

Cytological Study



Introduction

Chromosome is a prime genetic material with morphological entity that often has shown considerable change in its structural components and in number as well, in the process of evolution and speciation. Such chromosomal changes have often played much role in causing morphometric variation. Thus, in many cases instead of emphasizing on morphological traits along with chemical ones chromosomal features also have been proved to be a worthy aid. According to Stebbins 1971, cytogenetic studies are more significant in the study of plant diversity and evolutionary aspects. Analysis of karyotype has since long time contributed in understanding evolutionary trends within particular plant groups and the significance of changes in chromosome numbers (Mercado-Ruaro and Delgado-Salinas 1998), chromosome length and karyotype symmetry – asymmetry (Poggio *et al.* 2007).

The genus *Crinum* L. belongs to the family Amaryllidaceae, one of the largest families of monocotyledons containing 85 genera and 1300 species of tropical and subtropical region of the world (Willis 1973). All the species of this genus are geophytes; for this, they propagate mainly through vegetative mode. Many of the species are in use as horticultural plants for their large and attractive flowers. The disputed systematic consideration of many genera of this family has made many earlier workers inquisitive about the chromosomal features of these plants. The importance of the study of karyotype is being more appreciated in framing a natural and phylogenetic system of classification. Chromosomal morphology of plants in vogue of their taxonomy has been established since a long time back (Stebbins *et al.* 1937, Stebbins 1938, Gunderson 1950).

In the light of such knowledge chromosomal analyses of two species of *Crinum* L., *C. asiaticum* and *C. latifolium* have been carried out, not only remaining confined to the species level, but also including infraspecific ones. Enumeration of chromosome number for some diploid species, under this genus, revealed different chromosome numbers by different authors as, $2n = 24$ (Tomita 1931 and Sugiura 1936) and $2n=22$ (Sharma and Ghosh 1954, Sharma and Bhattacharya 1956, Bose 1965). Infraspecific variation in chromosome number has been described earlier by Sharma and Bhattacharya (1956). In addition to presenting the individual accounts of chromosomal features of eight provenances of *C. asiaticum* and ten provenances of *C. latifolium* a comparative account of two species has been taken for consideration here.

Materials and Methods

The species *C. asiaticum* and *C. latifolium* both has been collected from different locations of West Bengal as well as from different states of India. All these collections from different populations were considered as different ‘provenances’.

The list of respective provenances are as here in below, -

Table 5.1: Name of different provenance of *Crinum asiaticum* L.

Sl.No.	Name of Species	Location	Name of Provenance	Latitude (°N)	Longitude (°E)
01	<i>Crinum asiaticum</i> L.	Kolkata, West Bengal	CAKO	22.571	88.420
02	<i>Crinum asiaticum</i> L.	Mungpoo, West Bengal	CAMO	26.974	88.339
03	<i>Crinum asiaticum</i> L.	Nadia, West Bengal	CANA	23.265	88.436
04	<i>Crinum asiaticum</i> L.	North 24 pargana, West Bengal	CANO	22.135	88.401
05	<i>Crinum asiaticum</i> L.	PaschimMedinipur, West Bengal	CAPA	22.430	87.321
06	<i>Crinum asiaticum</i> L.	PurbaMedinipur, West Bengal	CAPU	21.900	87.536
07	<i>Crinum asiaticum</i> L.	Shillong, Meghalaya	CASH	25.581	91.887
08	<i>Crinum asiaticum</i> L.	Sundarban, West Bengal	CASU	21.949	89.183

Table 5.2: Name of different provenance of *Crinum latifolium* L.

Sl.No.	Name of Species	Location	Name of provenance	Latitude (°N)	Longitude (°E)
01	<i>Crinum latifolium</i> L.	Assam	CLAS	26.979	94.643
02	<i>Crinum latifolium</i> L.	Bankura, West Bengal	CLBA	20.574	86.798
03	<i>Crinum latifolium</i> L.	Gangtok, Sikkim	CLGA	27.338	88.606
04	<i>Crinum latifolium</i> L.	Kashmir	CLKA	33.778	76.576
05	<i>Crinum latifolium</i> L.	Kolkata, West Bengal	CLKO	22.571	88.420
06	<i>Crinum latifolium</i> L.	Nadia, West Bengal	CLNA	23.265	88.436
07	<i>Crinum latifolium</i> L.	Odisha	CLOD	19.314	87.794
08	<i>Crinum latifolium</i> L.	PaschimMedinipur, West Bengal	CLPA	22.430	87.321
09	<i>Crinum latifolium</i> L.	PurbaMedinipur, West Bengal	CLPU	21.900	87.536
10	<i>Crinum latifolium</i> L.	Shillong, Meghalaya	CLSH	25.581	91.887

Cytological studies

All bulbs were rooted by placing on moist sand soil (3:1) mixture; tips from 4–5 mm long root were excised and pre-treated with aqueous solution of Para dichlorobenzene for 4 hours at about 10°C. The roots were fixed in a mixture of glacial acetic acid: ethanol (1:3 v/v) and kept for couple of hours. Roots were stained with 2% aceto-orcein stain. Stain roots were squashed on clean slides with a drop of 45% glacial acetic acid. Cells with scattered metaphase chromosomes were examined and photographed by Leica DM 1000 microscope attached camera at higher magnification. Chromosomes from ten metaphase plates for each provenance were considered for measurement.

Karyotype analysis

Karyotype analysis was carried out using Ideokar 1.2 software. For analysis and comparison of the karyotype the chromosomes of different populations of *Crinum* were categorized on the basis of their length and centromeric position. Karyotype asymmetry was estimated by different methods, Arano index of karyotype asymmetry (AsK %), the total form percent (TF %), the r-value, relative length of chromosome (RL%) and asymmetry index (AI), the intra-chromosomal asymmetry index (A1) and inter-chromosomal asymmetry index (A2), degree of asymmetry of karyotype (AI index). The karyotype categories were made according to Stebbins 1937, equations and calculations of these parameters.

Results

All the studied provenances have shown somatic chromosome number as $2n = 22$ with basic chromosome number $x = 11$. Though, all provenances have same number of chromosome, karyomorphologically they differ from each other to different extent. Karyotypes of these provenances of two species expressed diversity in respect of chromosome types, length of individual chromosome, asymmetry index (Stebbins), Arano index of karyotype etc.

All the eight provenances of *C. asiaticum* L. having the same chromosome number showed different chromosome lengths.

Longest chromosome pair of Kolkata provenance (CAKO) is $36.09 \mu\text{m}$ and shortest chromosome is $10.60 \mu\text{m}$. It showed asymmetric karyotype with 2B type and according to centromere position it has $4m + 18sm$ chromosome type (Table 5.3 and 5.4).

