Variability for Flower Characters in Cultivated and Wild Species of *Gossypium*, L.

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Cotton is the most important fibre crop of world, belonging to genus Gossypium. This genus includes approximately 50 species distributed in arid to semi-arid regions. Hybridization and introgression have played important role in the evolution of new world cotton. The success of crossing, i.e. identification of a true hybrid can be established using morphological characters like presence/absence of floral and foliar nectaries, leaf lobbing, petal spot and colour. Hence efforts were made during present investigation for characterization of the cotton species including perennial cotton and other races and wild cotton belonging to the genomes and sub genomes. In case of 'A' genome longest peduncle length was observed in Punaspatti where as flower colour ranged from dark yellow to pink-wish white. In 'B' genome all four species had flowers with varying intensity. In this group the largest petal spot was recorded in *G. anomalum*. In the 'B' genome species the shortest peduncle was observed in *G. aridum* while it was longest in *G. armourianum* whereas the flower colour varies its intensity from cream white to yellow. In the genome E flower colour appears from light yellow to yellow with petal spot. *G. longicalyx* belonging to F genome shows yellow flower without petal spot. The peducle length in A_1D_1 genome was shortest in Seridov and longest in Exotic-3. The flower colour of this genome produced cream to yellow flowers. These results revealed that there is wide range in the floral characters of races and perennial types of cultivated cottons as well as wild species of Gossypium. Qualitative characters are under the control of either single or two genes. The information on flower characters will certainly useful for selecting desired types from the segregation of populations both for improved yield, fibre quality parameters coupled with resistance to diseases and pests.

Key words: *Gossypium*, Flower characters, Wild species, Cultivated species, Variability

Cotton is a leading fibre crop of the world (Murthy and Acharya, 1975; Fryxell, 1992) belonging to genus *Gossypium*. This genus includes approximately 50 species distributed in arid to semi-arid regions of the tropics and sub-tropics. Four species independently domesticated for their fibre in Africa-Asia and the Americas. *Gossypium* species exhibit extraordinary variation ranging from herbaceous perennials to small trees with diverse array of reproductive and vegetative characteristics. Similarly parallel level of cytogenetical and genomic diversity has arisen during the global radiation of the genus leading to the evolution of eight groups (A-G and K) of diploid (n=13) (Wendel and Cronn, 2003) tropical and sub-tropical regions of the world (Percival *et al*,1999 Endrizi *et al*, 1985). Among these species 44, are diploid and fall into A to G and K genomes and the remaining are allotetraploids with progenitors of *G. herbaceum* var. *africanum* (AA) and *G. raimondii* (D_5D_5) (Wendel, 1989). There are four cultivated species, the New World allopolyploids *G. hirsutum* and *G. barbadense* and the old world diploids *G. herbaceum* and *G. arboreum*.

Many of the various species of both diploid and tetraploid provide the most intriguing sources of genetic variability for cotton variety improvement. Difficulties arise in the transfer of wild diploids into tetraploids. These species arise from chromosome structural differences (Niles,1980). Fertility relationship among species is highly variable, and only about two thirds of the interspecific hybrids studied produce fertile F_1 s (Anonymuos,1968).The exotic species are the sources of useful genes (Table 1) for improvement of fibre properties, cold tolerance and resistance to diseases and insects (Fryxell, 1976). Further, nuclear complements of two upland cottons when combined with cytoplasm of seven wild *Gossypium* species; these provide a valuable and unique germplasm source for cotton improvement (Meyer, 1973;1975).

Hybridization and introgression have played important role in the evolution of New World cotton (Hutchinson, 1959). Adoption of standardized systems of introgression, precise evaluation of the selective value of a particular gene complex, sophisticated techniques with suitable adjustments in the breeding system for accelerating the rate of introgression and controlled experimentation are necessary to achieve the desired goals of interspecific gene transfer. The various aspects of introgressive gene transfer in *Gossypium* for diseases and pest resistance (Mehetre *et al.*, 2002 a), for fibre

quality parameters (Mehetre *et al.*, 2004 a), problems of wide hybridization ((Mehetre *et al.*, 2002 b) and embryo rescue as tool to achieve interspecific hybridization (Mehetre *et al.*, 2004 b) are reviewed critically.

The success of a cross, i.e., identification of a true hybrid can be established using morphological characters like presence/ absence of floral and foliar nectaries, leaf lobbing, petal spot and color etc. However, these characters may not be significantly distinct. Cytological data are more reliable for the identification of interspecific cotton hybrids because, the hybrid between tetraploid and diploid is triploid and distinct from its parent for chromosome number and pairing. However, such assessments require laborious experiments. Although isozyme markers are used to identify the hybrids of cultivars (Roxas *et al.*, 1993) the paucity of isozyme loci restricts their usefulness in breeding (Heletjaris *et al.*, 1986). Molecular marker analysis though offers an efficient alternative to this approach requires sophisticated laboratories and trained scientific manpower, which is not readily available everywhere. Hence, for confirmation hybrids, one has to depend upon the expression of morphological characters in the F_1 hybrid in comparison with their parents. Hence efforts were made during present investigation for characterization of the cultivars and species including perennial cottons and other races, wild cotton belonging to genomes and subgenomes. Objective of the present investigation was to utilize this information for confirmation of hybridity of an interspecific hybrid of *Gossypium* L. spp. (Naryanan, *et al., 1984;* Mehetre and Pardeshi, 2004).

Materials and Methods

Various races and perennial types and cultivated diploid and tetraploid cottons and world species maintained in garden of wild species and cytogenetical stocks (Table 1) at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri comprised the experimental material. The observations were recorded on three randomly selected plants of each species, for different characters mentioned in Table 1.

The fully opened three flowers were collected for recording observations. The flowers were dissected for recording observations of petals. Area (mm^2) of petal, petal spot, bracteoles, and calyx was measured using area meter-Am-100, Model–SE 213 CE ADC Bio-Scientific Limited, England. Measurements and counts of other floral parts were recorded with help of scale/ ruller. The averages of ten observations were considered for statistical analysis (Syndecor and Cocharn, 1967).

Results

During present studies the variability for different floral characters (Table 1) was studied in species, races and perennial types of diploid (*G. arboreum* and *G. herbaceum*) and a tetraploid (*G. hirsutum*) cotton (Plates I & II).

A Genome

A single race of *G. herbaceum* was available for the study. Peduncle length was 2.1 cm, it produced flower with yellow colour, the petal of 29 mm width and 34 mm length was present. The petal spot area was 166 mm^2 (12.7 mm x 29.7 mm). The average calyx area (196 mm^2) was observed with width (8.9 mm) and length (27.9 mm). It had bract area of 531 mm^2 with the bract width (24.4 mm) and length (58.9 mm) on an average three number of teeth. It produced yellow coloured anther with the anther number 121; style length of (1.90 cm) and ovary length of 0.7 cm having 23 average ovule/ovary.

In *G. arboreum*, two perennial cotton *viz.*, ' Kudaikotti' and 'Punaspatti' and 3 races, *indicum*, *bengalense* and *sinense* were studied. Average peduncle length was 1.32 ± 0.25 cm, shortest (0.9 cm) and longest (1.6 cm) peduncle length was observed in Punaspatti and *bengalense* respectively.

