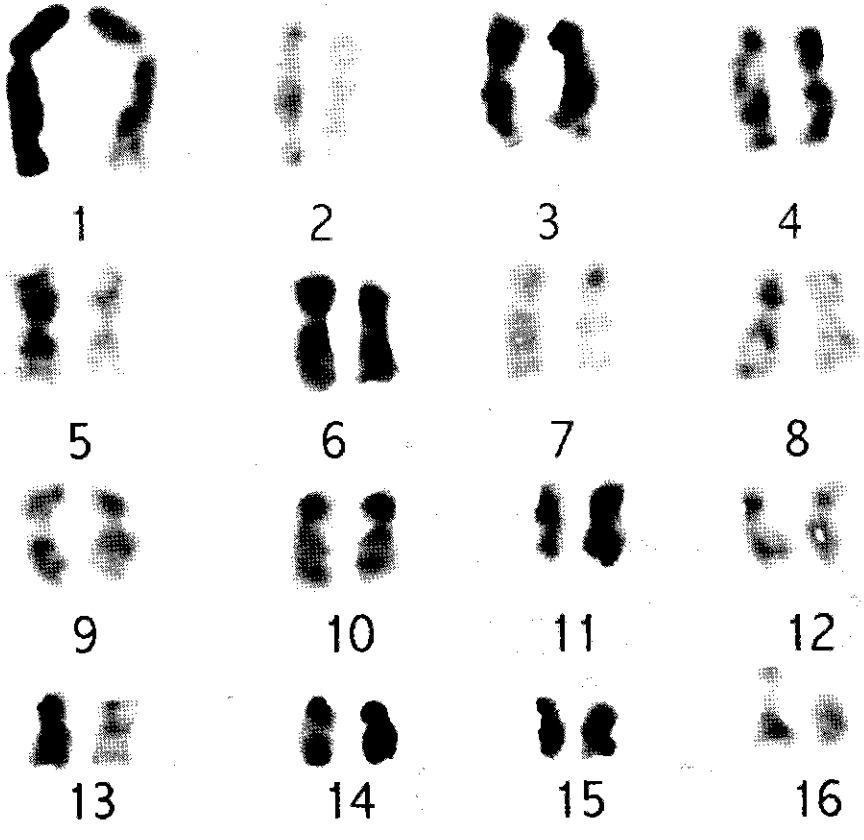


Figure 4f. Karyogram of E. oleifera *sixth metaphase spread*

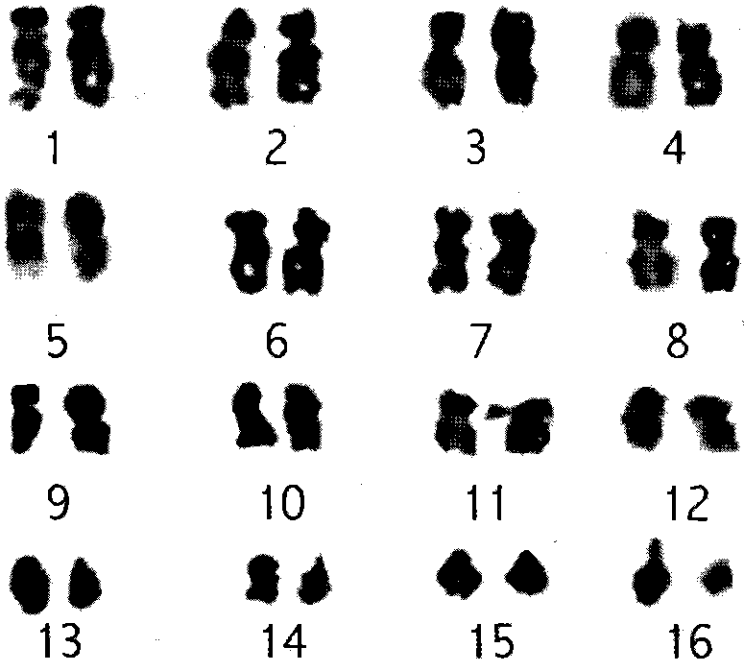


Figure 4g. Karyogram of E. oleifera *seventh metaphase spread*

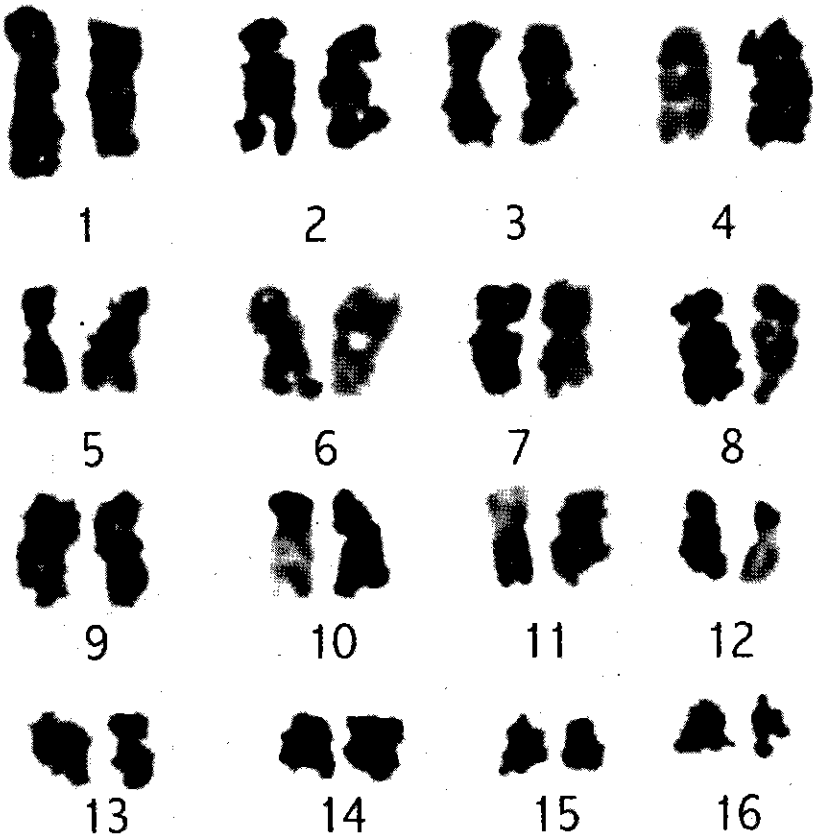


Figure 4h. Karyogram of E. oleifera *eighth metaphase spread*

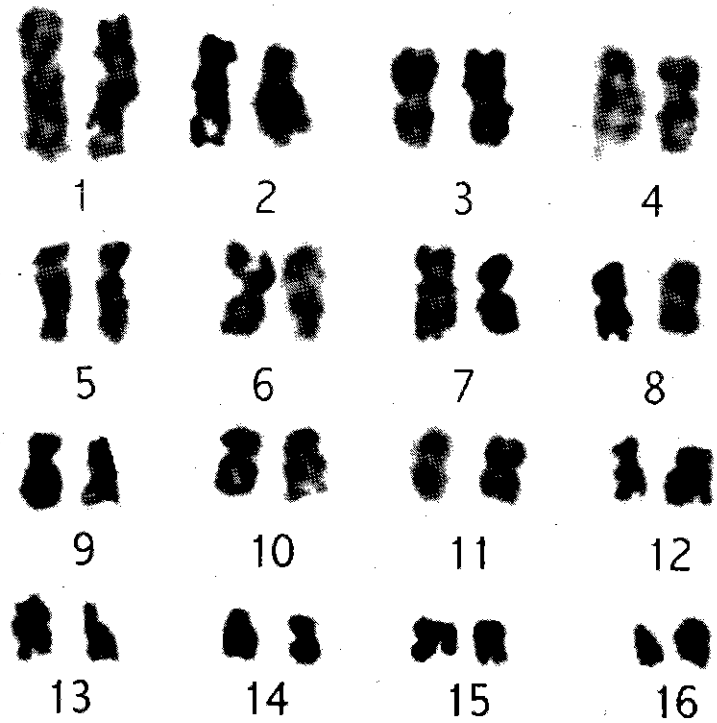


Figure 4i. Karyogram of E. oleifera *ninth metaphase spread*

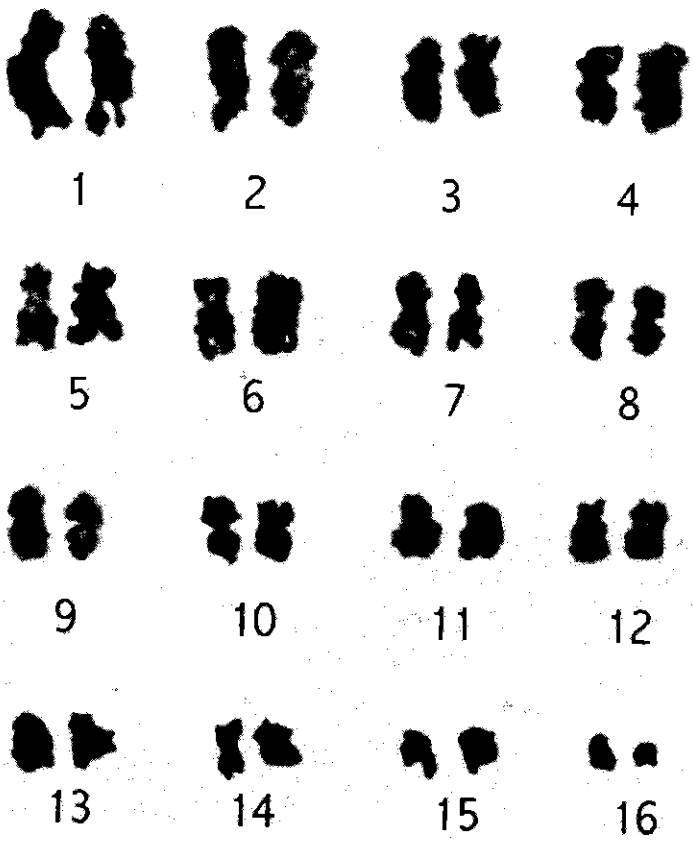


Figure 4j. Karyogram of E. oleifera *tenth metaphase spread*

TABLE 1. PAIRED T-TESTS OF *ELAEIS GUINEENSIS* SISTER CHROMOSOMES

Chr.	Average chromosome length (microns)										Performances of paired t-tests		
	A	B	C	D	E	F	G	H	I	J	t value	t critical	H_o accepted/rejected
1a	6.23	5.69	5.37	5.42	5.78	6.88	5.45	5.89	5.56	6.55			
1b	4.75	4.80	5.15	5.31	5.30	6.52	5.27	5.22	5.32	5.00	0.002501	1.96	Accepted
2a	3.80	4.45	4.70	4.35	4.67	4.30	4.71	4.99	5.31	4.80			
2b	3.80	4.44	4.38	4.08	4.39	4.05	4.58	4.55	4.51	4.51	0.001951	1.96	Accepted
