ISSN 1994-1501

Plant Environ. Dev. 2(1):33-45, 2008 (June)
©Department of Botany, University of Rajshahi.
e-mail: plant.environ.dev@gmail.com

Quantitative karyotypic analysis in five taxa of *Aloe*

M.A. Bari, M.M. Ud-Deen [1*] and G. Kabir [2]

Professor Sultanul Alam Cytogenetics Laboratory, Department of Botany,
University of Rajshahi, Rajshahi-6205, Bangladesh.
[1]Associate Professor,
Department of Crop Science and Technology, University of Rajshahi
[2]Professor, Department of Botany, University of Rajshahi.

*Corresponding author: Mobile: +88 01558340438,
email: muddeen05@yahoo.com

Abstract

Quantitative karyotypic analysis in five taxa of *Aloe* (taxa -1, 2, 3 and 4 with 2n=14 but taxon-5 with 2n=4X=28) revealed differences in chromosome length, total chromatin length (TCL) and total frequency (TF%). The identified chromosome pairs were I, II, IV, V, VI, VII in taxon-1; I, II, IV, V, VI, VII in taxon-2; II, III, V, VI in taxon-3; I, II, IV, V, VI, VII in taxon-4 and II, IV, V, VI, VII, IX, X, XI, XIII, XIV in taxon-5. Unidentified chromosomes were allocated to different morphological classes based on probabilistic inferences. Only the sub median (Sm) and sub terminal (St) chromosomes were observed. The proposed standard karyotype were $3M^{3St}+1S_1{}^{1St}+3S_2{}^{3Sm}$ for taxon-1, $1L^{1St}+3M^{3St}+3S_2{}^{3Sm}$ for taxon-2, $2L^{2St}+2M^{2St}+1S_1{}^{1Sm}+2S_2{}^{2Sm}$ for taxon-3, $3L^{3St}+1M^{1St}+3S_2{}^{3Sm}$ for taxon-4 and $3M^{3St}+5S_1{}^{5St}+6S_2{}^{6Sm}$ for taxon-5

Keywords: Karyotype, *Aloe*.

INTRODUCTION

Aloe (Aloaceae) with approximately 300 species is native to Africa, Madagascar and Arabia. Most species are diploid (2n=14), although a few are tetraploid and one is hexaploid (Brandham, 1971). Almost all the Aloaceae members are reported to have the bimodal karyotype and at the same time large heterozygous translocation have been found in natural populations (Brandham, 1976).

The highest degree of karyotypic orthoselection is found to occur in the African family Aloaceae. Although the basic karyotype is uniform in the family, major structural changes to the chromosomes are reported due to Robertsonian fusions, large translocations and other types of interchanges (Brandham, 1974; Riley and Majumdar, 1979). These were shown to occur in collected plants (Brandham, 1976) and also have been produced in cultivated Aloaceae by inbreeding the heterozygotes (Brandham, 1983). So a good number of cytological works have been done on *Aloe* by several workers such as Sato (1937, 1942), Marshak (1934) and

Snoad (1951). The investigation of Brandham (1971) and Vij *et al.* (1980) revealed that the genus *Aloe* possesses 2n=14 in diploid species and 4n=28 in tetraploid species.

Hence, the present work deals a separate approach regarding quantitative karyotypic variation in five taxa of *Aloe*.

MATERIALS AND METHODS

Five taxa of *Aloe* L. (taxon-1,2,3,4 and 5) were collected from the Medicinal Garden, Natore and also from the Botanical Garden, Rajshahi University and were transplanted in earthen plots.

For karyotypic study, the root tips were collected at about 11.00-11.30 am during the months of December to February. The young root tips (1-1.5 cm) were cut by a clean blade and treated with 0.002M 8-hydroxyquinoline in vials for 3-3.5 hour at 4^{0}C. The treated root tips were thoroughly washed by distilled water and were fixed in 1:3 aceto-alcohol for 48 hours at room temperature and then preserved in 70% ethanol at 4^{0}C in refrigerator. Staining of root tip chromosomes was done by haematoxylin method. Temporary slides using (0.5% acetocarmine) were examined under a compound microscope with 40X16 magnification and chromosomes were measured from photomicrographs. Chromosomes were classified according to Levan *et al.* (1964) as

- $15.96 \leq X \leq =$ large chromosome (L),
- $11.58 \leq X \leq 15.95 =$ medium (M),
- $7.20 \leq X \leq 15.57 =$ relatively short (S_1) and
- $\leq X \leq 7.19 =$ short chromosome (S_2).

Data on chromosome morphology (from three cells of each taxon with similar degrees of chromosome contraction) were taken as described by Ahmed *et al.* (1983) with some modification. The standard karyotype proposed for five taxa of Aloe were derived on the basis of centromeric formula, range and average chromatin length per chromosome. The total frequency (TF%) was calculated using the formula of Huziwara (1962). In case of chromosome morphology, uniformity regarding degree of contraction of chromosomes in the studied three cells were determined by comparing haploid total length of all the chromosomes in each cell of each taxa and standardized haploid length for three cells and chromosomes distribution in both of them were determined. The process was repeated for each of the three cells under study. The similarity and homogeneity of the distribution of chromosomal morphology in three cells were tested by using a contingency table incorporating chromosome length and arm ratio classes. The nonsignificant x^2 values indicated the chromosome to be homogenous for the frequency of haploid length and arm ratio classes.

In case of chromosome identification, the three points representing the haploid homologues of each chromosome should cluster closely and such cluster must contain one point from each studied cells (A, B, C). For each of the identified groups (chromosomes) of different cells, the mean ($\overline{X}$), standard error (SE) and coefficient of variation percentage (CV%) were determined for length and arm ratio using the diploid values. The chromosomal groups of three points indicated the numbers of distinct individually identifiable chromosomes in each taxa. On the other hand, the groups of seven points indicated two chromosomes so similar morphologically that they could not be distinguished from each other but identifiable from the rest.