Provenance from Mongpoo (CAMO) showed longest chromosome pair to be of $37.88 \mu\text{m}$ lengths, in contrast, the shortest is of $13.68 \mu\text{m}$. It also has shown asymmetric karyotype with 2B type and $14m + 8sm$ chromosome type (Table 5.5 and 5.6).

In Nadia provenance (CANA) the longest and the shortest chromosome pair were noted as $16.53 \mu\text{m}$ and $5.93 \mu\text{m}$ respectively. It was noted to be 2B type of karyotype with chromosome type $8m + 6sm + 8st$ (Table 5.7 and 5.8).

North 24 parganas (CANO) showed $26.70 \mu\text{m}$ and $11.28 \mu\text{m}$ as longest and shortest chromosome pair respectively. It has shown 2B type of karyotype with $6m + 16sm$ chromosome type (Table 5.9 and 5.10).

Paschim Medinipur provenance (CAPA) was found with chromosome length 37.88 μm to 11.86 μm . Class asymmetry of karyotype of this population was recorded as 2B type as per Stebbin's (1937) and chromosome types were found to be 10m + 12sm (Table No 5.11 and 5.12).

Provenance of Purba Medinipur (CAPU) showed length of the tallest chromosome as 34.17 μm and shortest as 13.81 μm . It is also indicated 2B type of Class asymmetry of karyotype and chromosome types are 8m + 10sm + 4st (Table No 5.13 and 5.14).

Shilong provenance (CASH) of *C. asiaticum* L. showed rather lesser length of chromosome, as the largest one was found to be 9.21 μm and length of the shortest chromosome as 2.46 μm . In this population 2C type of Class asymmetry of karyotype was scored and chromosome types were recorded as 12m + 4sm + 6st (Table No 5.15 and 5.16).

Sundarban provenance of *C. asiaticum* L. was found with a range of chromosome length as 21.04 μm to 09.46 μm , 2B type as class asymmetry of karyotype and three different groups of chromosome types- 8m + 12sm + 2st (Table No 5.17 and 5.18).

Likewise, karyotype of total ten provenances of *Crinum latifolium* L. from different localities showed subtle variations in different features of karyotype. The highlighted differences are as below -

C. latifolium of Assam have chromosome length range 19.84 μm to 7.14 μm . the population have supported 2B type of karyotype class asymmetry index with 4M + 8m + 8sm + 2st chromosome type (Tape 5.19 and 5.20).

C. latifolium of Bankura have chromosome length 16.36 μm to 04.87 μm . It is also shown 2B type of Class asymmetry index and chromosome types are 4m + 12sm + 6st (Table no 5.21 and 5.22).

C. latifolium Gangtok of Sikkim state has shown ranges of chromosome length are 27.92 μm to 11.57 μm . It is also showing 2B asymmetry class index karyotype with chromosome types are 10m + 6sm + 6st (Table no 5.23 and 5.24).

C. latifolium of Kashmir total length of the chromosome range are 11.75 μm to 03.81 μm . It has been showing Class asymmetry of karyotype 2B types and types are 11m + 6sm + 4st (Table no 5.25 and 5.26).

Provenances of Kolkata for this species have shown ranges of chromosome length are 15.92 μm to 5.52 μm . Here also Karyotype Class asymmetry index is 2B and chromosome types are 2m + 10m + 10sm (Table no 5.27 and 5.28).

C. latifolium of Nadia have shown 17.31 μm to 05.54 μm length of chromosome. It is also showing 2B type of karyotype Class asymmetry index and four different type of chromosome 2M + 10m + 6sm + 4st (Table No 5.29 and 5.30).

C. latifolium of Orissa state is shown range of the chromosome length 22.31 μm to 6.63 μm . It is different from other populations in karyotype Class asymmetry index – 2C type and have contained chromosome types 14m + 6sm + 2 st (Table No 5.31 and 5.32).

Provenances of Paschim Medinipur for this species are shown tallest and shortest chromosome lengths are 23.78 μm and 10.40 μm respectively. Karyotype of this

provenance shown 2B Class asymmetry index and total 22 chromosome separated in 3 groups 10m + 6sm + 6st (Table No 5.33 and 5.34).

Analysis of the chromosome morphology of Purba Medinipur in case of *Crinum latifolium* L. showing the larger chromosome than others here it is noted that longest chromosome size is 53.69 μm and shortest chromosome length is 12.12 μm . It is also different in case of karyotype class asymmetry index followed by Stebbins 2 C, whether total 22 chromosomes are shown in two groups 18m + 4sm (Table No 5.35 and 5.36).

The provenance from Shilong has shown length of the chromosome is 33.17 μm to 12.53 μm . It has 2B karyotype class asymmetry index and chromosome types are 16m + 4sm + 2st (Table No 5.37 and 5.38).

Table 5.3: Chromosome type of *Crinum asiaticum* (CAKO)

Chromosome Pairs	Long arm (μm)	Short arm (μm)	Total length (μm)	Types
1	26.71	09.37	36.09	m
2	23.04	11.21	34.25	sm
3	23.44	08.97	32.42	sm
4	22.02	07.54	29.56	sm
5	20.59	07.95	28.54	sm
6	19.37	07.95	27.32	sm
7	13.86	08.97	22.83	m
8	14.06	07.95	22.02	sm
9	13.45	07.34	20.79	sm
10	12.03	06.52	18.55	sm
11	06.72	03.87	10.60	sm

Table 5.4: Chromosome parameters of *Crinum asiaticum* (CAKO)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	02.10
Chromosome length (CL)	23.99
r-value	00.52
Relative length of chromosome (RL%)	03.85
Centromeric index (CI)	00.33
Chromosome types	4m + 18sm
Form percentage of chromosome (F%)	01.23
Total chromosome length of the haploid complement (HCL)	623.76
Total form percentage (TF%)	31.94
Class asymmetry index (Stebbins)	2B
Class asymmetry index (S%)	29.38
Arano index of karyotype asymmetry (AsK%)	68.06
Intrachromosomal asymmetry index (A1)	00.48
Interchromosomal asymmetry index (A2)	00.33
Symmetry index (S%)	29.38
Mean centromeric index (xCI)	00.34
Degree of karyotype asymmetry (A)	00.33
Mean centromeric asymmetry (xCA)	32.89
Coefficient of variation of chromosome length (CVCL)	32.64
Coefficient of variation of centromeric index (CVCI)	20.03
Asymmetry index (AI)	162.97

Table 5.5: Chromosome type of *Crinum asiaticum* (CAMO)