3a	3.75	4.01	4.36	4.01	4.11	3.99	4.49	4.54	4.30	4.44			
3b	3.73	3.81	4.36	3.78	4.00	3.93	4.46	4.32	4.29	4.34	0.003602	1.96	Accepted
4a	3.70	3.27	4.32	3.67	3.92	3.79	4.46	4.25	4.19	4.26			
4b	3.66	3.69	4.20	3.48	3.90	3.78	4.03	4.19	4.15	4.22	0.019713	1.96	Accepted
5a	3.47	3.60	4.09	3.33	3.75	3.67	3.99	4.05	4.10	4.10			
5b	3.45	3.54	3.81	3.23	3.60	3.66	3.52	3.91	3.75	4.01	0.003467	1.96	Accepted
6a	3.44	3.54	3.80	3.21	3.53	3.63	3.50	3.79	3.67	3.96			
6b	3.09	3.48	3.73	3.15	3.44	3.48	3.32	3.75	3.66	3.73	0.002280	1.96	Accepted
7a	3.08	3.45	3.68	3.13	3.37	3.44	3.23	3.74	3.64	3.53			
7b	2.93	3.30	3.56	2.94	3.33	3.40	3.10	3.70	3.57	3.38	–	1.96	Rejected
8a	2.92	3.27	3.43	2.92	3.31	3.37	3.06	3.58	3.47	3.37			
8b	2.89	3.20	3.39	2.74	3.00	3.31	2.99	3.51	3.32	3.10	0.001585	1.96	Accepted
9a	2.88	3.12	3.33	2.68	2.83	2.94	2.99	3.23	3.25	3.05			
9b	2.86	3.00	3.11	2.68	2.77	2.94	2.98	2.98	3.11	2.86	0.004441	1.96	Accepted