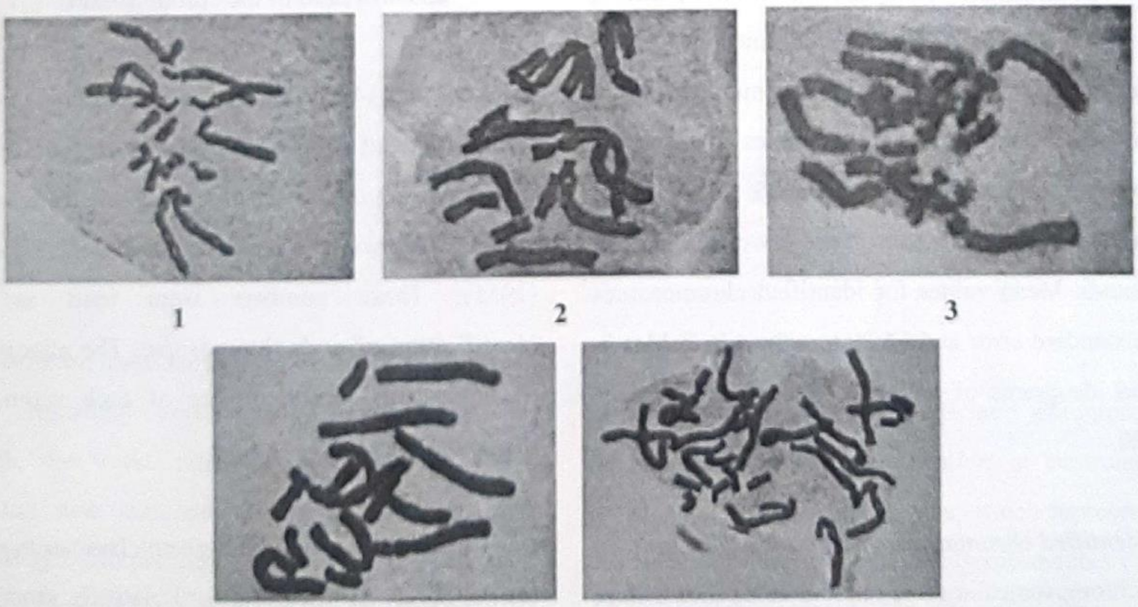
RESULTS AND DISCUSSION

Chromosome morphology

The karyotype analysis of five taxa of *Aloe* revealed that all the taxa had x=7 and confirmed to be 2n=14 in diploid types (taxa-1,2,3 and 4) and 2n=4X=28 in tetraploid types (taxon-5). Similar results were found by Fedorov (1969), Moore (1973) and Sapre (1978).

Representative complements at desirable stage of contraction are shown in Figs. 1-5. Lengths and arm ratios of the respective chromosome complements of the five taxa plotted on separate scatter diagrams are shown in Figs. 6-10. Homologous chromosomes were circled on the scatter diagram. The chromosomes of haploid complements were numbered in decreasing order of length and increasing order of arm ratio within the same length (Rhoades, 1955). Morphology of chromosomes differed and the differences were observed regarding chromosome length, total chromatin length (TCL), centromeric position and chromosome type in both the taxa of *Aloe*.

Quantitative method was applied to develop a standard karyotype. Comparison between chromosome complements of the five taxa were made based on the distribution of identified chromosomes. The chromosomes may not always have the same total length (Sindhu *et al.*, 1982) because of variation from cell to cell and differences due to fixation. Major changes regarding morphology of the chromosomes are associated with the cell division process (Wilson and Morrison, 1973).


1 2 3

4 5

Figures 1-5: Metaphase plates (Ca 640x) used for quantitative karyotype analysis in five taxa of *Aloe*. 1. Taxon-1, 2. Taxon-2, 3. Taxon-3, 4. Taxon-4 and 5. Taxon-5.

This sort of investigation is important for understanding the generic or species interrelationship and evolutionary trends (Bhatt and Dasgupta, 1976; Mehra and Choda, 1978; Feden, 1980).

Chromosome identification

Corresponding chromosomes in different complements were determined through grouping technique applied to combined scatter diagram for the three haploid complements involving 21 chromosome for taxon-1, 2, 3 and 4, and 42 chromosomes for taxon-5 and these are given in Figures 11-15.

Each point in scatter diagram represented the specific chromosome in a particular haploid complement. Three different symbols A, B, C represented the studied cells and numbering 1-7 (taxon-1,2,3,4) and 1-14 (Taxa-5) for the individual chromosome. The numbers of identified chromosomes were found to be 6 in taxa-1 and 4, and 4 in taxa-3. All of the chromosomes were identifiable in taxa-2 and ten chromosomes were identified in taxa-5. The mean values of identified chromosomes among five taxa were found to be highest (19.89 □m) in taxa-2 and lowest (2.82 □m) in taxa-5. Mean values for identified chromosomes with standard error and CV% are given in Tables 1-6 and ideograms of five taxa are given in Figures 16-20.

Unidentified chromosomes and their allocation

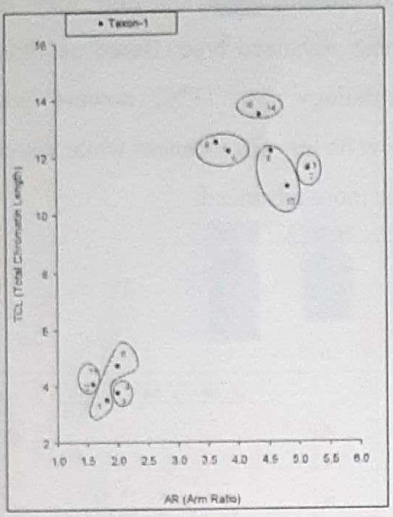
All chromosomes in three haploid components were classified in different morphological categories on the basis of total length and arm ratio within the length classes. The class interval 4.375μm for length was chosen arbitrarily and the range for arm ratio as recommended by Kutarekar and Wanjari (1983) were used. This classification was superimposed on the scatter diagram of the haploid complements as a grid of length and arm ratio classes.

