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Table 2: *Chromosome configuration in* Crotalaria incana

Coll. no.	I	II	III	IV	No. of cells	% of total cells
147	—	5	—	1	17	6·32
147	—	3	—	2	10	3·72
147	2	4	—	1	03	1·11
147	2	6	—	—	02	0·74
147	—	7	—	—	237	88·11
Average	·037	6·68	—	·15		
103-b	—	4	2	—	03	3·33
103-b	—	5	—	1	08	8·89
103-b	—	7	—	—	79	87·78
Average	—	6·72	·067	·089		

submedian centromeres are found in both. But a pair of chromosomes with median centromere found in *C. mucronata* is not seen in *C. incana* (fig 5). The loss of this pair of chromosomes in *C. incana* may be due to translocation of chromatin material to the other chromosomes with submedian centromere. There is not also much difference in the absolute length of chromosomes in both the species (table 1). Translocation is further evidenced by the formation of multivalents in *C. incana* (figs 7-9) whereas in *C. mucronata* this is not observed. Such a type of descending aneuploidy with reciprocal translocation has been demonstrated in *Crepis* (Tobgy 1943) and in *Haplopappus* (Jackson 1965).

Stebbins (1950) is of the opinion that the reduction in basic number often involves rearrangements of chromosomes. This process is very clearly seen in other collections of *C. incana* (coll. no: 147 and 103-*a*, figs 1-2, table 1), wherein modification of karyotype is noticed (i.e. $S''_2 + S_2 + J_{10}$ to $S''_4 + J_{10}$ to $S''_2 + J_{12}$. This descending aneuploidy and specialization in karyotype are accompanied by morphological specializations like annual nature of plants, reduction in size of leaflets, pubescent nature of plants, small flowers, few flowered racemes, reduction in size of pod and fewer seeds in *C. incana* as compared to *C. mucronata*.

The variation of karyotypes within a species (*C. incana*) is in accordance with morphological specialization. Such karyotypic variations at species level are of significant value from the speciation point of view. Stebbins (1958) and Clausen (1951) are of the opinion that these variations are due to high chromosomal repatterning and may be the initial step in speciation. The existence of laggards, late disjunction of bivalents and univalent in case of *C. incana* points towards the existence of gross structural differences among the genomes involved.

Further, *C. incana* having morphological specialization with increase in chromosome size exhibits the end point of increased size. Such cases are also observed in other members of Leguminosae (Senn 1938*b*). From the present study of karyomorphology it can be concluded that *C. incana* is more advanced than *C. mucronata*.

Summary

Cytology of *C. incana* and *C. mucronata* has been studied with a view to explain the origin of 2n=14 in *C. incana* from *C. mucronata* (2n=16) on the basis of translocation. Both show close similarity in their morphology and karyotypes.

Different types of karyotypes are seen in different collections of *C. incana*, like $S''_4 + J_{10}$; $S''_2 + J_{12}$ and $S''_2 + S_2 + J_{10}$ but the different collections of *C. mucronata* have only one type of karyotype i.e. $S''_2 + S'_2 + V_2 + J_{10}$. The karyotype ($S''_2 + S'_2 + V_2 + J_{10}$) of *C. mucronata* has possibly given rise to karyotype ($S''_2 + S_2 + J_{10}$) of *C. incana* as a result of translocation.

The repatterning of karyotype has resulted in cytotypes with increased morphological specializations in *C. incana*, an initial step towards speciation.

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KARYOTYPE STUDIES IN *ARECA CATECHU* L., *A. TRIANDRA* ROXB. AND *A. CATECHU* X *A. TRIANDRA* HYBRIDS

K. V. A. Bavappa, M. K. Nair[1] and M. J. Ratnambal[2]

Central Plantation Crops Research Institute, Kasaragod-670 124, India

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In the family Palmae, the first large scale attempt at using the cytological information such as chromosome number, size and morphology as an aid in the classification was made by Sharma and Sarkar (1956). They observed gross differences between the karyotypes of *Areca catechu* L. and *A. triandra* Roxb. and suggested separate generic status for the two species and emphasised the need for a thorough study of the morphological and anatomical characters of the various species of *Areca*. The chromosome morphology of a few cultivars of *A. catechu* from Assam was reported by Raghavan (1957) and that of an ecotype of *A. catechu* from South Kanara was studied by Bavappa (1963). Studies on the karyomorphological difference in eight cultivars of *A. catechu*, four ecotypes of *A. triandra* and their hybrids are presented in this paper.