10a	2.78	2.89	3.10	2.55	2.75	2.89	2.86	2.82	3.10	2.65			
10b	2.78	2.61	2.80	2.48	2.67	2.80	2.72	2.80	3.00	2.60	0.003244	1.96	Accepted
11a	2.76	2.56	2.70	2.44	2.51	2.79	2.67	2.79	2.93	2.53			
11b	2.45	2.45	2.65	2.41	2.50	2.55	2.63	2.64	2.91	2.52	0.008617	1.96	Accepted
12a	2.39	2.43	2.57	2.25	2.42	2.53	2.55	2.56	2.83	2.32			
12b	2.37	2.32	2.44	2.25	2.41	2.36	2.53	2.49	2.64	2.32	0.006169	1.96	Accepted
13a	2.31	2.29	2.36	2.16	2.39	2.21	2.52	2.46	2.62	2.11			
13b	2.09	2.28	2.31	2.09	2.37	2.11	2.41	2.44	2.33	1.97	0.003182	1.96	Accepted
14a	2.04	2.21	2.23	2.05	2.28	2.07	2.35	2.27	2.32	1.94			
14b	1.98	2.09	2.21	1.87	2.27	1.97	2.25	2.03	2.03	1.93	0.002551	1.96	Accepted
15a	1.85	1.93	2.14	1.87	2.25	1.91	2.23	1.91	2.01	1.92			
15b	1.73	1.91	1.84	1.83	2.25	1.81	2.20	1.86	1.92	1.79	0.005273	1.96	Accepted
16a	1.69	1.89	1.63	1.61	2.11	1.81	2.11	1.64	1.82	1.61			
16b	1.28	1.59	1.54	1.56	1.58	1.69	1.59	1.30	1.68	1.02	0.000444	1.96	Accepted

N.b Chromosome lengths are averages from three measurements.