Standard length was used in plotting which resulted in vertical displacement of the points in the combined scatter diagram. The mean of the groups of identified chromosomes in the scatter diagram did not change as a result of standardization. The unidentified chromosomes were distributed to the various morphological classes using probabilistic inferences on:

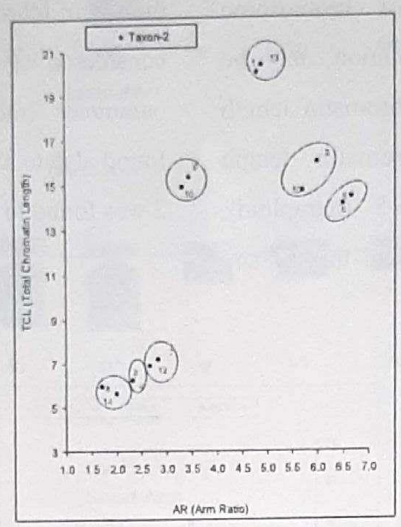
a. the frequency of chromosomes in a given cell per haploid set,
b. occurrence of points in the combined scatter diagram and
c. the examination of the original total length and arm ratio of the chromosomes.

All the 7 and 14 haploid chromosome complements were numbered in decreasing order of total length and increasing order of arm ratio within each length classes following the convention of Rhoades (1955). These numbers were used as the identification of each chromosome. The allocations of unidentified chromosomes of each taxon are given in Tables 7-11.

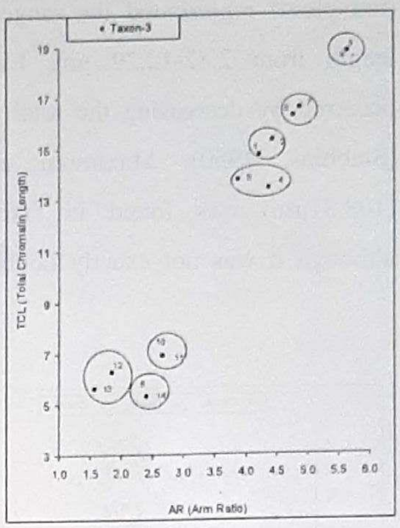
Chromosome frequency in a given class per haploid set (L=Large, M=Medium, S_1=Relatively short and S_2=Short). The symbol for the identified chromosomes were placed using the mean values for length and arm ratio, and for unidentified chromosomes at approximate locations as ascertained from original data. The symbols for the remaining unidentified ones were placed arbitrarily with in the appropriate class boundaries without indicating any specific value for length and arm ratio.



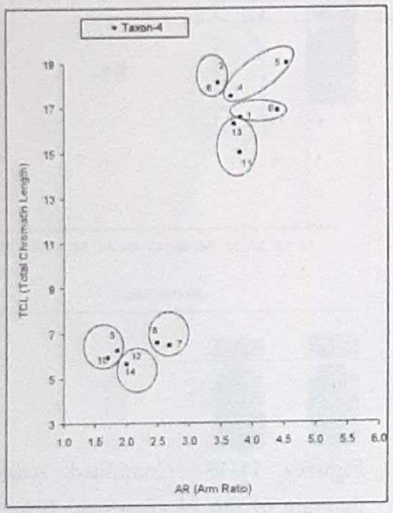
6



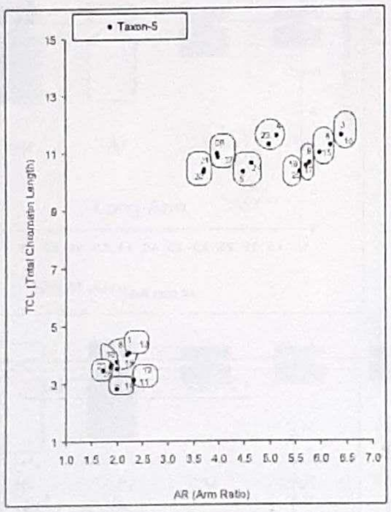
7



8



9



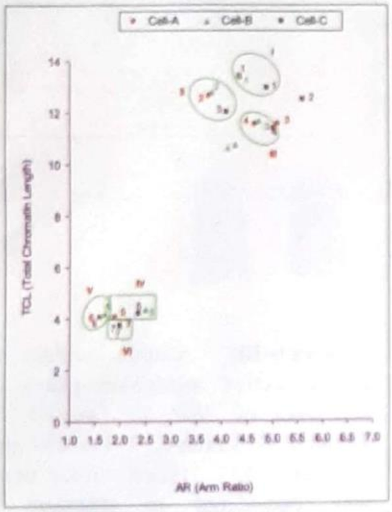
10

Figures 6-10: Scatter diagram of the respective metaphase plates in five taxa of *Aloe*. 6. Taxon-1, 7. Taxon-2, 8. Taxon-3, 9. Taxon-4 and 10. Taxon-5. (Each circled point was considered to represent a homologoue).

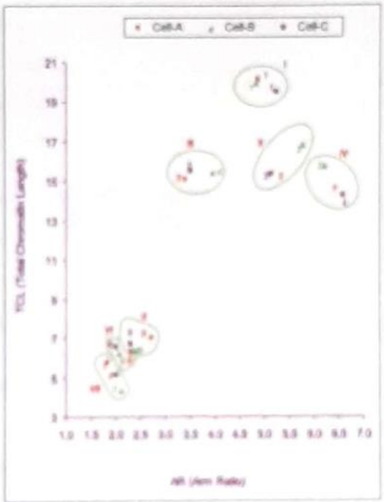
Proposed standard karyotype

Data regarding chromosome morphology, i.e. length, arm ratio, relative length, TCL%, TF%, position and chromosome types were recorded (Table 12). Morphological features of the proposed standard karyotypic formula of the five taxa of *Aloe* are summarized in Table 13. The chromosomes of the five taxa in the present investigation were found to differ from each other regarding length, total chromatin length (TCL), TF% and chromosome type. But there was no variation in centromeric position in the four diploid taxa, which represented always 4 sub-terminal (St) and 3 sub-median (Sm) pairs of chromosomes. On the other hand, the tetraploid taxa represented 8 sub-terminal (St) and 6 sub-median (Sm) pairs of chromosome, which is exactly double to the diploid ones.

