Karyomorphological Studies in Asiatic Cottons II.

Karyotypic analysis of species and races of Asiatic cottons based on nucleolar chromosomes and symmetry of karyotype

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In this paper, thorough karyomorphological study has been made covering all the karyotypic details like the number of chromosomes having secondary constriction and satellite; number of median, submedian and subterminal chromosomes; F%; TF%; relative length of individual chromosomes and relative length of shortest chromosome.

Materials and methods

Materials and methods of investigation is the same as in our previous paper "Karyomorphological studies in Asiatic cottons I" except karyotypic parameters which are mentioned below.

F% and T.F.% were calculated as given by Huziwara (1962).

$$F\% = \frac{\text{Short arm length of the chromosome}}{\text{Total length of the chromosome}} \times 100$$

$$T.F.\% = \frac{\text{Total sum of short arm lengths}}{\text{Total sum of chromosome lengths}} \times 100$$

$$\text{Relative length} = \frac{\text{Chromosome length}}{\text{Absolute length}} \times 100$$

$$\text{Relative length of shortest chromosome} = \frac{\text{Length of shortest chromosome}}{\text{Length of largest chromosome}} \times 100$$

(Abbreviations used to specify the type of chromosome: M, median; SM, submedian; ST, subterminal; SC, secondary constriction; S, satellite).

Results and discussion

The results have been discussed under the headings of nucleolar chromosomes and symmetry of karyotype.

Nucleolar chromosomes

There was reduction in the number of median secondarily constricted chromosomes from *persicum* (0.69) to *wightianum* (0.60) in *G. herbaceum* and from *indicum* (0.83) to *bengalense* (0.14) in *G. arboreum* but there was increase in the submedian secondarily constricted chromosomes from *persicum* (0.69) to *wightianum* (1.20) and *indicum* (0.66) to *bengalense* (0.85) (Table 1).

Number of median satellite chromosomes reduced from *persicum* (1.30) to *wightianum* (1.00) in *G. herbaceum* and from *indicum* (0.83) to *bengalense* (0.42) in *G. arboreum* but there

Table 1. Details of somatic chromosomes of *Gossypium herbaceum*, *Gossypium arboreum* and their races

Race/Culture	2n chro- mosome no.	Number of chro- mosomes			Karyotype formulae	Number of secondarily constricted chromosomes			Number of satelli- te chromosomes						
		M	SM	ST		M	SM	ST	Total	M	SM	ST	Total		
<i>G. herbaceum</i>															
race <i>persicum</i>															
1449	26	9	4	—	7M+1M(SC)+1M(S)+2SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
5497	26	9	4	—	7M+1M(SC)+1M(S)+2SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
6455	26	9	4	—	7M+1M(SC)+1M(S)+2SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
DM 125	26	8	5	—	6M+2M(S)+5SM			—	—	—	—	2	—	—	2
SM 14	26	8	5	—	6M+2M(S)+5SM			—	—	—	—	2	—	—	2
SM 150	26	6	7	—	4M+2M(S)+7SM			—	—	—	—	2	—	—	2
SM 43	26	8	5	—	6M+2M(S)+5SM			—	—	—	—	2	—	—	2
SM 81	26	9	4	—	7M+1M(SC)+1M(S)+2SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
SM 41	26	9	4	—	7M+1M(SC)+1M(S)+2SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
SM 141	26	9	4	—	7M+1M(SC)+1M(S)+2SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
SM 73	26	11	2	—	9M+1M(SC)+1M(S)+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
SM 143	26	10	3	—	8M+1M(SC)+1M(S)+1SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
SM 88	26	10	3	—	8M+1M(SC)+1M(S)+1SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
Average of race		8.84	4.15	0.00				0.69	0.69	—	1.38	1.30	0.69	—	2.00
race <i>wightianum</i>															
Jayadhar	26	6	6	1	4M+1M(SC)+1M(S)+4SM+2SM(S)+1ST			1	—	—	1	1	2	—	3
R 51-238	26	6	7	—	4M+1M(SC)+1M(S)+5SM+1SM(SC)+1SM(S)			1	1	—	2	1	1	—	2
MDS 42	26	7	5	1	6M+1M(S)+3SM+2SM(SC)+1ST(S)			—	2	—	2	1	—	1	2
DB 3-12	26	9	4	—	6M+1M(SC)+2M(S)+3SM+1SM(SC)			1	1	—	2	2	—	—	2
2 5-B-6	26	6	7	—	6M+3SM+2SM(SC)+2SM(S)			—	2	—	2	—	2	—	2
Average of race		6.80	5.80	0.40				0.60	1.20	—	1.80	1.00	1.00	0.20	2.20
Average of species		8.27	4.61	0.11				—	—	—	—	—	—	—	—

was increase in the submedian satellite chromosomes from *persicum* (0.69) to *wightianum* (1.0) and *indicum* (0.83) to *bengalense* (1.71) (Table 1).