TABLE 2. PAIRED T-TESTS OF *ELAEIS OLEIFERA* SISTER CHROMOSOMES

Chr.	Average chromosome length (microns)										Performances of paired t-tests		
	A	B	C	D	E	F	G	H	I	J	t value	t critical	H_o accepted/rejected
1a	5.16	6.51	4.80	5.56	5.66	6.13	4.04	5.35	5.00	4.58			
1b	4.94	5.69	4.26	4.76	5.32	5.75	3.73	4.29	4.76	3.96	0.000114	1.96	Accepted
2a	4.07	4.16	4.07	4.32	4.00	4.58	3.61	4.17	3.80	3.59			
2b	3.75	4.02	3.86	3.86	3.95	4.56	3.51	4.11	3.70	3.54	0.004007	1.96	Accepted
3a	3.74	4.01	3.85	3.67	3.74	4.55	3.40	3.99	3.69	3.51			
3b	3.70	3.92	3.86	3.66	3.68	3.90	3.36	3.96	3.62	3.43	0.032432	1.96	Accepted
4a	3.64	3.90	3.49	3.63	3.58	3.70	3.32	3.91	3.61	3.37			
4b	3.63	3.90	3.43	3.60	3.57	3.64	3.31	3.90	3.49	3.29	0.006190	1.96	Accepted
5a	3.54	3.84	3.32	3.50	3.54	3.63	3.29	3.89	3.48	3.22			
5b	3.49	3.74	3.20	3.44	3.54	3.60	3.25	3.67	3.45	3.12	0.002286	1.96	Accepted
6a	3.32	3.55	3.15	3.42	3.43	3.55	3.14	3.66	3.28	3.04			
6b	3.27	3.49	3.09	3.41	3.40	3.54	3.11	3.59	3.26	3.02	0.000312	1.96	Accepted
7a	3.09	3.46	2.95	3.20	3.33	3.41	2.99	3.56	3.23	2.87			
7b	2.89	3.41	2.90	3.14	3.22	3.32	2.93	3.53	3.06	2.85	0.000798	1.96	Accepted
8a	2.65	3.26	2.77	2.71	3.19	3.28	2.93	3.47	3.06	2.8			
8b	2.63	3.21	2.56	2.54	3.18	2.94	2.83	3.46	3.03	2.76	0.009911	1.96	Accepted
9a	2.63	3.19	2.48	2.53	3.15	2.94	2.76	3.33	2.90	2.75			
9b	2.57	3.15	2.47	2.46	3.08	2.90	2.61	3.33	2.63	2.71	0.007870	1.96	Accepted
10a	2.51	3.14	2.45	2.41	2.90	2.87	2.58	3.31	2.58	2.43			
10b	2.42	2.92	2.24	2.41	2.78	2.83	2.36	3.28	2.42	2.41	0.001514	1.96	Accepted
11a	2.38	2.91	2.21	2.34	2.77	2.63	2.35	3.01	2.33	2.35			
11b	2.32	2.57	2.18	2.31	2.69	2.60	2.30	2.93	2.23	2.15	0.005307	1.96	Accepted
12a	2.32	2.53	2.10	2.21	2.68	2.59	2.29	2.79	2.21	2.13			
12b	2.28	2.53	2.03	2.18	2.54	2.46	2.02	2.61	2.07	2.09	0.001665	1.96	Accepted
13a	2.26	2.35	1.86	2.13	2.53	2.46	2.01	2.60	1.99	2.02			
13b	2.24	2.27	1.62	2.04	2.41	2.18	1.99	2.48	1.83	1.73	0.000706	1.96	Accepted
14a	2.22	2.27	1.55	1.87	2.32	1.99	1.98	2.21	1.71	1.64			
14b	2.08	2.27	1.51	1.84	2.20	1.95	1.90	1.83	1.68	1.46	0.008493	1.96	Accepted
15a	2.00	1.79	1.51	1.83	1.86	1.87	1.74	1.66	1.63	1.39			
15b	1.79	1.59	1.46	1.80	1.85	1.75	1.64	1.53	1.62	1.37	0.002608	1.96	Accepted
16a	1.61	1.59	1.31	1.73	1.72	1.37	1.17	1.50	1.39	1.34			
16b	1.55	1.41	1.15	1.47	1.50	1.36	1.09	1.30	1.19	1.33	0.000473	1.96	Accepted

N.b Chromosome lengths are averages from three measurements.

E. guineensis and E. oleifera respectively. Acceptance of H_0 indicates good homology (that is, no significant differences between the homologues) while rejection of H_0 indicates significant differences between them. Paired t-tests performed on *E. guineensis* showed no significant difference for all chromosome pairs except Pair 7 *(Table 1)*. The difference in Pair 7 may have been caused by varying degrees of chromosome condensation between spreads and differences in slide preparations, and also error in measurement. However, all the chromosome pairs of *E. oleifera* showed no significant differences between their members *(Table 2)*.

The mean percentage lengths of *E. guineensis* and *E. oleifera* chromosomes relative to their total haploid lengths are shown in *Tables 3* and *4*, respectively. The average mean lengths of homologous chromosome pairs for each metaphase spread were calculated and the total mean length of all the chromosome pairs was obtained. The percentage relative lengths of individual chromosome pairs were then calculated. Both the *E. guineensis* and *E. oleifera* chromosomes can be divided into three groups on the basis of length. For *E. guineensis*, Pair 1 was assigned to Group I as it was exceptionally long (10.98% of total haploid chromosome length), Pairs 2-9 to Group II (medium length chromosomes: individually, 5.86% - 8.79% of total haploid chromosome length) and Pairs 10-16 to Group III (medium short chromosomes: individually, 3.22%-5.47% of total haploid chromosome length) *(Table 3)*. The results obtained are consistent with those of Maria *et al.* (1995).