Materials and Methods

Chromosome morphology was studied from the root tip squashes following the method developed by Jagathesan and Ratnambal (1967). Average values for 5 cells were arrived at for the chromosome length and arm ratio (long/short). Chromosomes were paired and numbered according to the order of descending length. They were classified as median (long arm/short arm=1·00 to 1·33) sub-median (long arm/short arm=1·34 to 1·66) and subterminal (long arm/short arm=1·67 and above) based on their arm ratio. Chromosomes falling within the same length were arranged in the decreasing order of arm indices, the end of long arm always directing downwards (Heneen, 1962).

Results

The 2n chromosome number of *A. catechu*, *A. triandra* and their hybrids was found to be 32. The total chromatin length, range of absolute length of individual chromo-

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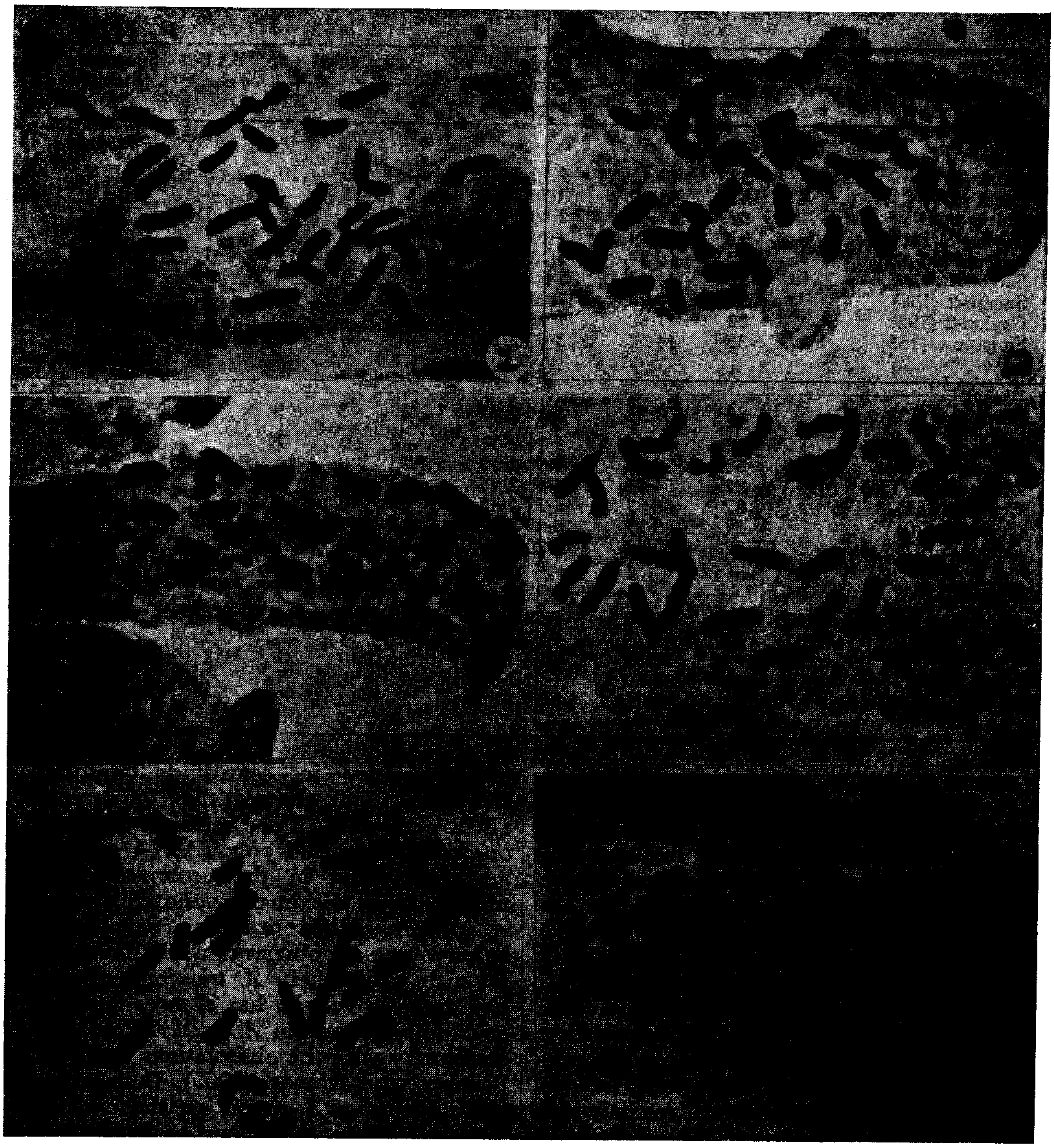
[1] and [2]: CPCRI, Regional Station, Vittal-574 243, Karnataka.