Chromosome Pairs	Long arm (μm)	Short arm (μm)	Total length (μm)	Types
1	21.92	15.96	37.88	M
2	17.36	12.98	30.34	M
3	19.47	06.66	26.13	sm
4	11.75	09.99	21.75	M
5	13.68	07.19	20.87	sm
6	13.33	06.66	19.99	sm
7	10.17	08.59	18.76	m
8	10.17	07.01	17.19	sm
9	10.52	04.91	15.43	m
10	07.54	07.01	14.55	m
11	07.01	06.66	13.68	sm

Table 5.6: Chromosome parameters of *Crinum asiaticum* (CAMO)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	1.73
Chromosome length (CL)	19.36
r-value	0.68
Relative length of chromosome (RL%)	03.85
Centromeric index (CI)	00.39
Chromosome types	14m + 8sm
Form percentage of chromosome (F%)	01.46
Total chromosome length of the haploid complement (HCL)	503.43
Total form percentage (TF%)	38.04
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	61.95
Intrachromosomal asymmetry index (A1)	00.32
Interchromosomal asymmetry index (A2)	00.35
Symmetry index (S%)	26.85
Mean centromeric index (xCI)	00.39
Degree of karyotype asymmetry (A)	00.21
Mean centromeric asymmetry (xCA)	21.59
Coefficient of variation of chromosome length (CVCL)	35.43
Coefficient of variation of centromeric index (CVCI)	22.50
Asymmetry index (AI)	157.48

Table 5.7: Chromosome type of *Crinum asiaticum* (CANA)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	12.28	04.07	16.35	st
2	10.41	04.26	14.68	sm
3	08.53	04.47	13.02	sm
4	08.22	03.95	12.18	sm
5	09.26	02.39	11.66	st
6	08.53	02.60	11.14	st
7	09.06	01.77	10.83	st
8	04.68	03.22	07.90	m
9	04.37	03.22	07.60	m
10	03.85	03.12	06.97	m
11	03.12	02.81	05.93	m

Table 5.8: Chromosome parameters of *Crinum asiaticum* (CANA)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	02.41
Chromosome length (CL)	10.43
r-value	00.56
Relative length of chromosome (RL%)	04.55
Centromeric index (CI)	00.34
Chromosome types	8m + 6sm + 8st
Form percentage of chromosome (F%)	01.43
Total chromosome length of the haploid complement (HCL)	229.53
Total form percentage (TF%)	31.39
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	68.60
Intrachromosomal asymmetry index (A1)	00.44
Interchromosomal asymmetry index (A2)	0.29
Symmetry index (S%)	35.03
Mean centromeric index (xCI)	00.34
Degree of karyotype asymmetry (A)	00.32
Mean centromeric asymmetry (xCA)	32.24
Coefficient of variation of chromosome length (CVCL)	29.88
Coefficient of variation of centromeric index (CVCI)	35.05
Asymmetry index (AI)	85.26

Table 5.9: Chromosome type of *Crinum asiaticum* (CANO)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	19.27	07.42	26.70	sm
2	17.99	07.28	25.27	sm
3	17.56	06.56	24.13	sm
4	16.27	06.56	22.84	sm
5	12.28	08.85	21.13	m
6	13.13	06.71	19.84	sm
7	12.13	06.85	18.99	sm
8	09.13	08.42	17.55	m
9	10.13	05.28	15.41	sm
10	08.56	03.71	12.27	sm
11	06.71	04.56	11.27	m

Table 5.10: Chromosome parameters of *Crinum asiaticum* (CANO)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.87
Chromosome length (CL)	19.26
r-value	00.59
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.36
Chromosome types	6m + 16sm
Form percentage of chromosome (F%)	01.59
Total chromosome length of the haploid complement (HCL)	423.82
Total form percentage (TF%)	35.14
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	64.85
Intrachromosomal asymmetry index (A1)	00.40
Interchromosomal asymmetry index (A2)	00.25
Symmetry index (S%)	42.24
Mean centromeric index (xCI)	00.36
Degree of karyotype asymmetry (A)	00.27
Mean centromeric asymmetry (xCA)	27.25
Coefficient of variation of chromosome length (CVCL)	25.83
Coefficient of variation of centromeric index (CVCI)	21.78
Asymmetry index (AI)	118.59

Table 5.11: Chromosome type of *Crinum asiaticum* (CAPA)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	20.39	17.48	37.87	m
2	19.15	06.86904	26.01909	sm
3	18.11	06.86	24.97	sm
4	17.90	06.03	23.93	sm
5	14.57	07.70	22.27	sm
6	14.77	06.04	20.81	sm
7	11.65	08.53	20.18	m
8	09.99	09.15	19.15	m
9	11.24	06.24	17.48	sm
10	07.70	06.86	14.57	m
11	06.45	05.41	11.86	m

Table 5.12: Chromosome parameters of *Crinum asiaticum* (CAPA)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.92
Chromosome length (CL)	21.30
r-value	00.60
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.36
Chromosome types	10m + 12sm
Form percentage of chromosome (F%)	01.62
Total chromosome length of the haploid complement (HCL)	468.55
Total form percentage (TF%)	35.76
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	64.24
Intrachromosomal asymmetry index (A1)	00.39
Interchromosomal asymmetry index (A2)	00.31
Symmetry index (S%)	30.22
Mean centromeric index (xCI)	00.36
Degree of karyotype asymmetry (A)	00.27
Mean centromeric asymmetry (xCA)	27.36
Coefficient of variation of chromosome length (CVCL)	31.12
Coefficient of variation of centromeric index (CVCI)	24.45
Asymmetry index (AI)	127.22

Table 5.13: Chromosome type of *Crinum asiaticum* (CAPU)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	18.17	15.99	34.16	m
2	17.81	15.08	32.90	m
3	20.17	07.09	27.26	sm
4	18.54	05.81	24.35	st
5	17.81	06.18	23.99	sm
6	15.08	06.72	21.81	sm
7	13.81	03.81	17.63	st
8	09.27	07.99	17.26	m
9	10.72	05.63	16.36	sm
10	09.63	05.45	15.08	sm
11	07.99	05.81	13.81	m

Table 5.14: Chromosome parameters of *Crinum asiaticum* (CAPU)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.92
Chromosome length (CL)	21.91
r-value	00.61
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.37
Chromosome types	8m + 10sm + 4st
Form percentage of chromosome (F%)	01.65
Total chromosome length of the haploid complement (HCL)	482.10
Total form percentage (TF%)	36.38
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	63.61
Intrachromosomal asymmetry index (A1)	00.39
Interchromosomal asymmetry index (A2)	00.29
Symmetry index (S%)	38.83
Mean centromeric index (xCI)	00.36
Degree of karyotype asymmetry (A)	00.27
Mean centromeric asymmetry (xCA)	26.85
Coefficient of variation of chromosome length (CVCL)	29.94
Coefficient of variation of centromeric index (CVCI)	24.40
Asymmetry index (AI)	122.68