For *E. oleifera*, chromosome Pair 1 was also assigned to Group I (long chromosome) as it was 10.69% of total haploid chromosome length. Pairs 2-9 were assigned to Group II (medium length chromosomes: individually, 6.05% - 8.49% of total haploid chromosome length) and Pairs 10-16 to Group III (medium short chromosomes: individually, 3.01%-5.69% of total haploid chromosome length) *(Table 4)*. The results obtained for *E. oleifera* were consistent with the results for *E. guineensis*. *Table 5* presents data on the arm ratios of *E. oleifera* chromosomes. The ratios classify the centromeric locations of the chromosomes into either median (1.00-0.80: metacentric), submedian (0.79-0.40: submetacentric) or subterminal (0.39-0.10: acrocentric). The results showed that *E. oleifera* contains two subterminal (ST) or acrocentrics, thirteen submedian (SM) or submetacentrics and one telocentric (T) chromosome pair (no ratio).

Paired t-tests were also performed to ascertain whether the *E. guineensis* and *E. oleifera* chromosome pairs are significantly different. The results of H_0 and t-values *(Table 6)* showed no significant difference between *E. guineensis* and *E. oleifera* chromosome pairs. As *E. guineensis* and *E. oleifera* can be crossed to produce interspecific (OxG) hybrids, it may be expected that their compatibility would be reflected by similarity in chromosome lengths and genome compositions. A study by Hardon and Tan (1969) on the morphology and crossability of *E. guineensis* and *E. oleifera* and the vigour, cytology and fertility of their F1 hybrids clearly indicated that the two species are genetically closely related and that gene exchange can occur between them.

DISCUSSION

There have been several cytological studies on *E. guineensis* (Imam ,1982; Low, 1990; Wong, 1992; Pang, 1993; Maria *et al.*, 1995) and one report on the karyotype (Maria *et al.*, 1995). All of them reported the chromosome number of *E. guineensis* as 2n=32. However, we are not aware of any cytogenetic information on *E. oleifera*. This species is an exotic source of new genetic variability for improving *E. guineensis* as it produces an oil with a high iodine value (Johnson, 1985). Its height growth is also very slow, less than half of that of *E. guineensis* (Hardon and Tan, 1969).

There are various methods for karyotyping. They include conventional staining of chromosomes with aceto-orcein, as was performed in this study, and chromosome banding techniques such as C-banding, G-banding, N-banding *etc*. More recently, fluorescent banding methods have been developed. Fluorescent banding was employed by Hizume *et al.* (1983, 1989, 1990, 1992 and 1993) to study the chromosomes of *Pinus, Larix* and *Pseudotsoga*. Miranda *et al.* (1997) used this method to characterize and compare the distribution of constitutive heterochromatin along the chromosomes of *Citrus, Poncirus* and *Fortunella*. Fluorescent stains used are chromomycin A_3