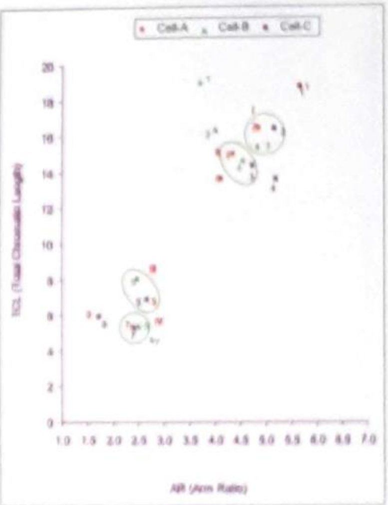
Longest chromosome (18.89µm, range 5.11-18.89µm) was observed in taxon-2 and shortest (3.75µm, range 3.75-13.28µm) in taxon-1 among four diploid taxa. On the other hand, taxon-5 (tetraploid) represented the range of chromosome length from 2.82-12.29 µm. Evolution may be occurred by decreasing the total chromatin length (Stebbins, 1950). Maximum chromatin length (108.81µm) was found in taxon-5 (tetraploid), although it was not exactly double to that of any diploid one. Considering this point striking result was found in the doploid taxa of *Aloe*. Taxon-4 having maximum chromatin length (87.23 µm) may be considered as less advanced and taxon-1 having minimum chromatin length (61.08 µm) may be considered as most advanced type. Based on other parameter (morphology, St, TF%) taxon-4 was found also to show its less advanceness while taxon-2 was found to be more advanced.