Figs 1-6: Somatic chromosomes, *A. catechu* Local (717), *A. catechu* China (111), *A. triandra* Indonesia-2 (154), *A. triandra* Ceylon-3 (87), *A. catechu* × *A. triandra* (248), and *A. catechu*×*A. triandra* (307).

Table 1: *Karyotype differences in* A. catechu, A. triandra *and their hybrids*

Plant	2n	Total *n* chromatin (μ)	Range of chromosome length (μ)	Chr. types			SAT-chr.	Symmetry (Stebbins)
				M	SM	ST		
A. catechu								
Local (471)	32	49·42	4·13-2·18	—	6	10	3	2A
Local (717)	32	43·97	3·78-1·83	5	11	—	—	1B
China (111)	32	41·64	3·59-1·72	—	1	15	1	3B
Ceylon-1 (191)	32	51·79	4·41-2·14	5	9	2	1	1B
Indonesia-6 (61)	32	46·81	4·12-1·93	—	3	13	1	2B
Saigon-1 (176)	32	44·48	3·67-1·92	—	9	7	1	2A
Saigon-2 (180)	32	50·78	4·15-2·13	—	3	13	1	2A
Ceylon-2 (192)	32	47·60	4·43-1·88	—	3	13	1	3B
Singapore (163)	32	44·52	3·62-2·11	—	6	10	2	2A
A. triandra								
Mauritius (109)	32	61·21	5·24-2·52	4	3	9	2	2B
Indonesia-1 (125)	32	48·04	4·04-2·02	—	9	7	1	2B
Indonesia-2 (74)	32	53·73	4·68-2·40	2	8	6	—	2A
Indonesia-2 (154)	32	54·14	4·41-2·44	3	7	6	—	2A
Ceylon-3 (55)	32	56·32	4·72-2·46	1	10	5	—	1A
Ceylon-3 (70)	32	59·77	4·89-2·62	—	11	5	—	1A
Ceylon-3 (87)	32	50·59	4·20-2·14	3	12	1	2	1A
Hybrids								
A. catechu × *A. triandra* (248)	32	56·80	6·19-2·21	6	4	6	—	2B
(287)	32	47·35	4·20-1·68	9	7	—	2	1B
(288)	32	55·88	5·77-1·99	2	11	3	2	2B
(307)	32	48·69	4·51-1·68	5	10	1	2	1B
Spontaneous hybrid	32	48·19	4·43-1·83	2	12	2	1	1B

somes and type of symmetry based on Stebbins' classification (1958) are given in table 1 and figures 1-27. In order to study the distribution pattern of the chromosomes, they were further grouped on the basis of their relative length (table 2).