TABLE 3. PERCENTAGE LENGTH OF *ELAEIS GUINEENSIS* CHROMOSOMES RELATIVE TO TOTAL HAPLOID LENGTH

Chr. No.	Mean chromosome length (microns) and % of total haploid length																				Mean %
	A		B		C		D		E		F		G		H		I		J		
	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	
1	5.49	11.57	5.24	10.53	5.26	9.99	5.36	11.44	5.54	10.89	6.70	13.07	5.36	10.42	5.56	10.47	5.44	10.14	5.78	11.28	10.98
2	3.80	8.01	4.44	8.92	4.54	8.62	4.22	9.01	4.53	8.90	4.18	8.15	4.64	9.02	4.77	8.98	4.91	9.15	4.66	9.09	8.79
3	3.74	7.88	3.91	7.86	4.36	8.28	3.90	8.32	4.06	7.98	3.96	7.32	4.48	8.71	4.43	8.34	4.30	8.01	4.39	8.57	8.17
4	3.68	7.76	3.70	7.43	4.26	8.09	3.58	7.64	3.91	7.68	3.78	7.37	4.24	8.24	4.22	7.95	4.17	7.77	4.24	8.27	7.82
5	3.46	7.29	3.57	7.17	3.95	7.50	3.28	7.00	3.68	7.23	3.66	7.14	3.36	6.53	3.98	7.50	3.92	7.31	4.06	7.92	7.26
6	3.26	6.87	3.51	7.05	3.76	7.14	3.18	6.79	3.48	6.84	3.56	6.94	3.41	6.63	3.77	7.10	3.66	6.82	3.84	7.49	6.97
7	3.00	6.32	3.38	6.79	3.62	6.88	3.04	6.49	3.35	6.58	3.42	6.67	3.16	6.14	3.72	7.01	3.60	6.71	3.46	6.75	6.63
8	2.90	6.11	3.24	6.51	3.41	6.48	2.83	6.04	3.16	6.21	3.34	6.51	3.02	5.87	3.54	6.67	3.40	6.34	3.24	6.32	6.31
9	2.87	6.05	3.06	6.15	3.22	6.12	2.68	5.72	2.80	5.50	2.94	5.73	2.98	5.79	3.10	5.84	3.18	5.93	2.96	5.78	5.86
10	2.78	5.86	2.75	5.53	2.95	5.60	2.52	5.38	2.71	5.33	2.84	5.54	2.79	5.42	2.81	5.29	3.05	5.68	2.62	5.11	5.47
11	2.60	5.48	2.50	5.02	2.68	5.09	2.43	5.19	2.50	4.91	2.67	5.21	2.65	5.15	2.72	5.12	2.92	5.44	2.52	4.92	5.15
12	2.38	5.02	2.38	4.78	2.50	4.75	2.25	4.80	2.42	4.76	2.44	4.76	2.54	4.94	2.52	4.75	2.74	5.11	2.32	4.53	4.82
13	2.20	4.64	2.28	4.58	2.34	4.45	2.20	4.69	2.38	4.68	2.16	4.21	2.46	4.78	2.45	4.61	2.48	4.62	2.04	3.98	4.52
14	2.01	4.24	2.15	4.32	2.22	4.22	1.96	4.18	2.28	4.48	2.02	3.94	2.30	4.47	2.15	4.05	2.18	4.06	1.94	3.79	4.17
15	1.79	3.77	1.95	3.86	1.99	3.78	1.85	3.95	2.25	4.42	1.86	3.63	2.22	4.31	1.88	3.54	1.96	3.65	1.86	3.63	3.85
16	1.48	3.12	1.74	3.50	1.58	3.00	1.58	3.37	1.84	3.62	1.75	3.41	1.85	3.60	1.47	2.77	1.75	3.26	1.32	2.58	3.22
TOTAL	47.44	100	49.77	100	52.64	100	46.86	100	50.89	100	51.28	100	51.46	100	53.09	100	53.66	100	51.25	100	100

N.b Chromosome lengths are averages between homologues

TABLE 4. PERCENTAGE LENGTH OF *ELAEIS OLEIFERA* CHROMOSOMES RELATIVE TO TOTAL HAPLOID LENGTH

Chr. No.	Mean chromosome length (microns) and % of total haploid length																				% Mean
	A		B		C		D		E		F		G		H		I		J		
	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	
1	5.05	10.90	6.10	11.89	4.53	10.59	5.16	11.22	5.49	11.05	5.94	11.79	3.88	9.07	4.82	9.43	4.88	10.86	4.27	10.14	10.69
2	3.91	8.44	4.09	7.97	3.97	9.28	4.09	8.89	3.98	8.01	4.57	9.07	3.56	8.33	4.14	8.10	3.75	8.34	3.56	8.45	8.49
3	3.72	8.03	3.97	7.74	3.75	8.77	3.66	7.96	3.71	7.47	4.22	8.37	3.38	7.90	3.98	7.79	3.66	8.14	3.47	8.24	8.04
4	3.64	7.85	3.90	7.60	3.46	8.09	3.62	7.87	3.58	7.21	3.67	7.28	3.32	7.76	3.90	7.63	3.55	7.90	3.33	7.90	7.71
5	3.51	7.57	3.79	7.39	3.26	7.62	3.47	7.55	3.54	7.13	3.62	7.18	3.27	7.65	3.78	7.40	3.46	7.70	3.17	7.52	7.47
6	3.29	7.10	3.52	6.86	3.12	7.30	3.42	7.44	3.42	6.88	3.54	7.02	3.12	7.30	3.62	7.08	3.27	7.28	3.03	7.19	7.15
7	2.99	6.45	3.44	6.71	2.93	6.85	3.17	6.89	3.28	6.60	3.36	6.67	2.96	6.92	3.54	6.93	3.14	6.99	2.86	6.79	6.78
8	2.64	5.70	3.24	6.32	2.67	6.24	2.62	5.70	3.18	6.40	3.11	6.17	2.88	6.74	3.46	6.77	3.04	6.76	2.78	6.60	6.34
9	2.60	5.61	3.17	6.18	2.48	5.80	2.50	5.44	3.12	6.28	2.92	5.79	2.68	6.27	3.33	6.52	2.76	6.14	2.73	6.48	6.05
10	2.47	5.33	3.03	5.91	2.34	5.47	2.41	5.24	2.84	5.72	2.85	5.65	2.47	5.78	3.30	6.46	2.50	5.56	2.42	5.74	5.69
11	2.35	5.07	2.74	5.34	2.20	5.14	2.32	5.04	2.73	5.50	2.62	5.20	2.32	5.43	2.97	5.81	2.28	5.07	2.25	5.34	5.29
12	2.30	4.96	2.53	4.93	2.06	4.82	2.20	4.78	2.61	5.25	2.52	5.00	2.16	5.05	2.70	5.28	2.14	4.76	2.11	5.01	4.99
13	2.25	4.86	2.31	4.50	1.74	4.07	2.08	4.52	2.47	4.97	2.32	4.60	2.00	4.68	2.54	4.97	1.91	4.25	1.88	4.46	4.59
14	2.15	4.64	2.27	4.43	1.53	3.58	1.86	4.04	2.26	4.55	1.97	3.91	1.94	4.54	2.02	3.95	1.70	3.78	1.55	3.68	4.11
15	1.89	4.08	1.69	3.29	1.49	3.48	1.81	3.94	1.86	3.74	1.81	3.59	1.69	3.95	1.60	3.13	1.61	3.58	1.38	3.28	3.61
16	1.58	3.41	1.50	2.92	1.23	2.88	1.60	3.48	1.61	3.24	1.36	2.70	1.13	2.64	1.40	2.74	1.29	2.87	1.34	3.18	3.01
TOTAL	46.34	100	51.29	100	42.76	100	45.99	100	49.68	100	50.40	100	42.76	100	51.10	100	44.94	100	42.13	100	100