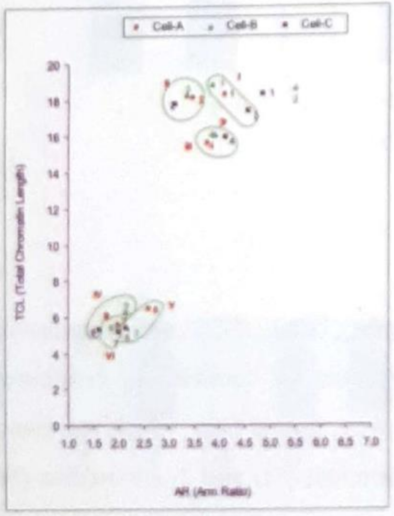
11



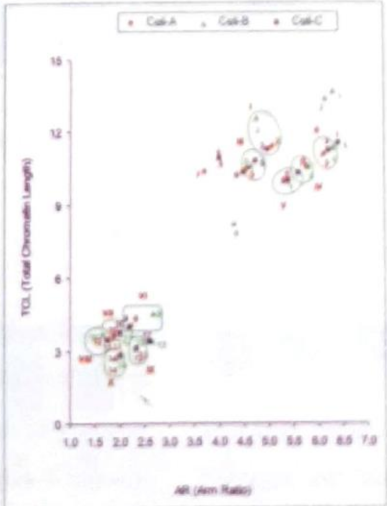
12



13

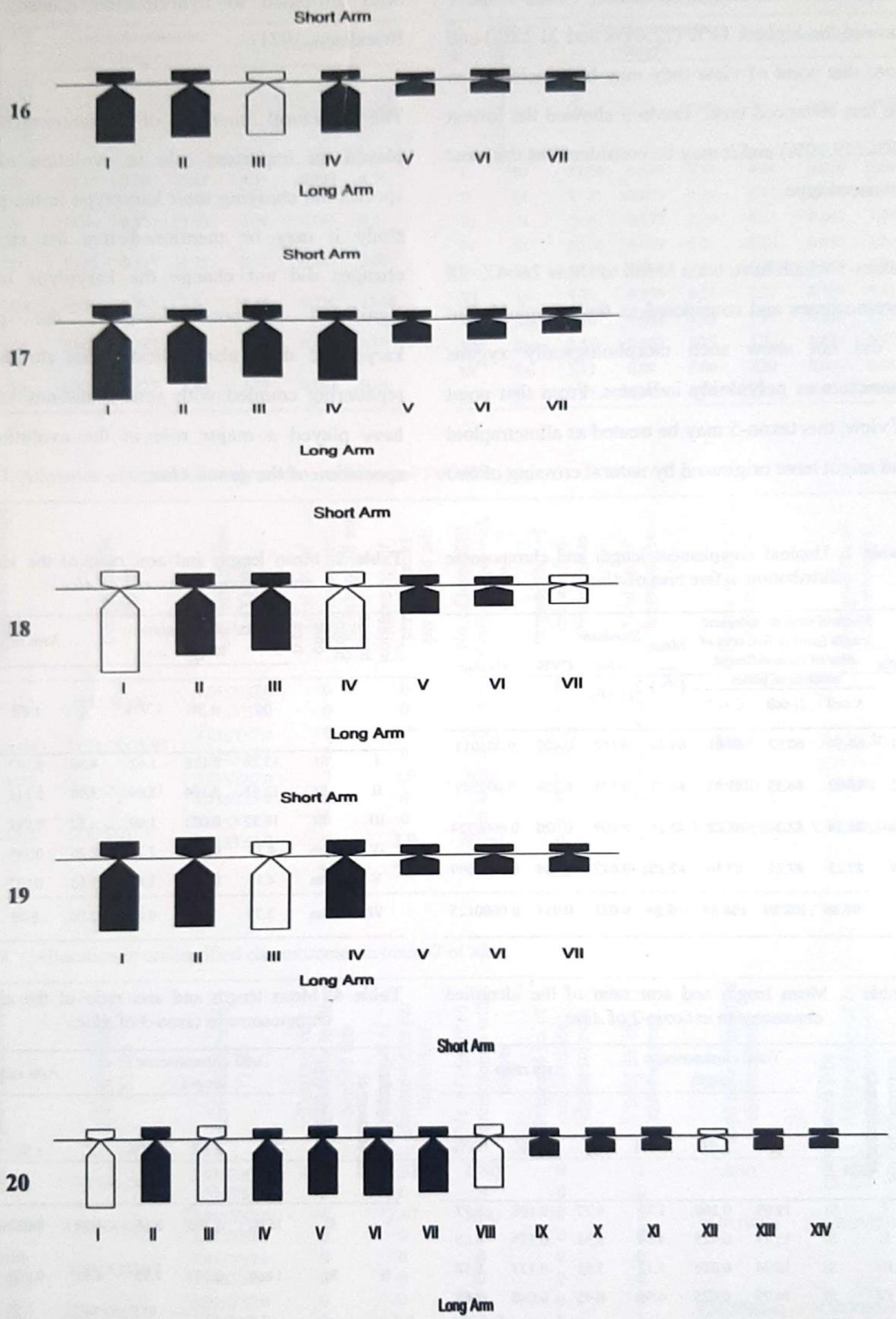


14



15

Figures 11-15: Combined scatter diagram of the 14 (fourteen) haploid chromosome values from each of the three cells of *Aloe*. (Group boundaries drawn around those chromosomes were recognizably homologous from each of three cells. 11. Taxon-1, 12. Taxon-2, 13. Taxon-3, 14. Taxon-4 and 15. Taxon-5).



Figures 16-20: Ideograms of identified chromosomes in taxon-1 (16), taxon-2 (17), taxon-3 (18), taxon-4 (19) and taxon-5 (20) of Aloe.

On the other hand, TF% is considered for indicating the primitive and advanced nature. Taxon-4 and 1 showed the highest TF% (22.64% and 21.28%) and from this point of view they may be considered as the less advanced type. Taxon-5 showed the lowest TF% (19.20%) and it may be considered as the most advanced type.

Taxon-5 which have been found to show 2n=4X=28 chromosomes and considered as the tetraploid. But it did not show such morphologically zygous characters as polyploidy indicates. From that point of view, this taxon-5 may be treated as allotetraploid and might have originated by natural crossing of two or more *Aloe* species. Polyploidy in the *Aloe* has been attributed to hybridization (Snoad, 1951; Brandham, 1971).

The structural changes of chromosomes have played an important role in evolution of *Aloe* species but studying their karyotype in the present study it may be mentioned that the structural changes did not change the karyotype in such significant manner. However, the present karyotypic study also indicates that chromosome repattering coupled with gene mutations and that have played a major role in the evolution and speciation of the genus *Aloe*.

Table 1. Haploid complement length and chromosome distribution in five taxa of *Aloe*.

Taxa	Haploid total complement length (μm) in five taxa of *Aloe* of three different metaphase plates			Mean ($\overline{X}$)	Standard error (± SE)	CV%	x^2 value
	A cell	B cell	C cell				
1	60.54	60.52	60.01	60.36	0.142	0.406	0.001014
2	84.02	84.35	83.83	84.07	0.124	0.256	0.000549
3	82.24	82.26	82.22	82.24	0.009	0.020	0.0000324
4	87.23	87.21	87.16	87.20	0.017	0.034	0.0000099
5	108.80	108.89	108.84	108.84	0.021	0.034	0.0000125

Table 2. Mean length and arm ratio of the identified chromosome in taxon-1 of *Aloe*.

lentifie hromo	hromo ome type	Total chromosome length			Arm ratio		
		$\overline{X}$	± SE	CV%	$\overline{X}$	± SE	CV%
I	St	13.28	0.128	1.67	4.56	0.147	5.58
II	St	12.51	0.194	2.69	3.90	0.111	4.03
III	St	11.57	0.073	1.09	4.82	0.091	3.30
IV	Sm	4.23	0.066	2.72	2.26	0.149	11.40
V	Sm	4.11	0.043	1.84	1.63	0.027	2.89
VI	Sm	3.75	0.00	0.00	2.00	0.00	0.00

Table 3. Mean length and arm ratio of the identified chromosome in taxon-2 of *Aloe*.

No. of identified chromosomes	Chromosome type	Total chromosome length			Arm ratio		
		$\overline{X}$	± SE	CV%	$\overline{X}$	± SE	CV%
I	St	19.89	0.160	1.39	4.79	0.108	3.77
II	St	15.84	0.425	4.64	5.34	0.174	5.65
III	St	15.34	0.010	1.12	3.61	0.137	6.58
IV	St	14.75	0.425	4.99	6.45	0.098	2.63
V	Sm	6.74	0.146	3.76	2.48	0.105	7.30
VI	Sm	6.37	0.083	2.26	2.13	0.079	6.45
VII	Sm	5.11	0.332	11.29	1.98	0.641	5.60

Table 4. Mean length and arm ratio of the identified chromosome in taxon-3 of *Aloe*.

No. of identified chromosomes	Chromosome type	Total chromosome length			Arm ratio		
		$\overline{X}$	± SE	CV%	$\overline{X}$	± SE	CV%
I	St	16.07	0.246	2.66	4.94	0.087	3.06
II	St	14.67	0.163	1.92	4.53	0.090	3.43
III	Sm	7.30	0.343	8.14	2.59	0.054	3.64
IV	Sm	5.36	0.040	1.32	2.43	0.027	1.94

Table 5. Mean length and arm ratio of the identified chromosome in taxon-4 of *Aloe*.