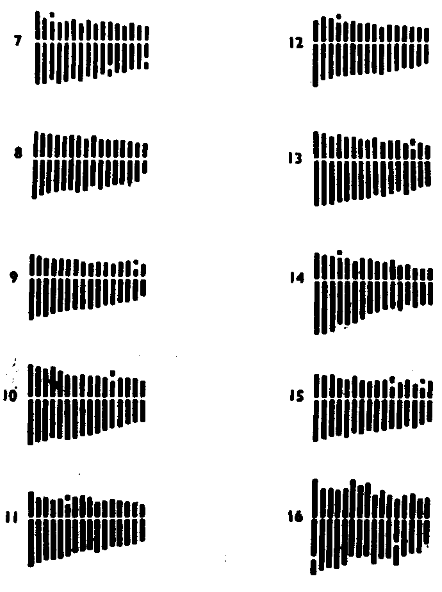
Discussion

Karyotypes of the different cultivars of *A. catechu* showed considerable differences in their gross morphological characteristics. Most of them had subterminal or submedian chromosomes. However, in one plant (717) there were only median and submedian chromosomes. The karyotype of the *A. triandra* ecotypes showed a higher frequency of submedian and median chromosomes as compared to *A. catechu* (table 1). A classification of the karyotype of the two species according to the degree of their asymmetry which recognises three grades of size differences and four grades of asymmetry in centromere position (Stebbins 1958) showed that karyotypes 1B, 2A, 2B and 3B are represented in *A. catechu* cultivars and only 1A, 2A and 2B are represented in the ecotypes of *A. triandra*. Even within the same cultivar of *A. catechu* two different types of asymmetry in karyotype are observed, while there was no such variation in *A. triandra* ecotypes. Evidently *A. triandra* has a more symmetrical karyotype than *A. catechu*. This is in conformity with the observations made by Bavappa and Raman (1965). Delineating the cultivars of *A. catechu* on the basis of standard karyotype seems to be rather difficult.

The use of karyotype symmetry-asymmetry in the study of species evolution is well known and in the Ranunculaceae (tribe Helleboreae), Levitsky (1931) showed that the most primitive species tend to have

Table 2: *Chromosome frequencies of* A. catechu, A. triandra *and interspecific hybrids in different relative length classes*

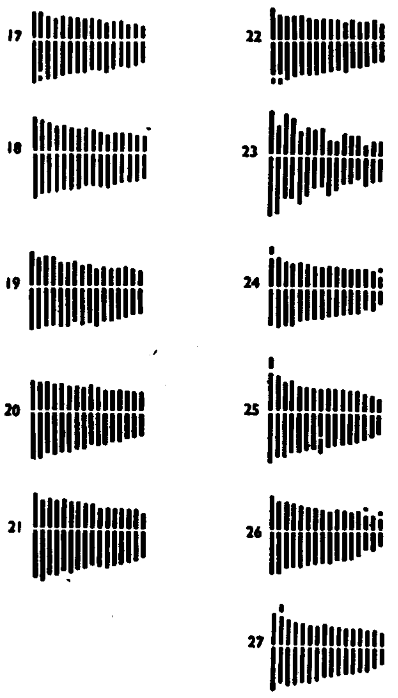
Plant	10·9	10·4	9·9	9·4	8·9	8·4	7·9	7·4	6·9	6·4	4·9	5·4	4·9	4·4	3·9	3·4
A. catechu																
Local (471)						1	1	3	2	3	2	2	2	—	—	
Local (717)					1	—	2	2	2	2	2	2	2	1	—	
China (111)					1	—	2	2	1	4	2	2	1	1	—	
Ceylon-1 (191)					1	1	2	1	3	1	2	2	2	1	—	
Indonesia-6 (61)					1	—	2	2	2	2	3	2	1	1	—	
Saigon-1 (176)						1	2	1	3	3	2	2	1	1	—	
Saigon-2 (180)						1	2	2	2	3	2	2	1	1	—	
Ceylon-2 (192)				2	1	1	1	1	1	1	1	3	2	2	—	
Singapore (163)						1	1	2	3	3	3	2	1	—	—	
A. triandra																
Mauritius (109)						1	1	2	4	2	4	—	1	1	—	
Indonesia-1 (125)					1	—	2	2	2	3	2	2	1	1	—	
Indonesia-2 (74)					1	—	2	2	1	3	3	2	2	—	—	
Indonesia-2 (154)						1	2	1	3	2	3	2	1	1	—	
Ceylon-3 (55)						1	2	2	2	3	2	2	1	1	—	
Ceylon-3 (70)						1	2	2	2	2	3	3	—	1	—	
Ceylon-3 (87)						1	1	1	2	3	4	2	1	1	—	
A. catechu × *A. triandra* (248)	1	—	—	1	1	1	—	1	1	2	2	1	2	2	1	
(287)				2	—	—	2	1	1	2	3	2	2	—	1	
(288)		1	—	—	1	—	1	1	2	3	2	2	1	1	1	
(307)				1	1	1	1	1	2	1	4	1	—	2	1	
Spontaneous hybrid				1	1	—	1	2	2	2	2	2	2	—	1	



Figs 7-16: Idiograms. *A. catechu* Local (471), *A. catechu* Local (717), *A. catechu* China (111), *A. catechu* Ceylon-1 (191), *A. catechu* Indonesia-6 (61), *A. catechu* Saigon-1 (176), *A. catechu* Saigon-2 (180), *A. catechu* Ceylon-2 (192), *A. catechu* Singapore (163) and *A. triandra* Mauritius (163).

chromosomes possessing median centromeres and of equal size. The total chromatin matter in all the ecotypes of *A. triandra* was higher than that of the cultivars of *A. catechu* (table 1). Delaunay (1926) demonstrated the gradual reduction in chromatin matter from primitive to advanced forms. Similar observations have been made in the different genera and tribes of palms (Sharma and Sarkar 1956). The fact that *A. catechu* has lesser chromatin matter and asymmetrical karyotype compared to *A. triandra* shows that the latter is more primitive.