Table 5.15: Chromosome type of *Crinum asiaticum* (CASH)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	05.53	03.67	09.21	m
2	05.66	01.86	07.52	st
3	05.72	01.68	07.41	st
4	04.93	01.62	06.56	st
5	04.21	01.92	06.14	sm
6	04.21	01.44	05.66	sm
7	03.37	01.98	05.35	m
8	02.64	02.52	05.17	m
9	02.34	02.34	04.69	m
10	02.11	01.98	04.09	m
11	01.38	01.08	02.46	m

Table 5.16: Chromosome parameters of *Crinum asiaticum* (CASH)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.97
Chromosome length (CL)	06.15
r-value	00.58
Relative length of chromosome (RL %)	04.54
Centromeric index (CI)	00.36
Chromosome types	12m + 4sm + 6st
Form percentage of chromosome (F %)	01.54
Total chromosome length of the haploid complement (HCL)	135.36
Total form percentage (TF %)	33.80
Class asymmetry index (Stebbins)	2C
Arano index of karyotype asymmetry (AsK%)	66.19
Intrachromosomal asymmetry index (A1)	00.42
Interchromosomal asymmetry index (A2)	00.45
Symmetry index (S%)	14.75
Mean centromeric index (xCI)	00.35
Degree of karyotype asymmetry (A)	00.28
Mean centromeric asymmetry (xCA)	28.74
Coefficient of variation of chromosome length (CVCL)	45.94
Coefficient of variation of centromeric index (CVCI)	24.35
Asymmetry index (AI)	188.71

Table 5.17: Chromosome type of *Crinum asiaticum* (CASU)

Chromosome Pairs	Long arm (μm)	Short arm (μm)	Total length (μm)	Types
1	10.87	10.17	21.04	m
2	11.75	03.68	15.43	st
3	13.15	04.91	18.06	sm
4	10.87	03.68	14.55	sm
5	07.54	05.26	12.79	m
6	06.48	04.91	11.39	m
7	07.18	03.85	11.04	sm
8	07.71	02.80	10.51	sm
9	07.18	03.15	10.34	sm
10	05.96	03.85	09.81	m
11	06.13	03.33	09.46	sm

Table 5.18: Chromosome parameters of *Crinum asiaticum* (CASU)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	02.04
Chromosome length (CL)	12.56
r-value	00.54
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.34
Chromosome types	8m + 12sm + 2st
Form percentage of chromosome (F%)	01.56
Total chromosome length of the haploid complement (HCL)	276.49
Total form percentage (TF%)	34.43
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	65.56
Intrachromosomal asymmetry index (A1)	00.45
Interchromosomal asymmetry index (A2)	00.24
Symmetry index (S%)	40.83
Mean centromeric index (xCI)	00.34
Degree of karyotype asymmetry (A)	00.31
Mean centromeric asymmetry (xCA)	31.15
Coefficient of variation of chromosome length (CVCL)	24.82
Coefficient of variation of centromeric index (CVCI)	21.58
Asymmetry index (AI)	115.00

Table 5.19: Chromosome type of *Crinum latifolium* (CLAS)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	14.92	04.92	19.84	st
2	11.90	04.44	16.34	sm
3	07.61	07.30	14.92	m
4	09.68	04.12	13.80	sm
5	08.41	04.28	12.69	sm
6	07.93	03.80	11.73	sm
7	05.87	05.07	10.94	m
8	04.28	04.28	08.56	M
9	04.28	03.80	08.08	m
10	03.96	03.96	07.92	M
11	04.12	03.01	07.13	m

Table 5.20: Chromosome parameters of *Crinum latifolium* (CLAS)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.73
Chromosome length (CL)	17.30
r-value	00.65
Relative length of chromosome (RL%)	03.88
Centromeric index (CI)	00.33
Chromosome types	4M + 8M + 8sm + 2st
Form percentage of chromosome (F%)	01.55
Total chromosome length of the haploid complement (HCL)	603.44
Total form percentage (TF%)	39.04
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	62.85
Intrachromosomal asymmetry index (A1)	00.33
Interchromosomal asymmetry index (A2)	00.34
Symmetry index (S%)	26.85
Mean centromeric index (xCI)	00.39
Degree of karyotype asymmetry (A)	00.22
Mean centromeric asymmetry (xCA)	29.21
Coefficient of variation of chromosome length (CVCL)	35.05
Coefficient of variation of centromeric index (CVCI)	22.77
Asymmetry index (AI)	156.48

Table 5.21: Chromosome type of *Crinum latifolium* (CLBA)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	10.44	05.92	16.36	sm
2	11.14	03.13	14.27	st
3	09.92	03.65	13.57	sm
4	08.70	03.48	12.18	sm
5	09.05	02.43	11.48	st
6	09.05	02.08	11.13	st
7	06.96	02.96	09.92	sm
8	05.22	02.78	08.00	sm
9	04.17	03.30	07.47	m
10	04.52	02.26	06.78	sm
11	02.61	02.26	04.87	m

Table 5.22: Chromosome parameters of *Crinum latifolium* (CLBA)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	02.17
Chromosome length (CL)	10.33
r-value	0.53
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	0.33
Chromosome types	4m + 12sm + 6st
Form percentage of chromosome (F%)	01.46
Total chromosome length of the haploid complement (HCL)	227.41
Total form percentage (TF%)	32.31
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	67.68
Intrachromosomal asymmetry index (A1)	00.46
Interchromosomal asymmetry index (A2)	00.31
Symmetry index (S%)	28.72
Mean centromeric index (xCI)	00.33
Degree of karyotype asymmetry (A)	00.32
Mean centromeric asymmetry (xCA)	32.72
Coefficient of variation of chromosome length (CVCL)	31.97
Coefficient of variation of centromeric index (CVCI)	25.62
Asymmetry index (AI)	124.74

Table 5.23: Chromosome type of *Crinum latifolium* (CLGA)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	21.11	06.81	27.92	st
2	17.02	07.26	24.28	sm
3	15.89	06.13	22.02	sm
4	15.21	06.35	21.56	sm
5	15.66	04.99	20.65	st
6	15.21	04.54	19.75	st
7	10.44	07.26	17.70	m
8	08.85	07.49	16.34	m
9	07.71	06.13	13.84	m
10	07.71	05.67	13.38	m
11	06.13	05.44	11.57	m

Table 5.24: Chromosome parameters of *Crinum latifolium* (CLGA)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	02.19
Chromosome length (CL)	18.40
r-value	00.56
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.34
Chromosome types	10m + 6sm + 6st
Form percentage of chromosome (F%)	01.51
Total chromosome length of the haploid complement (HCL)	404.80
Total form percentage (TF%)	33.20
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	66.79
Intrachromosomal asymmetry index (A1)	00.43
Interchromosomal asymmetry index (A2)	00.26
Symmetry index (S%)	34.95
Mean centromeric index (xCI)	00.34
Degree of karyotype asymmetry (A)	00.30
Mean centromeric asymmetry (xCA)	30.93
Coefficient of variation of chromosome length (CVCL)	26.63
Coefficient of variation of centromeric index (CVCI)	29.09
Asymmetry index (AI)	91.55

