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A System of Chromosome Classification and Nomenclature[1]

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Chromosome morphology is usually studied on the basis of the position of the primary constriction (or centromere or kinetochore), which is a principal landmark in contracted metaphase chromosomes. Cytologists have adopted several methods to determine the centromere locations and described the chromosomes as telocentric (centromere at one end of the chromosome), acrocentric (centromere near one end of the chromosome), submetacentric (centromere nearer to one end of the chromosome than the other) and metacentric (centromere at or near the middle of the chromosome). These four categories are not sharply distinct, but grade imperceptibly into each other (Stebbins 1971). The chromosomes are also described as median, nearly median, nearly submedian, submedian, nearly subterminal, subterminal, nearly terminal and terminal (Sharma and Sharma 1960, Sharma and Choudhury 1964, Adhikary 1963, 1974, Bose and Flory 1965). Thus there exists a great deal of confusion in describing a chromosome on the basis of centromere position.

Levan *et al.* (1964) recognised the location of centromere in median point (M), median region (m), submedian region (sm), subterminal region (st), terminal region (t) and terminal point (T). However, this system did not give due consideration to a number of oftquoted nomenclatures of centromere locations like nearly submedian and nearly subterminal. The system of Levan *et al.* (1964) was based on a) difference (d) between long arm (l) and short arm (s), where the whole chromosome =10 units; b) arm ratio (r) as the ratio of short arm/long arm; and c) centromeric index (i) as 100 s/c in the different regions, where c is the total length of the chromosome. Nevertheless, this system gave biased preference to the short arm of the chromosome in determining the arm ratio and the centromeric index. The criterion of difference (d) between long arm (l) and short arm (s) is not always helpful as evident from our study of karyotypes of *Aloe barbadensis* and *Furcraea gigantea* (Abraham and Nagendra Prasad 1979, 1980).

Recently, Adhikary (1974) proposed a system incorporating all the possible and up-to-date usage of centromere locations with reference to intermediate regions between terminal and median points. He recognised 4 fixed points and 4 intermediate regions. The fixed points were median (M), terminal (T), submedian (SM) and subterminal (ST). The intermediate regions were nearly median (nm), nearly terminal (nt), nearly submedian (nsm) and nearly subterminal (nst). This system was based on arm ratios, R_1 (short arm/long arm) and R_2 (long arm/short arm).

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Thus the arm ratios from both the arms were given equal importance.

A modification of these two systems is proposed here incorporating all the data from arm ratios and centromeric indices without particular preference to any arm. Four fixed points and six intermediate regions are recognised in each chromosome segment. Terminal (T) is the fixed point at one extreme end of a chromosome. The median (M), another fixed point, is exactly at the middle point of a chromosome. The exact middle point between these two points is designated as the submedian (SM) fixed point. Similarly, the exact fixed point between submedian and terminal points is termed the subterminal (ST) fixed point. Each chromosome segment between these four fixed points is again divisible into two equal halves to get four intermediate regions, namely, nearly median (nm), nearly submedian (nsm), nearly subterminal (nst) and nearly terminal (nt). Among the intermediate regions, nearly subterminal and nearly submedian, two subunits are recognised. Those towards the terminal point (T) are designated as nst (+) and nsm (+) and those away from the terminal point are designated as nst (−) and nsm (−) inorder to distinguish those regions lying on either side of the fixed points ST and SM. Thus 10 positions are recognised, of which 4 are fixed points and 6 are definite regions in between these points. This is against 2 fixed points and 2 regions recognised by Huziwara (1958), 2 fixed points and 4 regions by Levan *et al.* (1964) and 4 fixed points and 4 intermediate regions by Adhikary (1974). This kind of proportionate representation is free from bias. The limitations of all the intermediate regions are shown in Fig. 1. The details of chromosome nomenclature in relation to centromere location based on this system are presented in Table 1.