The flower colour ranged from dark yellow (race *Kudaikotti* and *Punaspatti*), pinkish white (race *indicum*) yellow (race *bengalense* and *sinense)*. The average size of petal was 27.86 ± 3.30 mm wide and 36.7 ± 4.40 mm long. Flowers of all the five types studied, showed petal spot of having an average area (150 ± 34.34mm^2) and width 12.66 ± 3.32mm and length 21.42 ± 4.23 mm. The width of petal spot ranged from 9.4 mm (race *indicum*) to 18.3 mm (race *sinense*) and longest petal spot length 24.4 mm (race *Kudaikotti*) and shortest 13.0 mm in *bengalense* was observed.

Calyx had an average area 185 ± 56.40 mm^2 with the width 9.02 ± 1.11 mm and length 32.84 ± 11.90 mm. The area of calyx ranged from 107 mm^2 (race *Punaspatti*) to 275 mm^2 (race *Kudaikotti*). The width of calyx ranged from 7 mm (race *bengalense*) to 10.2 mm (race *indicum*) and longest calyx 51. 8 mm (Kudaikotti) and shortest calyx 19.3 mm (punaspatti) was also observed. Bract had an average area 239.60 ± 31.93 mm^2 with the width 17.16 ± 1.36 mm and length 25.78 ± 3.75 mm. The width of bract ranged

Table 1. Variability in different wild species of cotton for different morphological characters

Characters	Diploid cultivated						
	G. herbaceum	*G. arboreum*, L. (perennials and races)					
	africanum Genome A_1	*Kudaikottii* A_2	*Punaspatti* A_2	*indicum* A_2	*bengalense* A_2	*sinenses* A_2	Average (SD)
Peduncle Length (cm)	2.1	1.5	0.9	1.4	1.6	1.2	1.32 (0.25)
Petal colour	Yellow	Dark yellow	Dark yellow	Pinkish white	Yellow	Yellow	
Petal area (mm^2)	426.0	413.0	789.0	208.0	585.0	598.0	518.60 (195.68)
Petal width (mm)	29.0	27.3	26.0	23.0	31.0	32.0	27.86 (3.30)
Petal length (mm)	34.0	36.5	36.0	29.0	41.0	41.0	36.7 (4.40)
Petal spot	P (+)	P (+)	P (+)	P (+)	P (+)	P (+)	
Petal spot area (mm^2)	166.0	142.0	140.0	110.0	144.0	214.0	150 (34.34)
Petal spot width (mm)	12.7	10.1	14.5	9.4	11.0	18.3	12.66 (3.32)
Petal spot length (mm)	29.7	24.4	24.1	23.4	13.0	22.2	21.42 (4.23)
Calyx area (mm^2)	196.0	275.0	107.0	193.0	148.0	202.0	185 (56.40)
Calyx width (mm)	8.9	9.8	8.9	10.2	7.0	9.2	9.02 (1.11)
Calyx length (mm)	27.9	51.8	19.3	31.5	22.0	39.6	32.84 (11.90)
Bractiole No.	3	3	3	3	3	3	3
Bract area (mm^2)	531.0	291.0	219.0	234.0	198.0	256.0	239.60 (31.93)
Bract width (mm)	24.4	19.5	16.3	15.7	16.5	17.8	17.16 (1.36)
Bract length (mm)	58.9	28.3	25.9	25.7	19.0	30.0	25.78 (3.75)
Teeth No.	5, 3, 2	2,3,3	5,4,3	1,1,1	1,2,2	2,4,3	2.60 (1.02)
Anther colour	Yellow	Yellow	Yellow	R. Yellow	Yellow	Yellow	
Anther Nos.	121	103	86	71	98	112	94 (14.24)
Style length (cm)	1.9	2.1	2.1	2.1	2.4	2.2	2.18 (0.12)
Ovary length (cm)	0.7	0.7	0.8	0.9	0.9	0.7	0.80 (0.09)
Ovule Nos.	23	20	17	21	18	21	19.40 (1.62)

Characters	*Gossypium* species Diploid wild of B genome				
	anomalum B_1	*triphyllum* B_2	*barbasonum* B_3	*capitis viridis* B_4	Average (SD)
Peduncle Length (cm)	0.5	0.3	0.7	0.5	0.50 (0.14)
Petal colour	Dull violet	Dull violet	Dull violet	Light red	
Petal area (mm^2)	642.0	524.0	567.0	617.0	587.50 (45.53)
Petal width (mm)	29.0	21.6	24.0	33.0	26.90 (4.42)
Petal length (mm)	34.0	36.8	43.0	37.0	37.70 (3.28)
Petal spot	P (+)	P (+)	P (+)	P (+)	
Petal spot area (mm^2)	268.0	253.0	290.0	176.0	246.75 (42.91)
Petal spot width (mm)	16.5	28.0	15.7	13.5	18.43 (5.64)
Petal spot length (mm)	44.2	33.0	25.5	34.8	34.38 (6.86)
Calyx area (mm^2)	282.0	223.0	203.0	300.0	252.0 (40.14)
Calyx width (mm)	12.7	15.0	16.0	16.3	15.0 (1.41)
Calyx length (mm)	52.8	33	33.3	64.4	45.87 (13.37)
Bractiole No.	3	3	3	3	3.0
Bract area (mm^2)	120.0	55.0	104.0	101.0	95.0 (24.20)
Bract width (mm)	4.6.0	3.6	4.1	4.3	4.15 (0.36)
Bract length (mm)	40.6	19.8	46.0	46.2	38.15 (10.83)
Teeth No.	3,3,3	3,3,3	3,3,3	3,3,3	3.0 (0.0)
Anther colour	Cream	Yellow	Yellow	Yellow	
Anther Nos.	103.0	97.0	107.0	88.0	98.75 (7.15)
Style length (cm)	1.7	2.2	2.2	1.8	1.97 (0.23)
Ovary length (cm)	0.6	0.5	0.6	0.5	0.55 (0.05)
Ovule Nos.	14	14	16	11	13.75 (1.78)

Characters	*Gossypium* species Diploid wild of D genome						
	thurberi D_1	*armourianum* D_{2-1}	*devidsonii* D_{3-1}	*aridum* D_4	*raimondii* D_5	*trilobum* D_8	Average (SD)
Peduncle Length (cm)	1.4	3.6	2.9	0.2	0.7	1.3	1.68 (1.19)
Petal colour	Cream	Yellow	P.Yellow	Pink	Cream	Cream	
Petal area (mm^2)	462.0	958.0	434.0	535.0	1278.0	441.0	684.67 (321.70)
Petal width (mm)	21.0	35.0	29.9	22.6	44.0	22.3	29.13 (8.28)
8.Petal length (mm)	24.5	42.0	30.9	39.4	48.0	24.8	34.93 (8.84)
Petal spot	P(+)	P(+)	P(+)	P(+)	P(+)	P(+)	
Petal spot area (mm^2)	123.0	211.0	242.0	209.0	672.0	99.0	259.339 (191.38)
Petal spot width (mm)	6.9	14.2	14.3	12.4	32.3	6.1	14.37 (8.66)
Petal spot length (mm)	23.0	33.8	16.8	11.2	38.1	20.6	23.92 (9.34)
Calyx area (mm^2)	110.0	283.0	136.0	319.0	517.0	82.0	241.17 (151.38)
Calyx width (mm)	10.4	15.2	4.2	17.0	21.2	7.6	12.60 (5.78)
Calyx length (mm)	15.5	27.9	21.8	33.5	54.6	15.0	28.22 (13.39)
Bractiole No.	3	Absent	3	3	3	3	3.00
Bract area (mm^2)	175.0	–	–	16.0	497.0	30.0	179.5 (193.59)
Bract width (mm)	12.2	–	17.4	3.3	29.4	4.3	9.60 (12.06)
Bract length (mm)	17.8	–	30.8	9.9	48.3	8.4	17.70 (18.11)
Teeth No.	1,1,1	–	7,8,8	1,1,1	17,14,14	1,1,1	4.30 (7.36)
Anther colour	Cream white	Yellow+ red spot	Yellow	Cream pink	Dark red	Cream white	
Anther Nos.	102	145	46	138	154	98	113.83 (36.88)
Style length (cm)	2.1	3.8	1.9	2.7	4.5	2.1	2.85 (0.97)
Ovary length (cm)	0.5	0.6	0.4	0.5	0.7	0.4	0.52 (0.110)
Ovule Nos.	22	18	20	16	28	22	21 (3.78)