It confirmed that the modification of median type chromosomes into submedian types had taken place from *persicum* to *wightianum* and from *indicum* to *bengalense* which would be due to loss of repetitive DNA in the course of evolution. Hence it was considered that *wightianum* is an advanced race compared to *persicum* in *G. herbaceum*, and *bengalense* is advanced race compared to *indicum* in *G. arboreum* which was in conformity with the suggestions of Stebbins (1971) in other plant species.

The secondarily constricted chromosomes increased from *persicum* (1.38) to *wightianum* (1.80) in *G. herbaceum* but decreased from *indicum* (1.50) to *bengalense* (1.00) in *G. arboreum*. There was increase in the satellite chromosomes from *persicum* (2.00) to *wightianum* (2.20) in *G. herbaceum* and *indicum* (1.83) to *bengalense* (2.28) in *G. arboreum* (Table 1). It is in agreement with the findings of Stebbins (1950) that the nucleolar organisers might be either lost or gained during evolution.

Jacob's (1942) observation of one pair of satellited and one pair of secondarily constricted chromosomes in the Asiatic cottons was true only in two cultures viz., 824 and Lohit of the present studies. Sikka *et al.* (1944) and Tutajuk and Sadytiova (1967) observed three pairs of satellited chromosomes in *G. herbaceum*. In the present karyotype analysis of thirty one cultures, fifteen had two pairs of satellited and two pairs of secondarily constricted chromosomes. The remaining cultures had varying number of satellited and secondarily constricted chromosomes (Plate 1 of previous paper *i.e.* Part I)

Symmetry of karyotype

In *G. herbaceum* and *G. arboreum* the average number of median, submedian and subterminal chromosomes was 8.27, 4.61, 0.11 and 7.46, 4.61, 0.92 respectively. In case of *G. arboreum* there was increase in the number of subterminal chromosomes at the expense of median chromosomes compared to *G. herbaceum*. Hence the karyotype of *G. arboreum* was asymmetric compared to *G. herbaceum*. Average number of median, submedian and subterminal chromosomes in *persicum* and *wightianum* of *G. herbaceum* was 8.84, 4.15, 0.00 and 6.80, 5.80, 0.40 respectively, in *indicum* and *bengalense* of *G. arboreum* it was 8.33, 4.00, 0.66 and 6.71, 5.14, 1.14 respectively (Table 1). It was observed that there was increase in the number of pairs of submedian and subterminal chromosomes at the expense of median chromosomes in the race *wightianum* compared to race *persicum* of *G. herbaceum* so also in *bengalense* compared to *indicum* of *G. arboreum*. Karyotypic analysis with respect to position of centromere also revealed that *persicum* had no subterminal chromosomes where as two cultures of *wightianum* (Jayadhar, MDS 42), four cultures of *indicum* (1187, 1042, 824, 875) and three cultures of *bengalense* (Lohit, LD 133, HD 11) had one pair of subterminal chromosomes. In *bengalense*, G 27 and LD 124 had two and three pairs of subterminal chromosomes respectively. Hence there was gradual increase in the number of subterminal chromosome pairs from *wightianum* to *indicum* and *indicum* to *bengalense*. Therefore, in *G. herbaceum* the race *wightianum* had asymmetric karyotype compared to that of race *persicum*, in *G. arboreum* race *bengalense* had asymmetric karyotype compared to that of race *indicum*.