Table 5.25: Chromosome type of *Crinum latifolium* (CLKA)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	07.27	04.48	11.75	m
2	05.99	05.03	11.02	m
3	05.69	03.27	08.96	sm
4	05.93	01.33	07.26	st
5	04.60	01.93	06.53	sm
6	04.24	02.12	06.36	sm
7	04.84	01.15	05.99	st
8	02.54	02.42	04.96	m
9	02.66	01.63	04.29	m
10	02.42	01.69	04.11	m
11	02.24	01.57	03.81	m

Table 5.26: Chromosome parameters of *Crinum latifolium* (CLKA)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	02.11
Chromosome length (CL)	06.61
r-value	00.55
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.34
Chromosome types	12m + 6sm + 4st
Form percentage of chromosome (F%)	01.54
Total chromosome length of the haploid complement (HCL)	145.51
Total form percentage (TF%)	33.94
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	66.05
Intrachromosomal asymmetry index (A1)	00.44
Interchromosomal asymmetry index (A2)	00.39
Symmetry index (S%)	28.86
Mean centromeric index (xCI)	00.34
Degree of karyotype asymmetry (A)	00.31
Mean centromeric asymmetry (xCA)	30.96
Coefficient of variation of chromosome length (CVCL)	39.03
Coefficient of variation of centromeric index (CVCI)	24.58
Asymmetry index (AI)	158.82

Table 5.27: Chromosome type of *Crinum latifolium* (CLKO)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	10.72	05.20	15.92	sm
2	07.55	02.60	10.15	sm
3	06.50	03.25	09.75	sm
4	06.74	02.60	09.34	sm
5	04.30	03.98	08.28	m
6	05.11	02.68	07.80	m
7	04.22	03.00	07.23	m
8	04.63	02.51	07.15	sm
9	03.49	03.16	06.66	m
10	03.49	02.84	06.33	m
11	02.76	02.76	05.52	M

Table 5.28: Chromosome parameters of *Crinum latifolium* (CLKO)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.76
Chromosome length (CL)	08.17
r-value	00.63
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.37
Chromosome types	10m + 12sm
Form percentage of chromosome (F%)	01.65
Total chromosome length of the haploid complement (HCL)	179.82
Total form percentage (TF%)	36.42
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	63.57
Intrachromosomal asymmetry index (A1)	00.37
Interchromosomal asymmetry index (A2)	00.29
Symmetry index (S%)	25.00
Mean centromeric index (xCI)	00.37
Degree of karyotype asymmetry (A)	00.25
Mean centromeric asymmetry (xCA)	24.74
Coefficient of variation of chromosome length (CVCL)	29.73
Coefficient of variation of centromeric index (CVCI)	20.16
Asymmetry index (AI)	147.46

Table 5.29: Chromosome type of *Crinum latifolium* (CLNA)

Chromosome Pairs	Long arm (μm)	Short arm (μm)	Total length (μm)	Types
1	13.33	03.97	17.31	st
2	09.56	04.19	13.76	sm
3	07.20	05.16	12.36	m
4	05.16	04.94	10.10	m
5	07.09	02.68	09.78	sm
6	08.06	01.50	09.56	st
7	04.73	03.12	07.84	m
8	03.54	03.55	07.09	M
9	03.44	03.01	06.45	m
10	03.44	02.79	06.23	m
11	03.11	02.47	05.59	sm

Table 5.30: Chromosome parameters of *Crinum latifolium* (CLNA)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.86
Chromosome length (CL)	09.49
r-value	00.66
Relative length of chromosome (RL%)	04.76
Centromeric index (CI)	00.38
Chromosome types	10m + 6sm + 2M + 4st
Form percentage of chromosome (F%)	01.75
Total chromosome length of the haploid complement (HCL)	199.30
Total form percentage (TF%)	36.78
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	63.21
Intrachromosomal asymmetry index (A1)	00.33
Interchromosomal asymmetry index (A2)	00.34
Symmetry index (S%)	32.29
Mean centromeric index (xCI)	00.38
Degree of karyotype asymmetry (A)	00.23
Mean centromeric asymmetry (xCA)	23.09
Coefficient of variation of chromosome length (CVCL)	34.15
Coefficient of variation of centromeric index (CVCI)	27.16
Asymmetry index (AI)	125.71

Table 5.31: Chromosome type of *Crinum latifolium* (CLOD)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	17.36	04.94	22.31	st
2	10.20	05.99	16.19	sm
3	07.57	07.26	14.83	m
4	09.15	05.47	14.62	m
5	07.36	05.78	13.14	m
6	06.21	05.99	12.20	m
7	06.84	02.73	09.57	sm
8	04.84	04.42	09.26	m
9	04.31	04.21	08.52	m
10	04.84	02.63	07.47	sm
11	04.10	02.52	06.62	m

Table 5.32: Chromosome parameters of *Crinum latifolium* (CLOD)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.62
Chromosome length (CL)	11.82
r-value	00.70
Relative length of chromosome (RL%)	04.54
Centromeric index (CI)	00.40
Chromosome types	14m + 6sm + 2st
Form percentage of chromosome (F%)	01.74
Total chromosome length of the haploid complement (HCL)	260.09
Total form percentage (TF%)	38.48
Class asymmetry index (Stebbins)	2C
Arano index of karyotype asymmetry (AsK%)	61.51
Intrachromosomal asymmetry index (A1)	00.29
Interchromosomal asymmetry index (A2)	00.36
Symmetry index (S%)	20.75
Mean centromeric index (xCI)	00.40
Degree of karyotype asymmetry (A)	00.19
Mean centromeric asymmetry (xCA)	19.61
Coefficient of variation of chromosome length (CVCL)	36.70
Coefficient of variation of centromeric index (CVCI)	21.51
Asymmetry index (AI)	170.59

Table 5.33: Chromosome type of *Crinum latifolium* (CLPA)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	16.13	07.64	23.77	sm
2	15.92	04.24	20.16	st
3	14.01	03.82	17.83	st
4	13.16	04.67	17.83	sm
5	12.74	04.45	17.19	sm
6	12.74	02.97	15.71	st
7	08.49	05.73	14.22	m
8	07.21	05.09	12.30	m
9	06.15	05.94	12.09	m
10	06.37	05.30	11.67	m
11	06.37	04.03	10.40	m