Characters	*Gossypium* species Diploid wild E genome			*Gossypium* species Diploid wild F genome	*Gossypium* species Diploid wild G genome	Tetraploid cultivated *G. babrbadense* race A_2D_2 genome
	stocksii E_1	*somalense* E_2	Average (SD)	*longicalyx* F_1	*Gbiskli* G_8	Kidney cotton A_2D_2
Peduncle Length (cm)	0.7	1.7	1.68 (1.19)	1.2	2.1	2.6
Petal colour	Light yellow	Yellow		Yellow	Pink	Dark yellow
Petal area (mm^2)	185.0	220.0	202.50 (17.50)	474.0	584.0	1164.0
Petal width (mm)	11.4	18.2	14.80 (3.40)	20.3	21.5	42.0
8.Petal length (mm)	26.7	28.7	27.7 (1.00)	29.5	27.2	48.0
Petal spot	P(+)	P(+)		–	P(+)	(P+)
Petal spot area (mm^2)	88.0	136.0	112.0 (24.40)	(Ab)	173.0	92.0
Petal spot width (mm)	5.3	8.9	7.1 (1.8)	(Ab)	9.8	4.8
Petal spot length (mm)	14.6	25.5	20.05 (5.45)	(Ab)	11.8	5.4
Calyx area (mm^2)	149.0	79.0	114.0 (35.0)	143.0	139.0	583.0
Calyx width (mm)	10.2	7.9	9.05 (1.15)	10.7	8.4	17.0
Calyx length (mm)	38.6	22.6	30.60 (8.0)	24.1	28.2	48.3
Bractiole No.	3	3	3.0	3	3	3
Bract area (mm^2)	129.0	411.0	270.0 (9141.0)	208.0	–	1102.0
Bract width (mm)	9.1	20.6	14.85 (5.75)	14.0	10.5	49.5
Bract length (mm)	33.8	56.1	44.95 (11.15)	36.1	12.4	64.0
Teeth No.	8,9,10	15,15,15	12.0 (3.0)	1,1,1	6,7,7	16,14,12
Anther colour	Cream	Yellow		Yellow	Yellow	Yellow
Anther Nos.	50	82	66.0 (16.0)	63	68	116.0
Style length (cm)	1.3	2.1	1.70 (0.40)	1.5	1.1	4.8
Ovary length (cm)	0.4	05	0.45 (0.05)	0.5	0.4	1.0
Ovule Nos.	9	10	9.50 (0.50)	8	20	27

Characters	Tetraploid cultivated *G hirsutum* races A_1D_1 genome						
	Palmeri A_1D_1	Punctatum A_1D_1	Morilli A_1D_1	Yellow.spotted A_1D_1	Exotic -3 A_1D_1	Seridov A_1D_1	Average (SD)
Peduncle Length (cm)	1.7	1.3	2.0	1.2	2.3	1.2	1.62 (0.42)
Petal colour	Cream to yellow	Cream to yellow	Cream to yellow	Cream to yellow	Cream to yellow	Cream to yellow	
Petal area (mm^2)	482.0	597.0	644.0	582.0	516.00	674.0	582.50 (66.94)
Petal width (mm)	22.0	32.0	28.0	32.1	29.0	32.0	30.85 (6.01)
Petal length (mm)	31.5	48.9	34.3	34.7	42.2	39.0	38.43 (5.82)
Petal spot	P(+)	P(+)	(P+)	(Ab)	(Ab)	P(+)	
Petal spot area (mm^2)	44.0	93.0	86.	(Ab)	(Ab)	156.00	94.75 (40.02)
Petal spot width (mm)	4.6	5.1	5.00	–	–	8.8	5.88 (1.70)
Petal spot length (mm)	15.5	18.6	17.4	–	–	12.6	16.03 (2.27)
Calyx area (mm^2)	352.0	425.0	226.0	250.00	196.0	179.0	271.33 (88.35)
Calyx width (mm)	17.50	15.5	9.4	11.9	9.4	6.8	11.75 (3.71)
Calyx length (mm)	46.0	76.4	26.2	32.3	32.0	25.0	39.65 (17.79)
Bractiole No.	3	3	3	3	3	3	3.0 (0.0)
Bract area (mm^2)	548.0	512.0	415.0	573.0	445.0	278.0	461.83 (98.80)
Bract width (mm)	23.1	24.1	22.4	27.7	21.6	17.9	22.80 (2.93)
Bract length (mm)	48.5	52.3	36.3	36.8	47	31.3	42.03 (7.61)
Teeth No.	8,6,7	8,9,7	11,10,9	10,9,9	2,3,3	5,5,5	7.0 (2.38)
Anther colour	Pale Yellow	Yellow	Pale Yellow	Pale Yellow	Yellow	Yellow	
Anther Nos.	77	101	98	84	107	112	96.50 (12.31)
Style length (cm)	2.1	2.5	2.3	2.8	2.2	2.6	2.42 (0.24)
Ovary length (cm)	0.8	0.8	0.9	0.8	0.8	0.8	0.82 (0.04)
Ovule Nos.	28	28	24	30	24	28	27.0 (2.24)