No. of identified chromosomes	Chromosome type	Total chromosome length			Arm ratio		
		$\overline{X}$	± SE	CV%	$\overline{X}$	± SE	CV%
I	St	18.17	0.365	3.48	4.16	0.167	6.96
II	St	18.06	0.120	1.15	3.30	0.085	4.51
III	St	15.89	0.113	1.23	3.92	0.083	3.66
IV	Sm	5.95	0.263	7.67	1.85	0.130	12.18
V	Sm	5.80	0.287	8.58	2.31	0.015	8.69
VI	Sm	5.47	0.123	3.92	1.99	0.003	0.24

Table 6. Mean length and arm ratio of the identified chromosome in taxon-5 of *Aloe*.

lentifi d hromc	hrom some type	Total chromosome length			Arm ratio		
		$\overline{X}$	± SE	CV%	$\overline{X}$	± SE	CV%
I	St	11.76	0.349	5.14	4.94	0.076	2.64
II	St	11.25	0.075	1.16	6.21	0.047	1.31
III	St	10.63	0.073	1.20	4.65	0.040	1.49
IV	St	10.50	0.079	1.31	5.73	0.050	1.51
V	St	10.10	0.084	1.45	5.48	0.054	1.72
VI	Sm	4.21	0.159	6.56	2.37	0.128	9.35
VII	Sm	3.70	0.038	1.78	1.96	0.030	2.65
VIII	Sm	3.55	0.087	4.25	1.72	0.024	2.47
IX	Sm	3.13	0.00	0.00	2.33	0.00	0.00
X	Sm	2.82	0.00	0.00	2.00	0.00	0.00

Table 7. Allocation of unidentified chromosomes in taxon- 1 of *Aloe*.

Types of chromosome	Length classes (X) µm	Arm ratio classes (Y) µm	Total no. of chromosomes in three haploid sets	Mean no. of chromosomes per haploid set	No. of identified chromosomes with names	Proposed no. of unidentified chromosomes	Total no. of chromosomes	Paired no. of identified chromosomes	Assigned no. of chromosomes
Large (L)	$15.96 \le X$	$3.01 \le Y \le 7.0$	0	0	0	0	0		
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Medium (M)	$11.58 \le X \le 15.95$	$3.01 \le Y \le 7.0$	9	3.0	2(St)	1(St)	3	I,II(St)	I,II,III(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Relatively short (S_1)	$7.20 \le X \le 11.57$	$3.01 \le Y \le 7.0$	3	1.0	1(St)	0	1	IV(St)	IV(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Short (S_2)	$2.81 \le X \le 7.19$	$3.01 \le Y \le 7.0$	0	0	0	0	0	V,VI,VII(Sm)	V,VI,VII(Sm)
		$1.51 \le Y \le 3.0$	9	3.0	3(Sm)	0	3		
			21	7.0	6.0	1.0	7.0		

Table 8. Allocation of unidentified chromosomes in taxon-2 of *Aloe*.

Types of chromosome	Length classes (X) µm	Arm ratio classes (Y) µm	Total no. of chromosomes in three haploid sets	Mean no. of chromosomes per haploid set	No. of identified chromosomes with names	Proposed no. of unidentified chromosomes	Total no. of chromosomes	Paired no. of identified chromosomes	Assigned no. of chromosomes
Large (L)	$15.96 \le X$	$3.01 \le Y \le 7.0$	4	1.33	1(St)	0	1	I(St)	I(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Medium (M)	$11.58 \le X \le 15.95$	$3.01 \le Y \le 7.0$	8	2.67	3(St)	0	3	II,III,IV(St)	II,III,IV(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Relatively short (S_1)	$7.20 \le X \le 11.57$	$3.01 \le Y \le 7.0$	0	0	0	0	0		
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Short (S_2)	$2.81 \le X \le 7.19$	$3.01 \le Y \le 7.0$	0	0	0	0	0	V,VI,VII(Sm)	V,VI,VII(Sm)
		$1.51 \le Y \le 3.0$	9	3.0	3(Sm)	0	3		
			21	7.0	7.0	0	7.0		

Table 9. Allocation of unidentified chromosomes in taxon-3 of *Aloe*.

Types of chromosome	Length classes (X) µm	Arm ratio classes (Y) µm	Total no. of chromosomes in three haploid sets	Mean no. of chromosomes per haploid set	No. of identified chromosomes with names	Proposed no. of unidentified chromosomes	Total no. of chromosomes	Paired no. of identified chromosomes	Assigned no. of chromosomes
Large (L)	$15.96 \le X$	$3.01 \le Y \le 7.0$	6	2	1(St)	1(St)	2	II(St)	I,II(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Medium (M)	$11.58 \le X \le 15.95$	$3.01 \le Y \le 7.0$	6	2	1(St)	1(St)	2	III(St)	III,IV(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Relatively short (S_1)	$7.20 \le X \le 11.57$	$3.01 \le Y \le 7.0$	0	0	0	0	0	V(Sm)	V(Sm)
		$1.51 \le Y \le 3.0$	1	0.33	1(Sm)	0	1		
Short (S_2)	$2.81 \le X \le 7.19$	$3.01 \le Y \le 7.0$	0	0	0	0	0	VI(Sm)	VI,VII(Sm)
		$1.51 \le Y \le 3.0$	8	2.67	1(Sm)	1(Sm)	2		
			21	7.0	4.0	3.0	7.0		

Table 10. Allocation of unidentified chromosomes in taxon-4 of *Aloe*.