The karyotypes of *A. catechu* × *A. triandra* hybrids showed wider variability in chromosome size than both the parents (table 2). Various workers have investigated how the phenotypic appearance of the parental chromosomes is changed under the influence of the hybrid genotype. Simonet (1931) in *Iris*, Navashin (1934) and Tobgy (1943, 1949) in *Crepis*, Levan (1935) in *Allium*, Darlington (1937) in *Tradescantia*, Hakansson (1943) in *Godetia*, Heneen (1962) in *Agropyron*, and Singh (1972) in *Rumex* observed varied responses of the



Figs 17-27: Idiograms. *A. triandra* Indonesia-1 (125), *A. triandra* Indonesia-2 (74), *A. triandra* Indonesia-2 (154), *A. triandra* Ceylon-3 (55), *A. triandra* Ceylon-3 (70), *A. triandra* Ceylon-3 (87), *A. catechu* × *A. triandra* (248), *A. catechu* × *A. triandra* (287), *A. catechu* × *A. triandra* (288), *A. catechu* × *A. triandra* (307), *A. catechu* × *A. triandra* Spontaneous hybrid.

hybrids to the new genotype with regard to retaining or changing the chromosome dimensions of the parental sets. In *A. catechu* and *A. triandra* the relative length of chromosomes ranged from 4·12 μ to 8·59 μ whereas in the hybrids the variation was from 3·45 μ to 10·72 μ. This clearly indicates that compensation effect has brought about a reduction in the length of the shortest chromosome and an increase in that of the longest chromosome.

The number of satellites in *A. catechu* varied from zero to three whereas in *A. triandra* and in the hybrids it varied from zero to two. No consistency in the presence/absence, number and position of the satellite could be observed either in the parents or in the hybrids. Deryaguin and Iordinsky (1971) have reported differences in the mode of phenotypic variability of satellited chromosomes in clones of interspecific hybrids of *Allium cepa* × *A. fistulosum*. In light of the above, the usefulness of this character seems to be limited in the classification of karyotypes in *Areca* species.

Summary

Studies on karyotypes of eight cultivars of *A. catechu* and four ecotypes of *A. triandra* revealed considerable differences in their gross morphological characteristics. Using Stebbins' classification, the karyotypes 1B, 2A, 2B and 3B were represented in *A. catechu* and 1A, 2A and 2B in *A. triandra*. *A. triandra* is considered primitive as it has a more symmetrical karyotype and also possesses more chromatin matter.

A compensation effect due to differential dimensions of the parental chromosome was observed in *A. catechu*—*A. triandra* hybrids. No consistency in the presence/absence, number and position of the satellite could be observed either in the parents or hybrids and it is inferred that the usefulness of this character in the classification of *Areca* karyotype is very limited.

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TRANSLOCATION STOCKS IN PEARL MILLET

B. R. Tyagi*

Department of Genetics and Plant Breeding, Banaras Hindu University, Varanasi-221005

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In pearl millet, *Pennisetum typhoides* (Burm.) Stapf. and Hubb. (2n=14), very limited information is available on linkage groups and genetics of important characters. Cytogenetic stocks, such as chromosomal translocations, are of considerable importance from both theoretical and practical points of view and form the best starting point for getting cytological and genetic information.

Series of translocation stocks have been developed in several plant species, including barley, maize, *Sorghum*, peas and *Vicia faba*. In pearl millet, although a few spontaneously occurring or induced translocation heterozygotes have been reported (Burton and Powell 1966, 1968, Krishnaswamy and Ayyangar 1942, Krishnaswamy 1962, Pantulu 1958, 1967, Singh and Tyagi 1973, Tyagi and Singh 1975), translocations have not been employed for genetic analysis or improvement of this crop. The present paper reports on the establishment of translocation stocks involving all 7 chromosomes and a set of 5 tester translocation stocks which may be used in linkage mapping, identifying new translocations, creating new gene blocks and for many other cytogenetic analysis as well as for pearl millet improvement.