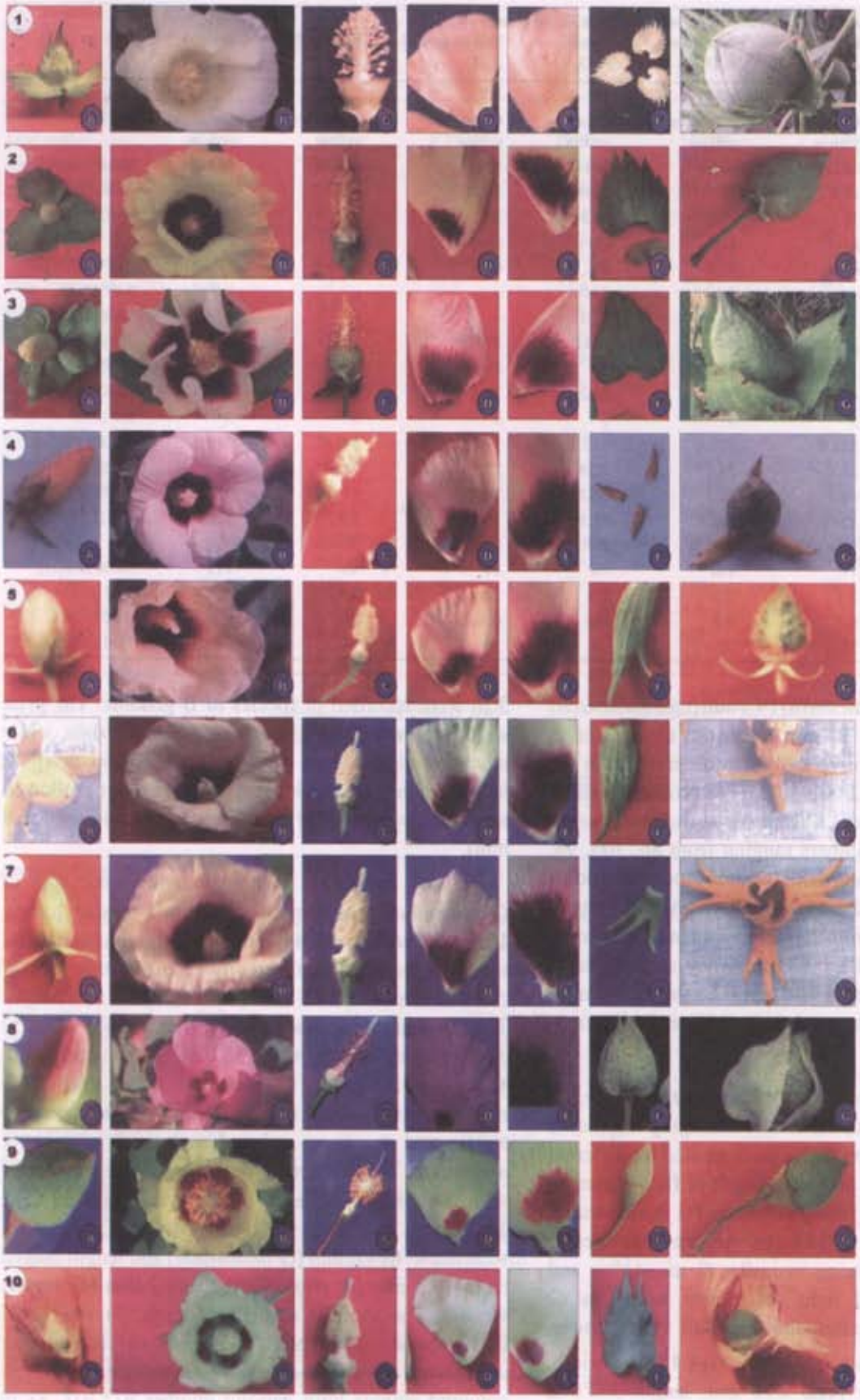
from 15.7 mm (race *indicum*) to 19.5 mm (race *Kudaikotti*) and longest bract of 30 mm (*sinense*), shortest bract of 19.0 mm (*bengalense*) were also observed with the average teeth number 2.60 ± 1.02. They produced yellow anthers (races *Punaspatti, Kudaikotti, bengalense, sinense* with the number of anthers ranging from 86, 103, 98, 112, respectively, among them *indicum* produced reddish yellow anthers with the number 71. They had varying style length ranging from 2.1 cm to 2.4 cm. The average style length was 2.18 ± 0.12 mm. They also produced average ovule numbers 19.40 ± 1.62, ranging from 17 to 21 and average ovary length 0.80 ± 0.09 cm.

B Genome

Four species namely G. anomalum,G. triphyllum, G. barbasonum and *G. capitis viridis* belonging to genome B_1, B_2, B_3 and B_4, respectively were studied for different floral characters. The peduncle length of flower ranged from 0.3 cm (*G. triphyllum*) to 0.7 cm (*G. barbasonum*) with average of 0.5 ± 0.14 cm. All the four species had flowers with varying intensity. *G. anomalum* and *G.capitis viridis* had light red flower where as *G. triphyllum* and *G. barbasonum* had dull violet flower.

Average petal size (mm), 26.90±4.42 mm width, 587.50 ± 45.53 mm^2 petal area and, length 37.70 ± 3.28 were recorded in species of B genome. The petal width was maximum (33 mm) in *Capitis viridis*, while it was minimum in a *G. triphyllum* (21.60 mm). *G. barbasonum* produced longest petal (43.0 mm) followed by *capitis viridis* (37.0 mm) and *G. trypymullum* (36.8 mm).

It was interesting to note that the petal spot of *G. anomalum* was largest (268 mm^2) in size having 16.5 mm width and 44.2 mm length. Smallest petal spot was recorded in *G. capitis viridis* having area of 176 mm^2 and size 13.5 mm width and 34.8 mm length. The average calyx area of four given species was 252 ± 40.14 mm^2, with the width 15.0 ± 1.41 mm and length 45.87 ± 13.37 mm. The maximum calyx width 16.3 mm and length 64.4 mm was observed in *G.capitis viridis* and minimum calyx length 12.7 mm in *G. anomalum*. The average bract area was 95 ± 24.20 mm^2 with the width 4.15 ± 0.30 mm and length 38.15 ± 10.83 mm. The bract width ranged from 3.6 mm (*G. triphyllum*) to 4.6 mm (*G. anomalum*) and length ranged from 19.8 mm (*G. triphyllum*) to 46.2 mm (*G. capitis viridis*). The average number of teeth (3) was equal in all species. They produced cream coloured anther with anther no. 103 in case of *G. anomalum* and yellow coloured anthers with varying number 97, 107, 88 in



S.N.	Gossypium, L.spp
1.	G. hirsutum, L. varJLH-168
2.	G.herbaceum, var GBHV.2
3.	G.arboreum var., Y-1
4.	G.anomlum, Waw. & Peyr.
5.	G.capitis viridis, Mauer
6.	G. barbosanum, Phill & Chem.
7.	G. triphyllum, (Harv.) Hochr.*
8.	G.sturtianum, J.H.Willis
9.	G.armourianum Kearney
10.	G.davidsonii Kell

a = Flower bud one day before blooming showing shape, size, colour, calyx and bracteole shape, size etc.

b = Fully opened flower showing size, colour, presence/absence of petal spot and size and colour intensity of petal spot

c = Androecium colour of anthers, filaments and exertion of stigma etc.