For the species *G. herbaceum* and *G. arboreum* the difference in the range of F% was 19.13 and 21.95 respectively. For the races *persicum* and *wightianum* of *G. herbaceum* the difference in the range of F% was 18.44 and 20.93 respectively, for *indicum* and *bengalense* of *G. arboreum* it was 21.14 and 22.64 respectively (Tables 2, 3). Hence it was observed that at species level *G. arboreum* had asymmetric karyotype compared to *G. herbaceum* and at racial level *wightianum* and *bengalense* had asymmetric karyotypes compared to *persicum* and *indicum* respectively in their respective species, since wider range of F% indicates asymmetric karyotype (Huziware

Table 2. Racial differences of karyotypic parameters in *Gossypium herbaceum*

Race/Culture	Range of F%	Difference of range of F%	TE%	Range of relative length (%)	Difference of relative length	Relative length of shortest chromosome (%)
<i>G. herbaceum</i>						
race <i>persicum</i>						
1449	30.88-50.00	19.12	41.27	5.494-9.491	3.997	57.89
5497	30.77-50.00	19.23	41.17	5.465-9.472	4.007	57.69
6455	30.77-50.00	19.23	41.23	5.466-9.484	4.018	57.63
DM 125	35.89-50.00	14.11	41.35	6.339-9.223	2.884	68.73
SM 14	36.79-50.00	13.11	41.69	6.554-8.805	2.251	74.43
SM 150	35.56-48.71	13.15	40.95	6.378-9.259	2.881	68.88
SM 43	35.47-50.00	14.53	41.42	6.364-9.529	3.165	66.78
SM 81	29.41-50.00	20.59	42.14	5.917-10.885	4.168	58.67
SM 41	27.78-50.00	22.22	41.17	5.604-10.129	4.525	55.33
SM 141	29.41-50.00	20.59	41.90	5.926-9.845	3.919	60.20
SM 73	29.11-50.00	20.89	42.06	6.280-9.438	3.158	66.43
SM 143	30.38-50.00	19.62	42.36	6.186-9.721	3.535	63.64
SM 88	26.57-50.00	23.33	40.89	6.223-9.778	3.555	63.63
Range		13.11-23.33	40.89-42.36		2.251-4.525	55.33-74.43
Average of race		18.44	41.51		3.543	63.08
<i>G. herbaceum</i>						
race <i>wightianum</i>						
Jayadhar	27.27-50.00	22.73	38.89	4.315-9.314	4.999	46.33
R 51-238	27.36-50.00	13.68	39.33	5.408-9.921	4.513	54.51
MD 42	21.14-50.00	28.86	38.70	5.565-9.281	3.716	59.96
DB-3-12	33.33-50.00	16.67	42.42	5.595-9.791	4.196	57.14
2 5-B-6	27.27-50.00	22.73	40.17	5.187-8.959	3.772	57.89
Range		13.68-28.86	38.70-42.42		3.716-4.999	46.33-59.96
Average of race		20.93	39.90		4.239	55.16
Average of species		19.13	41.06		3.736	60.87

Table 3. Racial differences of karyotypic parameters in *Gossypium arboreum*

Race/Culture	Range of F%	Difference of range of F%	TF%	Range of relative length (%)	Difference of range of relative length	Relative length of shortest chromosome
<i>G. arboreum</i>						
race <i>indicum</i>						
1187	23.03-50.00	26.97	39.77	6.059-9.019	2.960	67.18
853	25.00-50.00	25.00	39.26	4.879-9.754	4.875	50.02
860	33.33-50.00	16.67	42.27	5.706-9.677	3.971	58.97
1042	26.46-50.00	23.54	40.77	6.290-10.168	3.878	61.86
824	33.33-50.00	16.67	42.34	5.789-9.569	3.780	60.51
875	32.01-50.00	17.99	42.23	4.403-9.328	4.925	47.20
Range		16.67-29.97	39.26-42.34		2.960-4.925	47.20-67.18
Average of race		21.14	41.11		4.065	57.62
race <i>bengalense</i>						
LD 124	22.22-50.00	27.78	38.46	5.209-8.934	3.725	58.31
LD 132	27.59-50.00	22.41	43.13	6.470-9.972	3.502	64.88
Lohit	33.33-50.00	16.67	42.81	5.782-10.163	4.381	56.89
G 27	25.81-50.00	24.19	36.82	5.042-10.574	5.532	47.68
LD 133	25.81-50.00	24.19	41.45	4.859-9.664	4.804	50.28
LD 135	28.57-50.00	21.43	40.60	5.850-9.945	4.095	58.82
HD 11	28.17-50.00	21.83	40.39	5.858-9.958	4.100	58.82
Range		16.67-27.78	36.82-43.13		3.502-5.532	47.68-64.88
Average of race		22.64	40.52		4.306	56.53
Average of species		21.95	40.79		4.194	57.03

1962). These findings are in line with the observations made by Huziwarra (1962) and Sinha and Roy (1979) in *Aster* and *Phaseolus* respectively.