N.b Chromosome lengths are averages between homologues

TABLE 5. KARYOTYPE ANALYSIS OF *ELAEIS OLEIFERA* CHROMOSOMES

Chr.	Absolute length (microns)				Arm ratio	Class
	p	q	Average p	Average q	(p/q)	
1a	2.58	3.94				
1b	2.12	3.57	2.35	3.76	0.63	SM
2a	1.00	3.17				
2b	1.29	2.72	1.15	2.95	0.39	ST
3a	1.24	2.78				
3b	0.98	2.95	1.11	2.87	0.39	ST
4a	1.61	2.28				
4b	1.72	2.18	1.67	2.23	0.75	SM
5a	1.43	2.40				
5b	1.87	1.87	1.65	2.14	0.77	SM
6a	1.71	1.85				
6b	1.26	2.23	1.49	2.04	0.73	SM
7a	1.52	1.93				
7b	1.48	1.92	1.50	1.93	0.78	SM
8a	1.34	1.91				
8b	1.15	2.07	1.25	1.99	0.63	SM
9a	1.19	2.01				
9b	1.06	2.09	1.13	2.05	0.55	SM
10a	1.16	1.98				
10b	1.48	1.43	1.32	1.71	0.77	SM
11a	1.13	1.79				
11b	1.16	1.41	1.15	1.60	0.72	SM
12a	0.86	1.66				
12b	0.83	1.70	0.85	1.68	0.51	SM
13a	0.98	1.37				
13b	0.97	1.30	0.98	1.34	0.73	SM
14a	1.15	2.60				
14b	0.96	1.30	1.06	1.95	0.54	SM
15a	0.58	1.22				
15b	0.53	1.05	0.56	1.14	0.49	SM
16a	Absolute length = 1.59					T
16b	Absolute length = 1.41					T

SM = Submedian ST = Subterminal T = Telocentric

(CMA) and 4'-6-diamidino-2-phenylindole (DAPI). The fluorochrome CMA binds specifically to guanine base and DAPI to adenine and thymine bases, producing different banding patterns. This technique was tried on *Elaeis* but DAPI stained the chromosomes uniformly so that there was no significant distinguishing banding patterns (unpublished).

The cytological analyses we did on the chromosomes of *E. guineensis* and *E. oleifera* used their absolute lengths as the parameter analysed due to the difficulty in determining the locations of centromeres. In *E. guineensis*, this difficulty is greater than in *E. oleifera*. *Table 5* and the karyogram on *Figure 4b* show the different classes of *E. oleifera* chromosomes