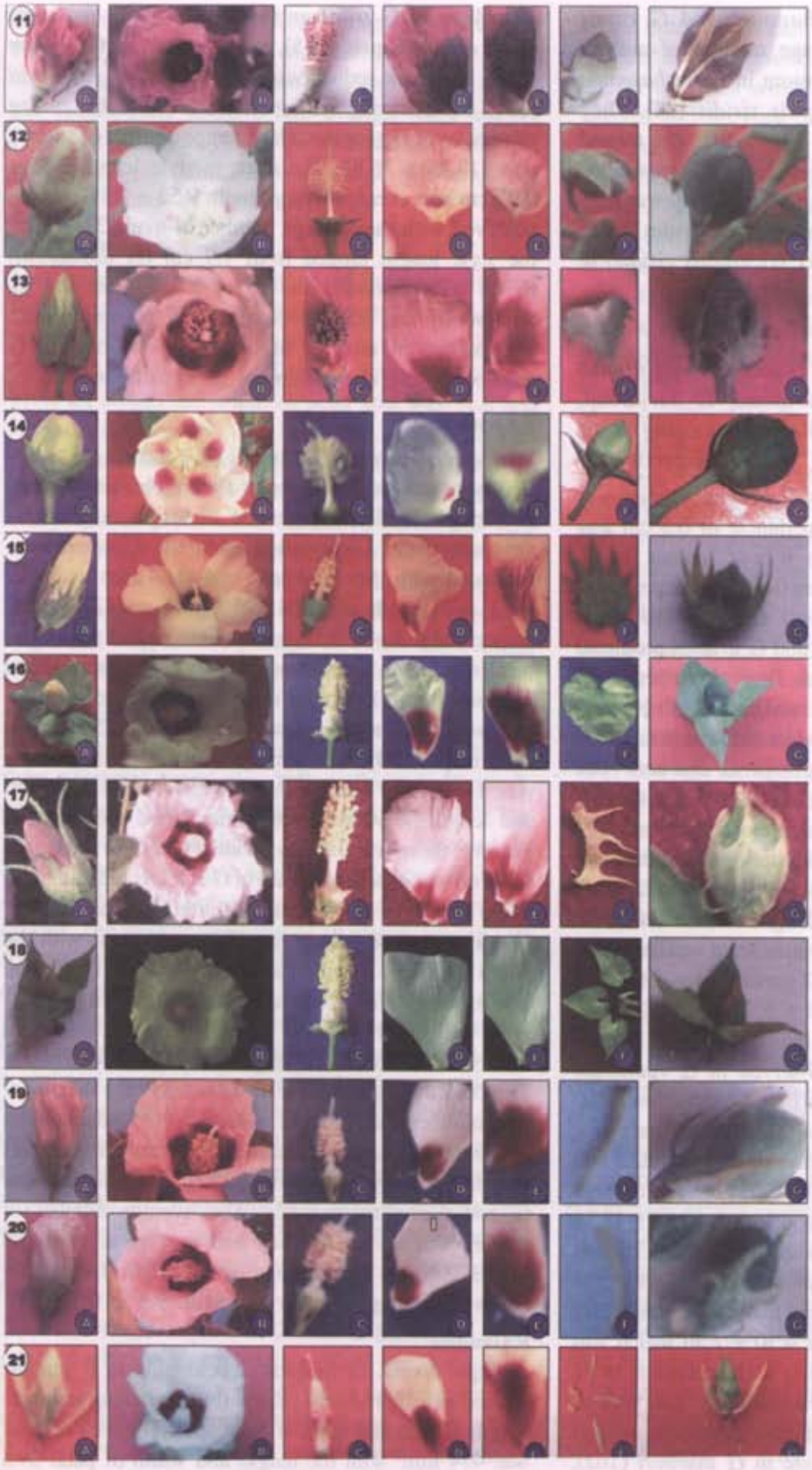
d = Individual petal showing colour, and size and colour intensity of petal spot

e = size and colour intensity of petal spot

f = calyx and bract:type, shape and size of bracteoles

g = bolls showing coverage of calyx and bracteoles

Plate 1



S.N.	*Gossypium, L.spp*
11.	*G. aridum (Rose & Standl.) Skov*
12.	*G. thurberi Tod.*
13.	*G. raimondii Ulbr*
14.	*G. trilobum (Moc. & Sess. ex DC) Skov Kearney*
15.	*G. stocksii Mast ex. Hook*
16.	*G. stocksii, Mast ex. Hook.**
17.	*G. bickii Prokh *
18.	*G.longicatyx Hutch & Lee.**
19.	*G.australe F. Muell *
20.	*G. nelsonii Fryx.**
21.	*G. areysianum Deflers*

a = Flower bud one day before blooming showing shape, size, colour, calyx and bracteole shape, size etc.

b = Fully opened flower showing size, colour, presence/ absence of petal spot and size and colour intensity of petal spot

c = Androecium colour of anthers, filaments and exertion of stigma etc.

d = Individual petal showing colour, and size and colour intensity of petal spot

e = size and colour intensity of petal spot

f = calyx and bract:type, shape and size of bracteoles

g = bolls showing coverage of calyx and bracteoles

Plate 1

case of *G. triphyllum*, *G. barbasonum* and *G. captis viridis*, respectively. The average number of anthers was 98.75 ± 7.15 having maximum in *G. barbasonum* (107) and minimum in *G. capitis viridis* (88). They having average style length of 1.97 ± 0.23 cm ranged from 1.7 cm (*G. anomalum* to 2.2 cm (*G. triphyllum* and *G. barbasonum*) and average ovary length was 0.55 ± 0.05 cm with the average number of ovules 13.75 ± (1.78), which ranged from 11 (*G. capitis viridis*) to 16 (*G. barbasonum*).

D Genome

Six wild *Gossypium* species of D genome were studied namely *G. thurberi*, *G. armourianum*, *G. davidsonii*, *G. aridum*, *G. raimondii*, *G. trilobum* belonging to the genome D_1, D_{2-1}, D_{3-1}, D_4, D_5 and D_8 respectively.

Average peduncle length of D genome species was 1.68 ± 1.19 cm. The shortest peduncle of 0.2 cm was observed in *G. aridum* while it was longest in G. *armourianum* (3.6 cm). The cream flowers were produced by *G. thurberi*, *G. trilobum* and *G. raimondii* while *G. armourianum*, *G. davidsonii* and *G. aridum* produced yellow, purple yellow and pink flowers, respectively. The maximum petal width (44 mm) and length (48mm) was observed in *G. raimondii* while shortest petals 21.0 mm width and 24.5 mm length in *G. thurberi*. The smallest (434 mm^2) and largest (1278 mm^2) flowers were produced by *davidsonii* and *raimondii*, respectively. All the D genomic species have dark petal spot. Petal spot of *G. raimondii* is largest with area of 672 mm^2, 32.3 mm wide and 38.1 mm length while *G. thurberi* (123 mm^2) and *G. trilobum* (99 mm^2) had smallest petal spot. Average calyx area of D genome was 241.17 ± 151.38 mm^2 with width 12.60 ± 5.78 mm and length 28.22 ± 13.39 mm. The maximum width (21.2 mm) and length (54.6 mm) was observed in *G. raimondii* and minimum width (4.2 mm) in *G. davidsonii* and length (15.0 mm) in *G. trilobum*. Maximum bract area (497 mm^2) was observed in case of *G. raimondii* and minimum bract area (16 mm^2) in *G. aridum*. The average bract width 9.60 ± 12.06 mm and length 17.70 ± 18.11 was observed and the bract width ranged from 3.3 mm (*G. aridum*) to 29.4 mm (*G. raimondii*) and bract length ranged from 8.4 mm (*G. trilobum*) to 48.3 (*G. raimondii*). The average teeth number was 4.30 ± 7.36 which was maximum in *G. raimondii* (15) and minimum in *G. thurberi*, *G. aridum and G. trilobum* (1). The various colors of anthers were also observed with varying number of anthers such as creamy white in *G. thurberi* (102), as well as in *G. trilobum* (98), yellow with red spots in *G. armourianum* (145), pink/reddish in *G. aridum* (138), and dark red or violet in case of *G. raimondii* (154), which having maximum number of anther among all species of D genome. The average number of anthers was 113.83 ± 36.88. The average style length 2.85 ± 0.97 cm and average ovary length 0.52 ± 0.11 cm was observed with the average number of ovule 21 ± 3.78, the style length ranged from 1.9 cm (*G. davidsonii*) to 4.5 (*G. raimondii*) and ovary length from 0.4 (*G. davidsonii*) and (*G. trilobum*) to 0.7 (*G. raimondii*). The maximum number of ovules is observed in *G. raimondii* (28) and minimum in *G. aridum* (16).