Types of chromosome	Length classes (X) µm	Arm ratio classes (Y) µm	Total no. of chromosomes in three haploid sets	Mean no. of chromosomes per haploid set	No. of identified chromosomes with names	Proposed no. of unidentified chromosomes	Total no. of chromosomes	Paired no. of identified chromosomes	Assigned no. of chromosomes
Large (L)	$15.96 \le X$	$3.01 \le Y \le 7.0$	10	3.00	2(St)	1(St)	3	I,II(St)	I,II,III(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Medium (M)	$11.58 \le X \le 15.95$	$3.01 \le Y \le 7.0$	2	0.67	1(St)	0	1	IV(St)	IV(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Relatively short (S_1)	$7.20 \le X \le 11.57$	$3.01 \le Y \le 7.0$	0	0	0	0	0		
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Short (S_2)	$2.81 \le X \le 7.19$	$3.01 \le Y \le 7.0$	0	0	0	0	0	V,VI,VII(Sm)	V,VI,VII(Sm)
		$1.51 \le Y \le 3.0$	9	3	3(Sm)	0	1		
			21	7.0	6.0	1.0	7.0		

Table 11. Allocation of unidentified chromosomes in taxon-5 of *Aloe*.

Types of chromosome	Length classes (X) µm	Arm ratio classes (Y) µm	Total no. of chromosomes in three haploid sets	Mean no. of chromosomes per haploid set	No. of identified chromosomes with names	Proposed no. of unidentified chromosomes	Total no. of chromosomes	Paired no. of identified chromosomes	Assigned no. of chromosomes
Large (L)	$15.96 \le X$	$3.01 \le Y \le 7.0$	0	0	0	0	0		
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Medium (M)	$11.58 \le X \le 15.95$	$3.01 \le Y \le 7.0$	10	3.00	1(St)	2(St)	3	II(St)	I,II,III(St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Relatively short (S_1)	$7.20 \le X \le 11.57$	$3.01 \le Y \le 7.0$	14	4.67	4(St)	1(St)	5	IV,V,VI,VII (St)	IV,V,VI,VII,VIII (St)
		$1.51 \le Y \le 3.0$	0	0	0	0	0		
Short (S_2)	$2.81 \le X \le 7.19$	$3.01 \le Y \le 7.0$	0	0	0	0	0	IX,X,XI,XIII,XIV(Sm)	IX,X,XI,XII, XIII,XIV(Sm)
		$1.51 \le Y \le 3.0$	18	6	5(Sm)	1(Sm)	6		
			42	14.0	10.0	4.0	14		

Table 12. Analysis of length, arm ratio, relative length, TCL%, TF%, centromeric position and chromosome type in five taxa of *Aloe*.

Taxa	Characters	I	II	III	IV	V	VI	VII
Taxon-1 TF% = 21.28%, Total chromatin =61.08	Long arm length (µm)	10.89	9.95	9.69	9.58	2.93	2.55	2.50
	Short arm length (µm)	2.40	2.56	1.94	1.99	1.30	1.56	1.25
	Total arm length (µm)	13.28	12.51	11.63	11.57	4.23	4.11	3.75
	Arm ratio	4.56	3.90	5.01	4.82	2.26	1.63	2.00
	Relative chromosome length (µm)	100.00	94.20	87.58	87.12	31.85	30.95	28.24
	TCL%	21.74	20.48	19.04	18.94	6.93	6.73	6.14
	Centromeric position	St	St	St	St	Sm	Sm	Sm
	Chromo-some type	M	M	M	S_1	S_2	S_2	S_2
Taxon-2 TF% = 20.30%, Total chromatin = 83.04	Long arm length (µm)	16.55	13.34	12.01	12.77	4.80	4.33	3.39
	Short arm length (µm)	3.34	2.50	3.34	1.98	1.94	2.04	1.72
	Total arm length (µm)	18.89	15.84	15.34	14.75	6.74	6.37	5.11
	Arm ratio	4.97	5.34	3.61	6.45	2.48	2.13	1.98
	Relative chromosome length (µm)	100.00	83.85	81.21	78.08	35.68	33.72	27.05
	TCL%	22.75	19.08	18.47	17.76	8.12	7.67	6.15
	Centromeric position	St	St	St	St	Sm	Sm	Sm
	Chromo-some type	L	M	M	M	S_2	S_2	S_2
Taxon-3 TF% = 20.21%, Total chromatin =82.05	Long arm length (µm)	15.60	12.70	12.01	11.80	5.26	3.80	3.65
	Short arm length (µm)	3.23	2.71	2.66	2.71	2.04	1.56	1.67
	Total arm length (µm)	18.83	16.07	14.67	14.51	7.30	5.36	5.31
	Arm ratio	5.00	4.94	4.53	4.43	2.59	2.43	2.29
	Relative chromosome length (µm)	100.00	85.34	77.91	77.06	38.77	28.41	28.20
	TCL%	22.95	19.59	17.89	17.68	8.90	6.86	6.47
	Centromeric position	St	St	St	St	Sm	Sm	Sm
	Chromo-some type	L	L	M	M	S_1	S_2	S_2
Taxon-4 TF% = 22.64%, Total chromatin = 87.23	Long arm length (µm)	14.63	13.85	14.79	12.66	3.86	4.05	3.65
	Short arm length (µm)	3.54	4.21	3.10	3.23	2.09	1.75	1.83
	Total arm length (µm)	18.17	18.06	17.89	15.89	5.95	5.80	5.47
	Arm ratio	4.16	3.30	4.80	3.92	1.85	2.31	1.99
	Relative chromosome length (µm)	100.00	99.39	98.46	87.45	32.75	31.92	30.10
	TCL%	20.83	20.70	20.50	18.22	6.82	6.65	6.27
	Centromeric position	St	St	St	St	Sm	Sm	Sm
	Chromo-some type	L	L	L	M	S_2	S_2	S_2

Continued Table 12.