Table 5.34: Chromosome parameters of *Crinum latifolium* (CLPA)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	02.41
Chromosome length (CL)	15.39
r-value	00.54
Relative length of chromosome (RL %)	04.54
Centromeric index (CI)	00.33
Chromosome types	10m + 6sm + 6st
Form percentage of chromosome (F %)	01.43
Total chromosome length of the haploid complement (HCL)	338.67
Total form percentage (TF %)	31.47
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK%)	68.52
Intrachromosomal asymmetry index (A1)	00.46
Interchromosomal asymmetry index (A2)	00.24
Symmetry index (S%)	42.85
Mean centromeric index (xCI)	00.33
Degree of karyotype asymmetry (A)	00.34
Mean centromeric asymmetry (xCA)	33.59
Coefficient of variation of chromosome length (CVCL)	24.67
Coefficient of variation of centromeric index (CVCI)	33.81
Asymmetry index (AI)	72.97

Table 5.35: Chromosome type of *Crinum latifolium* (CLPU)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	39.63	14.05	53.68	sm
2	18.97	12.19	31.16	m
3	14.73	13.04	27.77	m
4	13.21	10.50	23.71	m
5	13.55	08.30	21.85	m
6	12.53	06.43	18.96	sm
7	08.13	05.92	14.05	m
8	08.63	05.25	13.88	m
9	06.77	06.60	13.37	m
10	09.31	03.21	12.52	m
11	06.43	05.75	12.18	m

Table 5.36: Chromosome parameters of *Crinum latifolium* (CLPU)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.65
Chromosome length (CL)	20.93
r-value	00.67
Relative length of chromosome (RL %)	04.54
Centromeric index (CI)	00.39
Chromosome types	18m + 4sm
Form percentage of chromosome (F %)	01.72
Total chromosome length of the haploid complement (HCL)	460.58
Total form percentage (TF %)	37.80
Class asymmetry index (Stebbins)	2C
Arano index of karyotype asymmetry (AsK%)	62.19
Intrachromosomal asymmetry index (A1)	00.32
Interchromosomal asymmetry index (A2)	00.51
Symmetry index (S%)	18.29
Mean centromeric index (xCI)	00.39
Degree of karyotype asymmetry (A)	00.21
Mean centromeric asymmetry (xCA)	21.10
Coefficient of variation of chromosome length (CVCL)	51.06
Coefficient of variation of centromeric index (CVCI)	20.29
Asymmetry index (AI)	251.62

Table 5.37: Chromosome type of *Crinum latifolium* (CLSH)

Chromosome Pairs	Long arm (µm)	Short arm (µm)	Total length (µm)	Types
1	17.14	16.03	33.17	m
2	14.60	10.00	24.60	m
3	15.07	09.20	24.27	m
4	11.42	10.95	22.37	m
5	10.79	06.82	17.61	m
6	12.06	04.44	16.50	sm
7	12.22	03.33	15.55	st
8	08.25	06.50	14.75	m
9	09.68	04.44	14.12	sm
10	07.77	05.87	13.64	m
11	07.14	05.39	12.53	m

Table 5.38: Chromosome parameters of *Crinum latifolium* (CLSH)

Chromosome parameters	Value
No. of chromosome (2n)	22
Arm ratio (AR)	01.68
Chromosome length (CL)	18.74
r-value	00.66
Relative length of chromosome (RL %)	04.54
Centromeric index (CI)	00.38
Chromosome types	16m + 4sm + 2st
Form percentage of chromosome (F %)	01.81
Total chromosome length of the haploid complement (HCL)	412.38
Total form percentage (TF %)	39.84
Class asymmetry index (Stebbins)	2B
Arano index of karyotype asymmetry (AsK %)	60.16
Intrachromosomal asymmetry index (A1)	00.33
Interchromosomal asymmetry index (A2)	00.33
Symmetry index (S%)	35.41
Mean centromeric index (xCI)	00.38
Degree of karyotype asymmetry (A)	00.22
Mean centromeric asymmetry (xCA)	22.02
Coefficient of variation of chromosome length (CVCL)	33.01
Coefficient of variation of centromeric index (CVCI)	20.46
Asymmetry index (AI)	161.30



Figure 5.1: Scattered metaphase plate of CAKO. (Bar is 10µm)

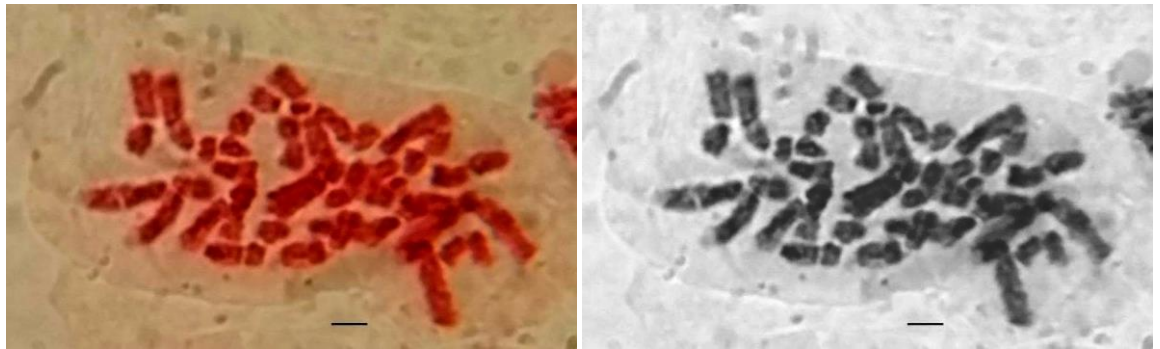


Figure 5.2: Scattered metaphase plate of CAMO. (Bar is 10µm)

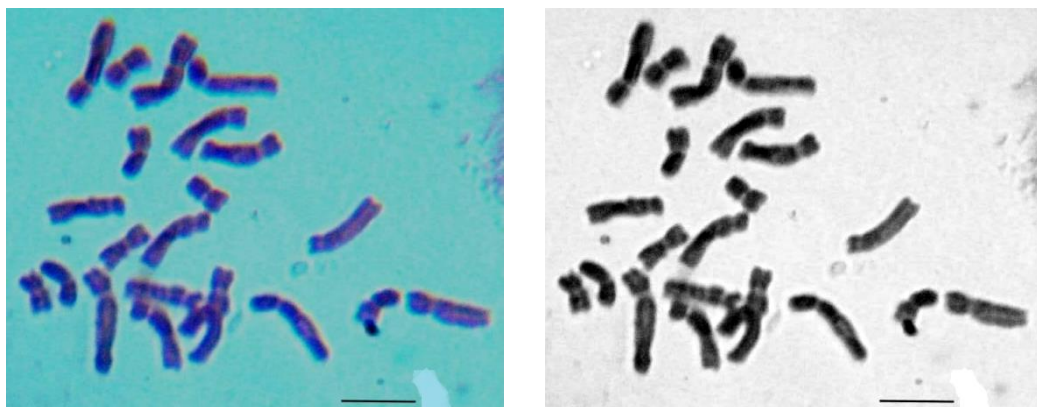


Figure 5.3: Scattered metaphase plate of CANA. (Bar is 10µm)