E Genome

Two species namely *G. stocksii* (E_1) and *G. somalence* (E_2) were studied for different flower characters. They had length of flower peduncle of length 0.7 and 1.7 cm respectively. Light yellow and yellow flowers were produced with the width of petal (11.4 mm and 18.2 mm) and length of petal (26.7 mm and 28.7 mm) respectively. Both the species had a petal spot. The petal spot of *G. somalence* was larger (136 mm^2) than *stocksii* 88 mm^2). Similar trend was observed for petal spot width (8.9 and 5.3 mm) and length (25.5 and 14.6 mm) respectively. The average calyx area of genome was 114 ± 35.0 mm^2 with the width 9.05 ± 1.15 mm and length 30.60 ± 8 mm. Among two species of E genome, the maximum calyx width (10.2 mm) and length (38.6 m) was observed in case of *G. stocksii* and minimum width (7.9 mm) and length (22.6 mm) in *G. somalense*. The average bract area was 270 ± 141 mm^2 with the width 14.85 ± 5.75 mm and length 44.95 ± 11.15 mm. The maximum bract width (20.6 mm) and length (56.1 mm) was observed in *G. somalense* while minimum bract width (9.1 mm) and length (33.8 mm) in *G. stocksii*. They had average no. of teeth 12.0 ± 3.0, the maximum teeth number observed in *G. somalense* (15) and minimum in *G. stocksii* (9). They produced cream coloured anthers (50) and faint yellow anthers (82) in *G. stocksii and G. somalense*, respectively. The average number of anthers was 66 ± 16. They had average style length 1.70 ± 0.40 cm and average ovary length 0.45 ± 0.05 cm with average number of ovule 9.5 ± 0.5.

F Genome

A single specis. *G. longicalyx* belonging to F genome studied which produced yellow flowers having peduncle length 1.2 cm and without petal spot. The area of petal was 474 mm^2 with the length and width of petal 29.5

and 20.3 mm respectively. The average calyx area was (143 mm^2) with width (10.7 mm) and length (24.1 mm) and average bract area 208mm^2 with the width (14 mm) and length (36.1 mm). It had average teeth number (1). It produced 63 yellow coloured anthers with the style length (1.5 cm) and ovary length (0.5 cm). The average number of (8) ovules.

G Genome

G bickii belonging to G_g genome, studied for its different floral characters produced pink flower having 2.1 mm peduncle length and area of petal was (584 mm^2) with, the length and width of 27.2 and 21.5 mm respectively, while the length and width of petal spot was 11.8 and 9.8 mm, respectively. The single G genome species i. e. *G bickii* had average calyx area of 139 mm^2 with width 8.4 mm and length 28.2 mm. The bract area in this species could not be measured because of very minute nature of the bracteoles. However, bract had length of 12.4 mm and width 10.5 mm. It produced an average 68 anthers/flower having yellow colour, style length (1.1 cm) and ovary length (0.4 cm). The average number of ovules in *G bickii* was 20/flower.

A_1D_1 Genome

Three races namely *Palmeri, Puntactum, Morilli* and three perennial types *viz.*, Yellow Spotted, Exotic-3, Seridov had average peduncle length 1.62 ± 0.42. The shortest (1.2 cm) peduncle length was recorded in Seridov and yellow spot while it was longest (2.3 cm) in Exotic-3. All of them were produced cream to yellow flowers. The average petal area of all species was 582.50 ± 66.94mm^2, among them Seridov had maximum petal area 674 mm^2 and Palmeri had minimum 482 mm^2. The maximum average petal width 32.1 mm was recorded in yellow spotted and minimum 22.0 mm was observed, in *Palmeri*, similarly the, longest petal was observed in *Punctatum* (48.9 mm) while shortest in palmeri (31.5 mm). *Palmeri, Punctatum, Morilli* and Seridov having petal spot while other do not have petal spot. The width of petal spot was maximum (8.8 mm) in Seridov and was minimum (4.6 mm) in *Palmeri*. Minimum length 11.8 mm in *Palmeri* and maximum (18.6 mm) in *Punctatum* was observed.

The average calyx area 271.33 ± 88.35 mm was observed with the length 39.65 ± 17.79 mm and width 11.75 ± 3.71mm^2. The width of calyx ranged from 6.8 mm (*Seridov*) to 17.5 mm (*Palmeri*) and longer calyx 76.4 mm was observed in *G punctuatum* and shorter (25.0 mm) in Seridov. They had average bract area 461.83 ± 98.80 mm^2 with the average length 42.03 ± 7.61 mm^2 and width 22.80 ± 2.93 mm. The various species had varying number of teeth, the *G morilli* was maximum (10) in number of teeth and exotic – 3 was minimum (3). The average number of teeth was 7.0 ± 2.38. The three species *G punctatum*, exotic – 3 and Seridov produced yellow coloured anthers with respective number 101, 107, 112 and *G palmeri, G morilli* and yellow spotted produced pale yellow coloured anthers such as 77, 98 and 84 in number, respectively. The average style length 2.42 ± 0.24 cm, average ovary length 0.82 ± 0.04 cm was observed with average number of ovules 27 ± 2.24. The yellow spotted was maximum (2.8 cm) in style length and *G palmeri* was minimum (2.1 cm). Similarly *G morilli* was maximum (0.9 cm) in ovary length and while rest of anthers having minimum (0.8 cm) ovary length. The yellow spotted having maximum (30) number of ovules.

A_2D_2 Genome

One perennial type of *G barbadense* under the name Kidney Cotton was studied, its yellow flower had peduncle length was 2.6 cm having dark yellow petals of size 42 mm width and 48 mm long. The petal area 1164 mm^2 was presented having petal spot area 92 mm^2. The length and width of petal spot was 5.4 mm and 14.8 mm respectively. It had calyx area 583 mm^2 with the width 17 mm and length 48.3 mm. The kidney cotton had larger bract area of 1102 mm^2 (64 mm x 49.5 mm) with 14 number of teeth. It produced yellow coloured 116 anthers and 27 ovules. Its style length and ovary length was 4.8 cm and 1 cm, respectively.

Corolla/Petal Colour

Corolla colour in the species of *Gossypium* studied is dependent upon the presence or absence of two distinct classes of sap soluble pigments-anthocyanin and flavonoids (Stephens, 1954). These two classes of pigments are controlled by independent genetic system and with few exceptions; there is little physical interaction between them (Hutchinson, 1931, Harland, 1937) established i) full yellow, pale and white constitute a multiple allelomorph series designated as **(y), (y/p)**, ii) The correlation between petal colour and petal size holds good for minor factors affecting corolla colour as well as for three members of the multiple allelomorph series and iii) The occurrence of plants with short petals and yellow flowers, or long petals and white flowers is

due to the reshuffling of modifying factors, their being a physiological relationship between petal colour and size.