Taxa	Characters	I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII	XIII	XIV
Taxon-5 TF% = 19.20%, Total chromatin =108.81	Long arm length (μm)	10.62	9.78	9.66	9.69	8.75	8.94	8.54	7.78	2.96	2.45	2.24	2.43	2.19	1.88
	Short arm length (μm)	1.67	1.98	2.08	1.56	1.88	1.56	1.56	1.88	1.25	1.25	1.30	1.04	0.94	0.94
	Total arm length (μm)	12.29	11.76	11.74	11.25	10.63	10.50	10.10	9.66	4.21	3.70	3.55	3.47	3.13	2.82
	Arm ratio	6.38	4.94	4.72	6.21	4.65	5.73	5.48	4.17	2.37	1.96	1.72	2.38	2.33	2.00
	Relative chromosome length (μm)	100.00	95.67	95.52	91.54	86.49	85.44	82.18	78.60	34.26	29.29	28.89	28.23	25.47	22.95
	TCL%	11.29	10.81	10.79	10.34	9.77	9.65	9.38	8.88	3.87	3.40	3.26	3.19	2.88	2.59
	Centromeric position	St	St	St	St	St	St	St	St	Sm	Sm	Sm	Sm	Sm	Sm
	Chromo-some type	M	M	M	S_1	S_1	S_1	S_1	S_1	S_2	S_2	S_2	S_2	S_2	S_2

Table 13. Proposed standard karyotypic formula in five taxa of *Aloe*.

Name of the taxa	Total no. of haploid set	Total no. of identified chromosome per haploid set	Total no. of unidentified chromosome per haploid set	Chromosome types				Proposed standard karyopype of total haploid set	Proposed karyotypic formula
				L	M	S_1	S_2		
Taxon-1	n=7	6	1	0	3	1	3	3Sm+4St	$3M^{3St}+1S_1^{1St}+3S_23^{Sm}$
Taxon -2	n=7	7	0	1	3	0	3	3Sm+4St	$1L^{1St}+3M^{3St}+3S_2^{3Sm}$
Taxon -3	n=7	4	3	2	2	1	2	3Sm+4St	$2L^{2St}+2M^{2St}+1S_1^{1Sm}+2S_2^{2Sm}$
Taxon -4	n=7	6	1	3	1	0	3	3Sm+4St	$3L^{3St}+1M^{1St}+3S_2^{3Sm}$
Taxon -5	n=14	10	4	0	3	5	6	6Sm+8St	$3M^{3St}+5S_1^{5St}+6S_2^{6Sm}$

REFERENCES

Ahmad, Q.N., E.J. Britten and D.E. Byth. 1983. A quantitative method of karyotypic analysis applied to the soyabean (*Glycine max*). Cytologia. 48:879-892.

Bhatt, R.P. and A. Dasgupta. 1976. Cytotaxonomy of Malvaceae. I. Chromosome number and karyotype analysis of *Hibiscus*, *Azanza*, and *Urena*. Cytologia. 41:207-217.

Brandham, P.E. 1971. The chromosomes of the Liliaceae:II. Polyploidy and karyotype variation in the Aloineae. Vew Bull. 25(3):381-389.

Brandham, P.E. 1974. Interchange and inversion polymorphism among populations of *Haworthia reinwardtii* var. chalumnesis. Chromosoma. 47:85-108.

Brandham, P.E. 1976. The frequency of spontaneous structural change. In: current chromosome research (Jones, K. and P.E. Brandham, eds.) PP. 77-87. Amsterdam.

Brandham, P.E. 1983. Evolution in a stable chromosome system. In: Brandham, P.E. Bennett M.D. eds. Kew Chromosome Conference II. London: George Allen and Unwin, 251-260.

Feden, R.B. 1980. Cytotaxonomy of Commelinaceae chromosome numbers of some African and Asian species. Bot. J. Linn. Soc. 81:301-325.

Fedorov, A. 1969. Chromosome numbers of flowering plants. Acadamy of Seiences of the U.S.S.R. VL. Komarov Botanical Institute, Leningrad.

Huziwara, Y. 1962. Karyotype analysis in some genera of compositae VIII. Further studies on the chromosome of Aster. Amer. J. Bot. 49:116-119.

Kutarekar, D.R. and K.B. Wanjari. 1983. Karyomorphological studies in some varieties of Bengal gram (*Cicer arietinum*). Cyologia. 45:699-705.

Lavan, A., K. Fredga and A.A. Sandberg. 1964. Nomenclature for centromeric position on chromosomes. Hereditas. 52:201-220.

Marshak, A. 1934. Chromosomes and compatibility in the Aloinae. Amer. J. Bot. 21:592-597.

Mehra, P.N. and S.P.Choda. 1978. Cytotaxonomic studies in the genus *Euphorbia* L. Cytologia. 43:217-235.

Moore, R.J. 1973. Index of plant chromosome numbers. Central Expt. Farm. Ottawa, Canada.

Rhoades, M.M. 1955. The cytogenetics of maize. In : Corn and Corn improvement. G.F. Spragve (Ed.), Academic Press, NewYork. Cytologia. 49:123-219.

Riley, H.P. and S.K. Majumdar. 1979. The Aloinae. A biosystematic survey. The University Press, Kentuchy.

Sapre, A. 1978. Karyotype of *Aloe barbadensis* Mill. A reinvestigation. Cytologia. 43:237-241.

Sato, D. 1937. Karyotype alternation and phylogeny. I. Analysis of karyotypes in Aloineae with special referance to the SAT-chromosome. Cytologia. Fujii Jub. 80:95.

Sato, D. 1942. Karyotype alternation and phylogeny in Liliaceae and allied families. Jap. J. Bot. 12:57-161.

Sindhu, J.S., A.E. Slinkard and G.J. Scoles. 1982. Karyotype analysis of *Lens orientales*. (Boiss). Hadle-Mazryyi. Cytologia. 49:151-155.

Snoad, B. 1951. Chromosome numbers of succulent plants. Heredity. 5:279-283.

Stebbins, G.L. 1950. Variation and evolution in plants. Columbia University Press. New York. Chapter VI : Isolation and the origin of species. PP. 189-250.

Vij, S.P., M. Sharma and I.S. Toor. 1980. Cytological investigations into some garden ornamentals II. The genus *Aloe* L. Cytologia. 45:515-532.

Wilson, G.B. and J.H. Morrison. 1973. Affiliated East-West Press Pvt. Led. New Delhi. Cytologia. pp. 1-319.