TABLE 6. PAIRED T-TESTS OF *ELAEIS OLEIFERA AND ELAEIS GUINEENSIS* CHROMOSOMES

	Mean chromosome length (microns)										Performances of paired t-tests		
Chr.	A	B	C	D	E	F	G	H	I	J	t value	t critical	H_o accepted/rejected
1 (E.o)	5.05	6.10	4.53	5.16	5.49	5.94	3.88	4.82	4.88	4.27			
1 (E.g)	5.49	5.24	5.26	5.36	5.54	6.70	5.36	5.56	5.44	5.78	0.014962	1.96	Accepted
2 (E.o)	3.91	4.09	3.97	4.09	3.98	4.57	3.56	4.14	3.75	3.56			
2 (E.g)	3.80	4.44	4.54	4.22	4.53	4.18	4.64	4.77	4.91	4.66	0.006845	1.96	Accepted
3 (E.o)	3.72	3.97	3.75	3.66	3.71	4.22	3.38	3.98	3.66	3.47			
3 (E.g)	3.74	3.91	4.36	3.90	4.06	3.96	4.48	4.43	4.30	4.39	0.008361	1.96	Accepted
4 (E.o)	3.64	3.90	3.46	3.62	3.58	3.67	3.32	3.90	3.55	3.33			
4 (E.g)	3.68	3.70	4.26	3.58	3.91	3.78	4.24	4.22	4.17	4.24	0.008275	1.96	Accepted
5 (E.o)	3.51	3.79	3.26	3.47	3.54	3.62	3.27	3.78	3.46	3.17			
5 (E.g)	3.46	3.57	3.95	3.28	3.68	3.66	3.36	3.98	3.92	4.06	0.055801	1.96	Accepted
6 (E.o)	3.29	3.52	3.12	3.42	3.42	3.54	3.12	3.62	3.27	3.03			
6 (E.g)	3.26	3.51	3.76	3.18	3.48	3.56	3.41	3.77	3.66	3.84	0.037067	1.96	Accepted
7 (E.o)	2.99	3.44	2.93	3.17	3.28	3.36	2.96	3.54	3.14	2.86			
7 (E.g)	3.00	3.38	3.62	3.04	3.35	3.42	3.16	3.72	3.60	3.46	0.022334	1.96	Accepted
8 (E.o)	2.64	3.24	2.67	2.62	3.18	3.11	2.88	3.46	3.04	2.78			
8 (E.g)	2.90	3.24	3.41	2.83	3.16	3.34	3.02	3.54	3.40	3.24	0.004016	1.96	Accepted
9 (E.o)	2.60	3.17	2.48	2.50	3.12	2.92	2.68	3.33	2.76	2.73			
9 (E.g)	2.87	3.06	3.22	2.68	2.80	2.94	2.98	3.10	3.18	2.96	0.085508	1.96	Accepted
10 (E.o)	2.47	3.03	2.34	2.41	2.84	2.85	2.47	3.30	2.50	2.42			
10 (E.g)	2.78	2.75	2.95	2.52	2.71	2.84	2.79	2.81	3.05	2.62	0.156841	1.96	Accepted
11 (E.o)	2.35	2.74	2.20	2.32	2.73	2.62	2.32	2.97	2.28	2.25			
11 (E.g)	2.60	2.50	2.68	2.43	2.50	2.67	2.65	2.72	2.92	2.52	0.093032	1.96	Accepted
12 (E.o)	2.30	2.53	2.06	2.20	2.61	2.52	2.16	2.70	2.14	2.11			
12 (E.g)	2.38	2.38	2.50	2.25	2.42	2.44	2.54	2.52	2.74	2.32	0.112453	1.96	Accepted
13 (E.o)	2.25	2.31	1.74	2.08	2.47	2.32	2.00	2.54	1.91	1.88			
13 (E.g)	2.20	2.28	2.34	2.20	2.38	2.16	2.46	2.45	2.48	2.04	0.069651	1.96	Accepted
14 (E.o)	2.15	2.27	1.53	1.86	2.26	1.97	1.94	2.02	1.70	1.55			
14 (E.g)	2.01	2.15	2.22	1.96	2.28	2.02	2.30	2.15	2.18	1.94	0.024468	1.96	Accepted
15 (E.o)	1.89	1.69	1.49	1.81	1.86	1.81	1.69	1.60	1.61	1.38			
15 (E.g)	1.79	1.92	1.99	1.85	2.25	1.86	2.22	1.88	1.96	1.86	0.001551	1.96	Accepted
16 (E.o)	1.58	1.50	1.23	1.60	1.61	1.36	1.13	1.40	1.29	1.34			
16 (E.g)	1.48	1.74	1.58	1.58	1.84	1.75	1.85	1.47	1.75	1.32	0.009403	1.96	Accepted

N.b E.o is *Elaeis oleifera*

E.g is *Elaeis guineensis*

where two pairs are subterminal (ST), thirteen submedian (SM) and one telocentric (T). Various reports have shown that palm chromosome complements consist of different compositions of chromosomes. For example, the genus *Sabal* contains metacentrics and submetacentrics chromosomes (2n=36) (Palomino and Quero, 1992). Johnson (1979) reported the karyotypes of two species of *Ceratolobus* (2n=26) having metacentrics and acrocentrics. Karyotypic studies of *Brassiophoenix schumannii* (2n=32) and *Sommieria affinis* (2n=34) showed that the chromosomes are made up of metacentrics, acrocentrics and also telocentrics. Okolo (1988) reported that the karyotypes of six species of *Raphia* contained chromosomes which are metacentrics, submetacentrics and acrocentrics. Palomino and Quero (1992) also reported a pair of chromosomes heteromorphic in both size and shape in *Sabal gretheriae*. This pair was almost three times bigger than the average *Sabal* chromosome. This phenomenon has not been encountered in the *Elaeis* genus.

Cytological analysis on 10 metaphase spreads of *E. guineensis* and *E. oleifera* showed that both species have a haploid number, n=16. This number falls within the dysploid series reported by Palomino and Quero (1992), that is, the presence of consecutive gametic numbers in *Palmae* ranging from n=13 to n=18. Palms of the subfamily *Coryphoideae* are considered to be the most primitive group with n=18 (Uhl and Druansfield, 1987). To conclude, using the standard karyotypes of *E. guineensis* and *E. oleifera* as references, these will assist in studying chromosomes from abnormal palms or tissue culture plantlets.

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