Petal Spot

Petal spot in new world cottons is due to a series of basal spot, genes differing from species to species in i) relative potency on standard genetical background and ii) mutability. Spot in *G. barbadense* is controlled by gene S^B. It is accompanied by series of genes modifier. The Y gene (yellow corolla) also acts as a strong modifier of S^B. Spot in *G. hirsutum* is due to S^H (a relatively rare gene) which is an allele of S^B and spotless S (Harland, 1936; Harland, 1937; Harland, 1939 and Leake, 1911); size and colour of corolla found correlated (Leake, 1911).

Pollen Colour

The genes symbol Pa and Pb have been assigned to *G. herbaceum* cream and *G. arboreum* pale pollen respectively. Genotypes of *G. anomalum* are reported to be *Pa Pb*, pollen colour being cream (Silow,1941; Ramanathan and Balasubrmanium, 1933).

Pollen varies among cotton breeding lines ranging from a near white colour to yellow or orange that favour food source for many adult insects. Variability in larval growth has been reported for tobacco budworm fed diets including yellow pollen (Hanny *et al.*, 1979; Bailey, 1981), such reduction in larval development is a additional source of insect pests resistance in cotton.

Boll weevil resistance associated with the frego bract trait (Bailey, 1981) which affect the feeding and oviposition behaviour of the boll weevil (Jones, 1972; Jones *et al.*, 1969). It is tolerant to *Heliothis zea* (Hedin, *et al.*, 1983; Jones *et al.*, 1978) to boll weevil (Ramanathan and Balasubramanium, 1933) and to bollworms (Karve *et al.*, 1977).

The narrow bract is also known as frego bract and is of twisting nature. In frego bract, the bracteole surface in greatly reduced. Hence such bracts do not provide shelter to bollworm larvae (Jones *et al.*,1964) on the other hand normal bract provides shelter to bollworm larvae. Moreover, it also contributes less trash in the lint. Contrary normal bracts, have large surface and cover more than half portion of the boll and hence contribute more trash in the lint.In addition frego bract genotypes have less boll rot (Jones *et al.*, 1969) and permit better penetration of insecticides on the flower buds. Thus frego bracts genotypes confer non-preference type of resistance to bollworms (Hunter *et al.*, 1965).

Caducous Bract

In cotton, persistent bracts remain till harvesting while caduceus bract fall before opening of bolls. Trait caduceus bract is governed by oligogenes hence, can be easily manipulated. The problems of disease can be controlled to some extent by developing cotton varieties with caduceus bract. Caducous bract is found in two wild species *G. armourianum* and *G. harknessii* both belonging to D genome (Muramoto, 1978).

Pedicel Length

Long pedicel is a desirable character which confers non preference type of resistance to bollworm, a long pedicel makes the movement of larvae more difficult from one boll to another. Cotton varieties with longer pedicel are more resistant to bollworms than those with shorter ones (Kadapa, 1988; Kadapa *et al.*, 1983).

From the date presented in Table 1, and Figures included plate 1 revealed that there is wide range in the floral characters of races and perennial types of cultivated cottons as well as wild species of *Gossypium*. Qualitative characters are under the control of either single or two genes (Sikka and Joshi,1960) and are included in the linkage groups. The information will certainly useful for selecting desired types from the segregation of populations both for improved yields, fibre quality parameters coupled with resistance to diseases and pests. Our attempts of preheating and handling of segregating material of *G. arboreum x G. anomalum* (Saitwal *et al.*, 2003 and Amolic, 2005), *G. arboreum x G. capitis viridis* (Amolic 2005), *G. herbaceum x G. anomalum* (Mehetre *et al.*, 2003) and *G. arboreum x G. thurberi* (Mehetre *et al.*, 2003 and Kale, 2005) has resulted in development of germplasm with promising germplasm lines marker characters *viz.*, ghost spot (Silow,1941), corrupted with pinkish petal colour, bract size and shape and improved fibre qualities of *G. anomalum* (Deodikar, 1950) and boll size, shape and yield of *G. arboreum* cotton(Amin, 1940). In addition introgression lines with white flower colour and naked seed of *G. thurberi* introgressed into *G. arboreum* cotton are also in F_5 generations. In these lines the chemical present in petals of *G. thurberi* repel the pink bollworm moth from egg laying is expected (Ganesan, 1947; Hutchinson *et al.*, 1938; Squire, 1939). If confirmed, these lines will be a source of pink as well as Heliothis resistance. Further, studies are in progress.

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References

Amin KC (1940) Interspecific hybridization between Asiatic and new world cottons *Indian J Agric Sci* **10(3)**: 404-413.

Amolik VL (2005) Evaluation of progenies of interspecific hybrids of *Gossypium* spp. for sucking pests complex, bollworms and fibre quality parameters. *Ph D thesis submitted to the Mahatma Phule Krishi Vidyapeeth, Rahuri 413 712 (MS).*

Anonymous (1968) Genetics and cytology of cotton 5th Co-op *Ser Bull* **139**: 84.

Bailey JC (1981) Growth comparision of *Helithois virescene* (F) larvae fed white, yellow and orange cotton pollen. *Proc Beltwide cotton prod Res Conf* 79.

Deodikar GB(1950) Cytogenetic studies on crosses of *Gossypium anomalum* with cultivated cotton II. Substitution and addition of *Gossypium anomalum* chromosomes in the genome of the cultivated tetraploid cottons. *Indian J Agric Sci* **20**: 399-414.

Endrizi TE, EL Turcotte and RJ Kohel (1985) Genetics, cytology and evolution of *Gossypium. Adv Genet,* **23**: 272-327.

Fryxell PA (1992) A revised taxonomic interpretation of *Gossypium* L. (Malvaceae) *Rheedea* **2**: 108-165.

Fryxell PA (1976)*Gossypium*, a case history. USDA-ARS-S-137. US Government Printing Office, Washington, DC.

Ganesan D(1947) Interspecific hybridization in cotton. *3rd Conf. Cotton Gr Prob India, ICCC, Bombay,* 80-86.

Hanny BW, JC Bailey, and JR Meredith (Jr) (1979) Yellow cotton pollen suppress growth of tobacco budworm. *Environ Entomol* **8**: 706-707.

Harland SC (1937) The genetics of cotton XVII increased mutability of a gene in *Gossypium purpurascens* as a consequences of hybridization with *Gossypium hirsutum. J Genet* **34**: 153-168.

Harland SC (1939) The genetics of cotton. Jonathan Cape, London 193.

Harland SC(1936) The genetical conceptionof the species. *Biol Rev* **11**: 82-112.

Hedin PA, JN Jenkin, DH Collum, WH White and WL Parrot (1983) Multiple factors in cotton contributing to resistance to the tobacco budworm *Heliothis viresences* (F.) in PA Hedin (ed), Plant Resistance to Insects. American Chemical Society, Washington, DC 347-365.

Helentjaris T, M Slocum, S Wright, A Schaeffer, J Nienhuis (1986) Construction of genetic linkage maps in maize and tomato using restriction fragment length polymorphism. *J Theor Appl Genet* **72**: 761-769.