Material and Methods

48 different translocation heterozygotes involving two pairs of chromosomes isolated in M_1 generation of gamma irradiation in an inbred line, I-55, of pearl millet (Tyagi and Singh 1975) were used. Selfed seeds from each translocation heterozygote were space planted as families. On

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*Present Address: Division of Genetics, Central Potato Research Institute, Simla-171001 (HP).

the basis of pollen sterility, all M_2 plants were grouped into (*i*) partially sterile (translocation heterozygotes) and (*ii*) fully fertile (suspected translocation or normal homozygotes). All plants of the second group were selfed and crossed with normal inbred lines. The seeds obtained were grown side by side. Plants showing normal pollen fertility when selfed, and partial sterility when crossed, indicated translocation homozygosity.

The mutual identity or independence of the translocated chromosomes in different stocks was determined by examining the metaphase I (M I) configurations of the diallele F_1 progenies produced by inter-crossing the translocation stocks.

For karyotype analysis, root tips from germinated seeds were treated with sat aq soln of alpha-bromonaphthalene at 60°C for 3h and fixed in Carnoy's solution with a small quantity of iron acetate added for 24h. They were washed in dist water and warmed in 9 : 1 aceto-carmine hydrochloric acid (N-HCl) mixture for 6 min at 60°C, transferred to 2% aceto-carmine and squashed in 1·5% aceto-carmine.

Ten well spread somatic mataphase plates for each homozygote were chosen for study. The normal and translocation stocks were compared for total chromosome length, long and short arm measurement and arm ratio (short/long) to identify the chromosomes involved in translocation and the stocks were designated according to the conventional system.

Observations

Breeding behaviour of the translocation heterozygotes and identification of homozygotes: Based on progeny tests of the fertile plants in the progenies of the translocation heterozygotes, ratio of the normal homozygotes, translocation heterozygotes and translocation homozygotes for the 48 translocations, as well as the pooled values, are presented in table 1. Except for the translocations T 9 and T 40, the remaining 46 segregated in a 1 : 2 : 1 ratio of the normal homo zygotes, translocation heterozygotes and translocation homozygotes as expected. The overall pattern was a close fit to the 1 : 2 : 1 ratio (x^2=2·239; 0·50>P>0·30). This indicated that usually the translocation gametes were as viable as normal gametes.

Crossing among the translocation stocks: The 48 homozygous translocation stocks were intercrossed in diallelic fashion to establish the mutual identity or independence of the translocated chromosomes. Sporocyte analysis of the F_1's at MI revealed whether the translocated chromosomes of the respective parents were identical or different.

Table 1: *Segregation of selfed translocation heterozygotes*

A	B	C	D	X (1: 2: 1 expected)
T1	13	19	8	1·350
T2	27	37	18	2·559
T3	19	22	13	3·350
T4	16	22	10	1·832
T5	11	15	6	1·687
T6	10	28	12	0·998
T7	15	40	10	4·229
T8	9	11	5	1·638
T9	24	30	8	8·322*
T11	21	38	15	1·026
T12	10	10	7	2·480
T13	30	48	15	4·925
T14	20	27	8	5·253
T15	13	31	9	2·131
T16	7	9	6	0·817
T17	20	33	12	1·983
T18	13	26	10	0·550
T19	26	36	15	3·129
T20	9	11	6	1·306
T21	10	14	8	0·750
T22	25	32	16	3·326
T23	15	20	8	2·615
T24	25	45	16	2·068
T25	34	50	21	3·456
T26	14	20	9	1·370
T27	15	29	11	0·641
T28	21	32	14	1·597
T32	20	42	18	0·300
T33	15	28	13	0·142
T34	14	25	9	1·124
T35	24	32	18	2·325
T36	8	12	7	2·211
T37	13	17	11	1·388
T38	17	29	14	0·365
T39	15	21	9	1·798
T40	8	17	1	6·229*
T41	18	29	11	1·688
T42	9	23	14	1·086
T46	17	25	11	1·527
T47	27	36	16	3·683
T48	19	29	13	1·261
T49	29	42	19	2·472
T50	10	15	4	2·516
T51	24	31	14	3·608
T55	19	30	13	1·225
T56	19	26	14	1·982
T57	19	24	12	1·827
T58	23	31	13	3·356
Average	18	27	12	2·239

*Significant at 5% level; A=translocation; B=normal homozygote; C=translocation heterozygote; D=translocation homozygote.

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