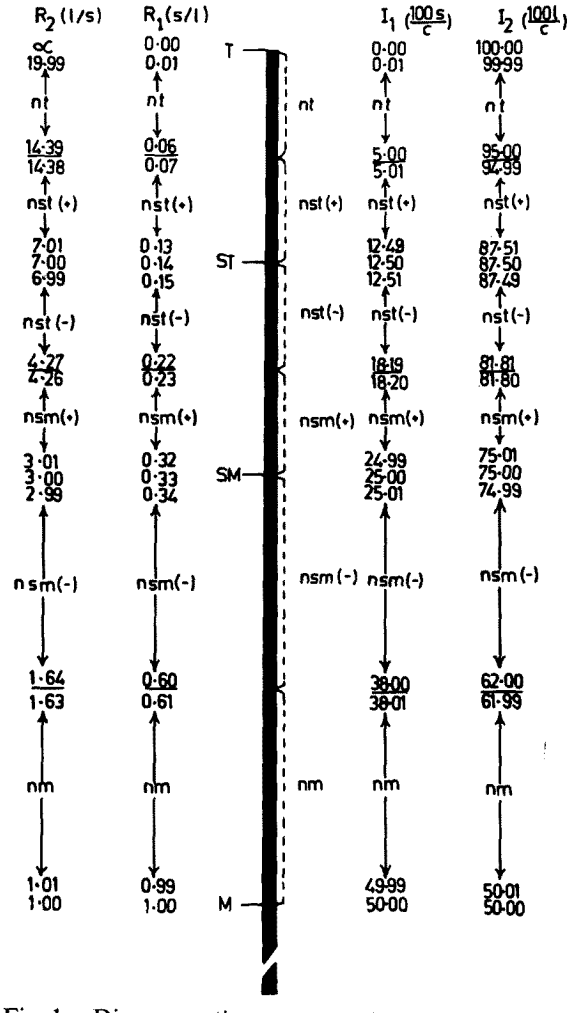

Fig. 1. Diagrammatic representation of relative positions of fixed points and limitations of all the intermediate regions.

After determining the mean length of all the chromosomes in a complement of any material from a number of good plates, the centromere location may be determined precisely in relation to the ratio of short/long arm (R_1) and long arm/short

arm (R_2); and the centromeric index from 100 s/c (I_1) and 100 l/s (I_2) of each chromosome as shown in Table 1.

In the present system due recognition is given to as many criteria as possible for the classification. In addition, this system recognises all the known centromeric locations so far described by cytologists. Also, it maintains the self explanatory terms for nomenclature of chromosomes. This system not only incorporates both the arm ratios and centromeric indices of both arms but also aid in tracing even minor differences in chromosome morphology. Thus according to this system the chromosomes can be termed effectively.

Table 1. Details of chromosome nomenclature in relation to centromere location based on arm ratios and centromeric indices

Nomenclature	Notation	R_1 s/l	R_2 l/s	I_1 100 s/c	I_2 100 l/c
Median	M	1.00	1.00	50.00	50.00
Nearly median	nm	0.99 to 0.61	1.01 to 1.63	49.99 to 38.01	50.01 to 61.99
Nearly submedian	nsm (−)	0.60 to 0.34	1.64 to 2.99	38.00 to 25.01	62.00 to 74.99
Submedian	SM	0.33	3.00	25.00	75.00
Nearly submedian	nsm (+)	0.32 to 0.23	3.01 to 4.26	24.99 to 18.20	75.01 to 81.80
Nearly subterminal	nst (−)	0.22 to 0.15	4.27 to 6.99	18.19 to 12.51	81.81 to 87.49
Subterminal	ST	0.14	7.00	12.50	87.50
Nearly subterminal	nst (+)	0.13 to 0.07	7.01 to 14.38	12.49 to 5.01	87.51 to 94.99
Nearly terminal	nt	0.06 to 0.01	14.39 to 19.99	5.00 to 0.01	95.00 to 99.99
Terminal	T	0.00	∞	0.00	100.00

This system is successfully used in determining the chromosome nomenclature of *A. barbadensis* and *F. gigantea* (Abraham and Nagendra Prasad 1979, 1980). Measurements and nomenclature of somatic chromosomes of these plants are given in Tables 2–4. Besides these, this system was effectively employed in determining the chromosome nomenclature of *Clematis grata* and *Lilium neilgherrense* (Abraham 1980).