Hunter RC, TF Leigh, C Lincoln, BA Waddle, and LA Bariola. (1965) Evaluation of a selected cross section of cottons for resistance to the Boll Weevil. *Arkansas Agriculture Experiment Station Bulletin* 700.

Hutchinson JB (1931) The genetics of cotton.Part IV the incidence of corolla colour and petal size in Asiatic cottons. *J Genet* **24**: 325-353.

Hutchinson JB (1959).The application of genetics to cotton improvement. Cambridge Univ Press London

Hutchinson JB, PD Gadkari and MAA Ansari (1938) The genetics of Gossypium & its application to cotton breeding. *I^st Conf Sci Res Wrkrs Cott India, ICCC,* Bombay. p. 296-312.

Jones JE (1972) Effect of morphological characters of cotton on insects and pathogens. *Proc Beltwide Cotton Prod Res Conf* p 88-92

Jones JE, JA Andries, LW Sloane, SA Phillips and JG Marshall (1969) Effects of frego bracts on boll rot, yield and other important characters of Upland cotton. *Proc Beltwide Cotton Prod Res Conf* p 111-112

Jones JE, LD Newsom and KW Tipton (1964) Differences in boll weevil infestation among several biotypes of upland cotton. *Proc Sixteenth Annu Cotton Improvement Conf* p 48-55.

Jones JE, JA Andries, LW Sloane, SA Phillips and JG Marshall (1969) Effects of frego bract on boll rot, yield and other important characters of upland cotton. *Proc Beltwide cotton prod Res Conf* 111-112.

Jones JE, BR Williams, JW Brand, DF Clower, and DT Bowman (1978) Interacting effects of the okra leaf, frego bract and glabrous traits on pest resistance and agronomic performance. *Proc Beltwide Cotton Prod Res Conf* p 84-85

Kadapa SN, G Thimmaiah, and BM Khadi (1983) Seminar on "Cotton productivity Challenges In 80s". Karnataka Chambers of Commerce and Industry, Hubli,27-29th Oct.27-29 pp 1-8.

Kadapa SN (1988) The role of morpho-histological attributes in bollworm resistance. *"Bollworm" Seminar, Nagpur, India* 32-243.

Kale MB (2005) Morphological, Cytological and RAPD analysis of Parents, F_1,F_2 and Backcross (BC_1) Generations of Interspecific Cross *Gossypium arboreum, L.* X *Gossypium thurberi,* Tod. *M.Sc. thesis submitted to the Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra).*

Karve AC, AG Zirpe and AC Bhalerao (1977) Bollworm resistance in hirsutumcotton. *Nimbkar Agricultural Research Institute, Phaltan (Satara)*

Leake HM (1911a) Studies on Indian cotton *J Genet* **1**: 205-272.

Leake HM (1911a) Experimental studies in Indian cotton. *Proc. Roy Soc Ser B* **83**: 447-451.

Mehetre SS and SU Pardeshi (2004) Cotton improvement through interspecific hybridization of *Gossypium spp* – potential, problems, remedies and achievements. *National Symposium on Cotton held at Hyderabad,* 49-63.

Mehetre SS, VL Gawande, and AR Aher (2002a) Incompatibility in wide hybridization of *Gossypium* species causes and remedies A Review. *J Cotton Res Dev* **16(2)**: 111-124.

Mehetre SS, SD Patil and VL Gawande (2002b) Introgression of disease and pest resistance from wild to cultivated species of *Gossypium* – A Review *J Cotton Res Dev* **16(2)**: 178-181.

Mehetre SS, VL Gawande, AR Aher and AS Mokate (2003) Cytomorphology of an interspecific hybrid involving *G. herbaceum* and *G. anomalum Nucleus* **6(3)**: 138-146.

Mehetre SS, SD Patil, and AR Aher (2004 a) Improvement of fibre properties through interspecific hybridization (A Review) *J Indian Soc Cotton Improv* **29(2)**: 55-64.

Mehetre SS, VR Patil, AR Aher and GC Shinde (2003) Interspecific hybrids involving Genetic Male Sterile Line of *Gossypium arboreum* and *Gossypium thurberi*. *SABRAO J Breed Genet* **35(2)**: 71-79.

Mehetre SS, M Gomes, S Eapen, AR Aher and GC Shinde (2004b) RAPD and Cytomorphological Analysis of F1,F2 and Amphidiploid (A_1) Generation of *Gosspiym arboreum x Gossypium capitis viridis*. *Cytologia* **69(3)**: 367-369.

Meyer VG (1973) Registration of sixteen germplasm lines of upland cotton. *Crop Sci* **13**: 778-779.

Meyer VG (1975) Male sterility from *Gossypium harkensssii J Hered* **66(1)**: 23-27.

Muramoto H(1978) Cadicous bracts in cotton.In *Proc. Beltwide cotton production-Mechanization Conference, January 9-12, 1978, Dallas, Texas, USA* :17-18.

Murthy MS, and KT Achaya (1975) Cotton seed chemistry and Technology. *Publication and Information Directorate, Council of Scientific and Industrial Research, New Delhi.*

Narayanan SS, J Singh and PK Varma (1984)). Introgressive gene transfer in *Gossypium* Goal, Problems, strategies and achievements. *Cot Fib Trop* **390**: 123-135.

Niles GA (1980) Plant breeding and improvement of the cotton plant. *Outlook an Agric*. **10(4)**: 152-158.

Percival AE, JF Wendel and JMcD Stewart (1999) Origin, history, technology and production (eds). Smith CW and Cothern, JT John Willey and Sons, Inc. USA: 33-64.

Ramnathan V. and R Balsubrahamanyam (1933) Inheritance of pollen colour in Asiatic Cottons. *Indian J Agric Sci* **3**: 1116-1123.

Roxas NJL, Y Tashiro, S Miyazali, A Takeshita, T Oshima (1993) Isozyme analysis in *Chrysanthemums grandiflora* Tzvelvev *J Jpn Soc Hortic Sci* **61**: 919-924.

Saitwal VM, SS Mehetre, AH Sonone and VL Gawande (2003) Cytomorphology of F_1, F_2 Backcross generations of interspecific cross *Gossypium arboreum x Gossypium anonalum*. *Cytologia*. **68(4)**: 317-327.

Sikka SM and AB Joshi (1960) Genetics In Cotton Monograph-I (eds. Sethi *et al.*) *Indian Central Cotton Committee (ICCC), Mumbai* 403-466.

Silow RA (1941) The comparative genetics of *Gossypium anaomalum* and the cultivated Asiatic cottons *J Genet* **42**: 259-358.

Squire FA (1939) A note on the resistance of *Hibiscus esculentus* and *Gossipium trloum II. Emp Cott Gr Rev* **16**: 268-271.

Stephens SG Genetic (1954) Interspecific homologies between gene loci in Gossypium. *I Pollen colour II Corolla colour*. **739:** 701-711 and 712-723.

Syndecor GW and WG Cochran (1967) Statistical methods (6th ed.) *Oxford and IBH Co., New Delhi.*

Wendel JR (1989) New tetra plod cotton contains old world cytoplasm. *Proc Natl Acad Sci USA* **86:** 4132-4136.

Wendel JF and RC Cronn (2003) Polyploidy and the evolutionary history of cotton. *Advn Agron* **78**: 139-186.