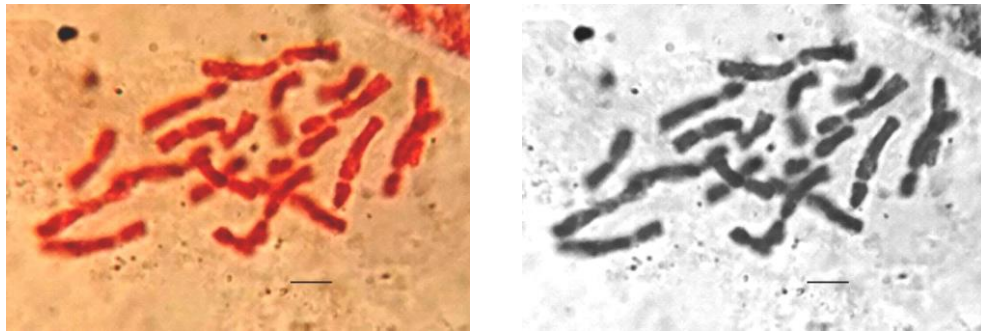


Figure 5.4: Scattered metaphase plate of CANO. (Bar is 10 μ m)

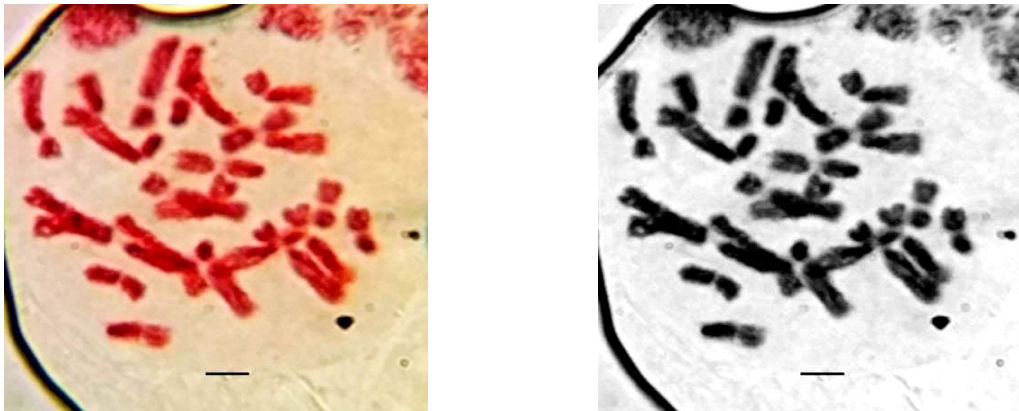


Figure 5.5: Scattered metaphase plate of CAPA. (Bar is 10 μ m)



Figure 5.6: Scattered metaphase plate of CAPU. (Bar is 10 μ m)

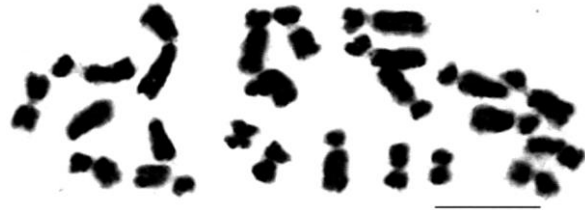
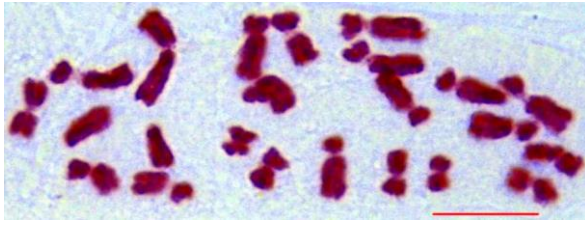


Figure 5.7: Scattered metaphase plate of CASH. (Bar is 10 μ m)

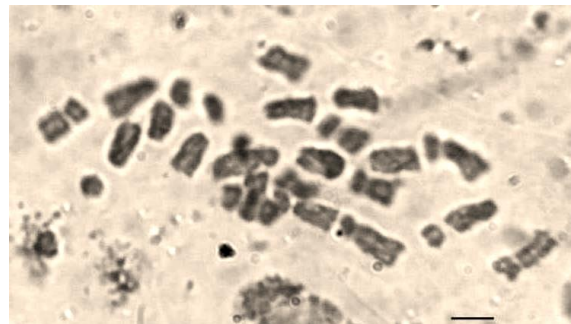


Figure 5.8: Scattered metaphase plate of CASU. (Bar is 10 μ m)

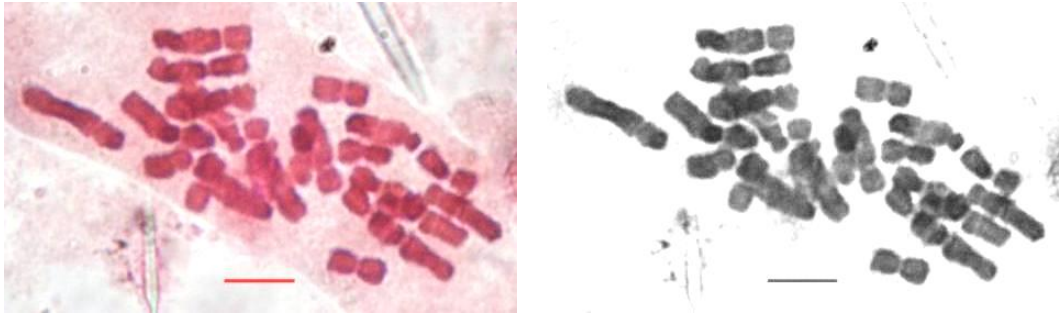


Figure 5.9: Scattered metaphase plate of CLAS. (Bar is 10 μ m)

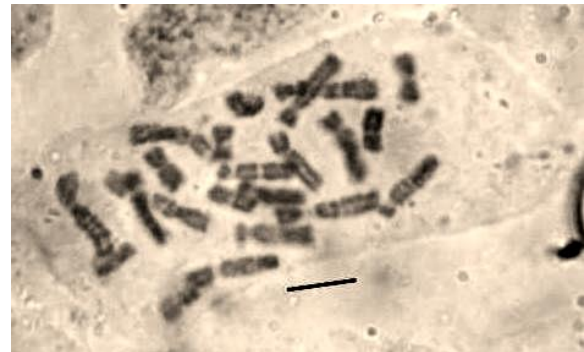


Figure 5.10: Scattered metaphase plate of CLBA. (Bar is 10 μ m)