In case of *G. herbaceum* and *G. arboreum* TF% was 41.06% and 40.79% respectively. TF% of the race *persicum* and *wightianum* was 41.51% and 39.90% respectively and that of *indicum* and *bengalense* was 41.11% and 40.52% respectively (Tables 2, 3). *G. arboreum* had asymmetric karyotype compared to *G. herbaceum*. The race *wightianum* had asymmetric karyotype compared to *persicum* in *G. herbaceum* and race *bengalense* had asymmetric karyotype compared to *indicum* in *G. arboreum* since lower TF% indicates asymmetric karyotype (Huziwarra 1962). The study is on par with the studies of Huziwarra (1962), Gupta Rani and Gupta (1978) and Sinha and Roy (1979) in *Aster*, *Crotalaria* and *Phaseolus* respectively.

Differences in the range of relative lengths for the species *G. herbaceum* and *G. arboreum* were 3.736 and 4.194 respectively and for the races *persicum* and *wightianum* of *G. herbaceum* it was 3.543 and 4.239 respectively and for the races *indicum* and *bengalense* of *G. arboreum* it was 4.065 and 4.306 respectively. *G. arboreum* had the asymmetric karyotype compared to *G. herbaceum* at species level. At racial level race *wightianum* had asymmetric karyotype compared to race *persicum* and race *bengalense* had asymmetric karyotype compared to race *indicum* since the wider range of relative length is an indication of asymmetric karyotype (Tables 2, 3).

G. arboreum and *G. herbaceum* had the relative lengths of shortest chromosome of 57.03% and 60.87% respectively. Relative length of shortest chromosome of race *wightianum* was lower (55.16%) compared to that of *persicum* (63.08%) in *G. herbaceum* and race *bengalense* had lower relative length of shortest chromosome (56.53%) compared to that of *indicum* (57.62%) in *G. arboreum*. Hence at the species level karyotype of *G. arboreum* was asymmetric compared to *G. herbaceum* and at racial level karyotypes of *wightianum* and *bengalense* were asymmetric compared to that of *persicum* and *indicum* respectively in their respective species (Tables 2, 3).

Considering the symmetry of the karyotype it has been concluded that *G. herbaceum* is primitive to *G. arboreum* at species level, and at racial level race *persicum* is relatively primitive compared to race *wightianum* in *G. herbaceum* and race *indicum* is primitive compared to race *bengalense* in *G. arboreum*.

Karyotypic analysis with respect to position of centromere, F%, TF%, relative length of individual chromosomes and relative length of shortest chromosome revealed that specialisation of karyotype has taken place as a result of chromosomal repatterning.

The karyotypic change in the process of evolution is from homotypic to heterotypic with the simultaneous change of morphology and habit of the plant i.e., from perennial form to annual forms; since the karyotypic studies of *G. herbaceum* race *africanum* which is a perennial wild form of Asiatic cottons made by Edwards (1977) revealed that it had no subterminal chromosomes, whereas in the present studies two of the varieties (Jayadhar, MDS 42) of the same species with annual habit had the subterminal chromosomes.

It is in agreement with the observations of Stebbins (1950) that the karyotype of the original unspecialised progenitors of most families of plants was essentially symmetrical and subsequent increased asymmetry of the karyotype in the position of centromeres and relative size of the chromosomes in the course of evolution was the frequent type of change accompanied by increased specialisation in habit and external morphology.

Though two races of *G. herbaceum* did not differ qualitatively they differed very much in quantitative characters. There was lot of variation between two races of *G. arboreum* with respect to qualitative characters apart from quantitative characters (Plate 2, Figs. 8, 9; Plate 3; Table 4 of the previous paper in series).

Summary

Karyotypic analysis of *Gossypium herbaceum* and *Gossypium arboreum* has been made taking the parameters like number of chromosomes having secondary constriction and satellite, position of centromere *i.e.* number of median, submedian and subterminal chromosomes, F%, TF%, relative length of individual chromosomes and relative length of shortest chromosome. It is concluded that at species level *G. herbaceum* is primitive to *G. arboreum* and at racial level *persicum* is primitive to *wightianum* in *G. herbaceum*, and *indicum* is primitive to *bengalense* in *G. arboreum*.

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