Table 2. Measurements of somatic chromosomes of diploid *A. barbadensis* at metaphase

Chromosome type	Chromosome number	Long arm (l) in μm	Short arm (s) in μm	Total length (c) in μm	Arm ratio		Centromeric index		Chromosome	
					s/l (R_1)	l/s (R_2)	$\frac{100\ s}{c}$ (I_1)	$\frac{100\ s}{c}$ (I_2)	notation	nomenclature
A	1, 2	9.67	3.67	13.34	0.38	2.63	27.51	72.48	nsm(−)	Nearly submedian(−)
B	3, 4	9.33	2.67	12.00	0.29	3.49	22.25	77.75	nsm(+)	Nearly submedian(+)
C	5, 6	9.00	2.67	11.67	0.30	3.37	22.88	77.12	nsm(+)	Nearly submedian(+)
D	7, 8	9.33	2.00	11.33	0.21	4.67	17.65	82.35	nst(−)	Nearly subterminal(−)
E	9, 10	3.00	1.67	4.67	0.56	1.80	35.76	64.24	nsm(−)	Nearly submedian(−)
F	11–14	2.67	1.67	4.34	0.63	1.60	38.48	61.52	nm	Nearly median

Table 3. Measurements of somatic chromosomes of triploid *A. barbadensis* at metaphase

Chromosome type	Chromosome number	Long arm (l) in μm	Short arm (s) in μm	Total length (c) in μm	Arm ratio		Centromeric index		Chromosome	
					s/l (R_1)	l/s (R_2)	$\frac{100\ s}{c}$ (I_1)	$\frac{100\ l}{c}$ (I_2)	notation	nomenclature
A	1– 3	11.00	2.33	13.33	0.21	4.73	17.48	82.52	nst(−)	Nearly subterminal(−)
B	4– 6	11.00	1.67	12.67	0.15	6.59	13.18	86.82	nst(−)	Nearly subterminal(−)
C	7– 9	9.67	2.33	12.00	0.24	4.15	19.42	80.58	nsm(+)	Nearly submedian(+)
D	10–12	8.67	1.67	10.34	0.19	5.19	16.15	83.85	nst(−)	Nearly subterminal(−)
E	13–15	2.67	1.33	4.00	0.49	2.00	33.25	66.75	nsm(−)	Nearly submedian(−)
F	16–21	2.33	1.00	3.33	0.43	2.33	30.03	69.91	nsm(−)	Nearly submedian(−)

Table 4. Measurements of somatic chromosomes of *F. gigantea* at metaphase

Chromosome type	Chromosome number	Long arm (l) in μm	Short arm (s) in μm	Total length (c) in μm	Arm ratio		Centromeric index		Chromosome	
					s/l (R_1)	l/s (R_2)	$\frac{100\ s}{c}$ (I_1)	$\frac{100\ l}{c}$ (I_2)	notation	nomenclature
A	1– 4	5.34	1.33	6.67	0.25	4.02	19.94	80.12	nsm(+)	Nearly submedian(+)
B	5– 6	5.67	0.67	6.34	0.12	8.32	10.57	89.43	nst(+)	Nearly subterminal(+)
C	7, 8	5.00	1.00	6.00	0.20	5.00	16.67	83.33	nst(−)	Nearly subterminal(−)
D	9, 10	5.00	0.67	5.67	0.13	7.46	11.82	88.18	nst(+)	Nearly subterminal(+)
E	11, 12	3.33	1.00	4.33	0.30	3.33	23.09	76.21	nsm(+)	Nearly submedian(+)
F	13, 14	1.67	1.67	3.34	1.00	1.00	50.00	50.00	M	Median
G	15–20	1.33	1.33	2.66	1.00	1.00	50.00	50.00	M	Median
H	21–24	1.33	1.00	2.33	0.77	1.33	42.91	57.08	nm	Nearly median
I	25–28	0.83	0.83	1.66	1.00	1.00	50.00	50.00	M	Median
J	29–34	0.66	0.66	1.32	1.00	1.00	50.00	50.00	M	Median

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Abstract

A system of chromosome classification and nomenclature based on arm ratios and centromeric indices from both the long and short arms is proposed. This will enable one to determine the correct position of centromere to name the chromosomes according to the known centromere locations. A table embodying nomenclature, notation, the arm ratio values and the values of centromeric indices is presented to serve as a key for chromosome classification. The advantage of the present system over the other systems is discussed with the help of a few examples.

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