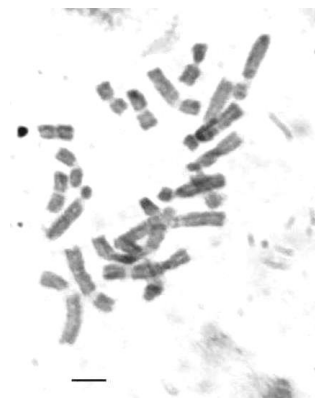


Figure 5.11: Scattered metaphase plate of CLGA. (Bar is 10 μ m)

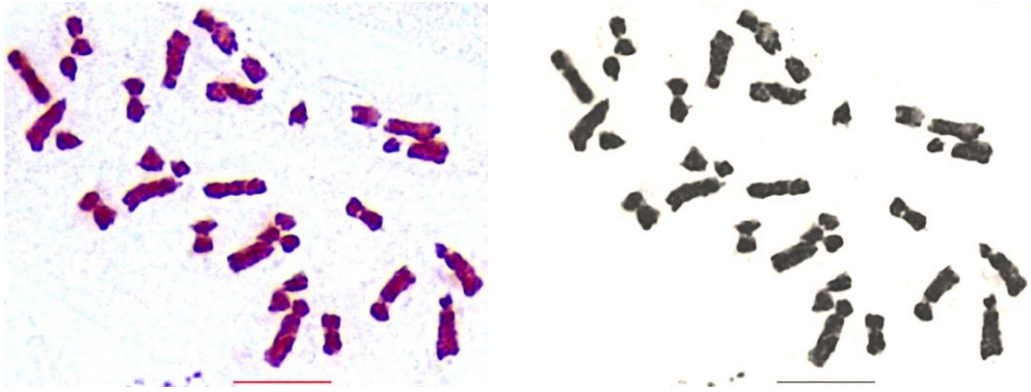


Figure 5.12: Scattered metaphase plate of CLKA. (Bar is 10µm)

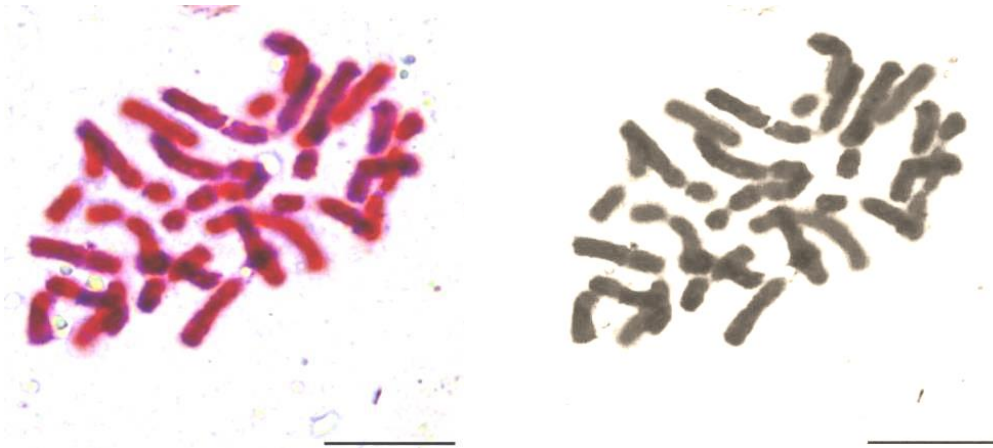


Figure 5.13: Scattered metaphase plate of CLKO. (Bar is 10µm)

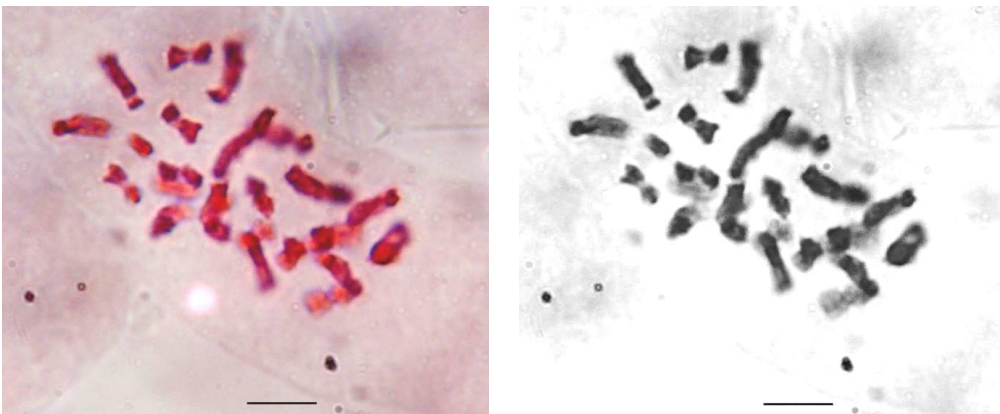


Figure 5.14: Scattered metaphase plate of CLNA. (Bar is 10µm)

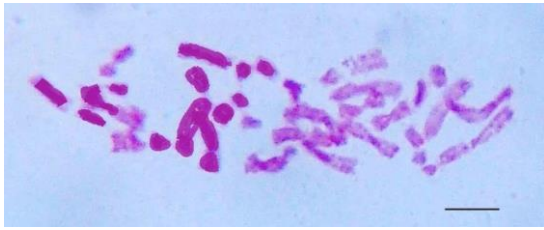


Figure 5.15: Scattered metaphase plate of CLOD. (Bar is 10 μ m)

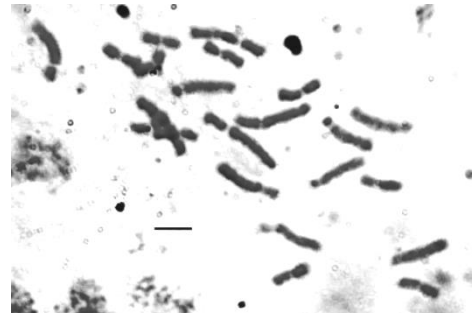
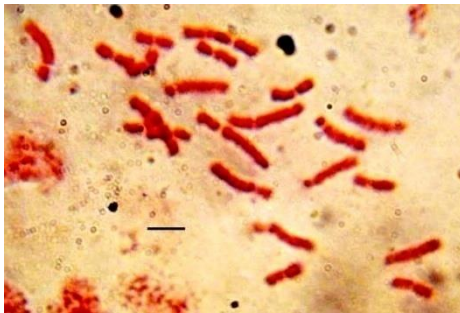


Figure 5.16: Scattered metaphase plate of CLPA. (Bar is 10 μ m)

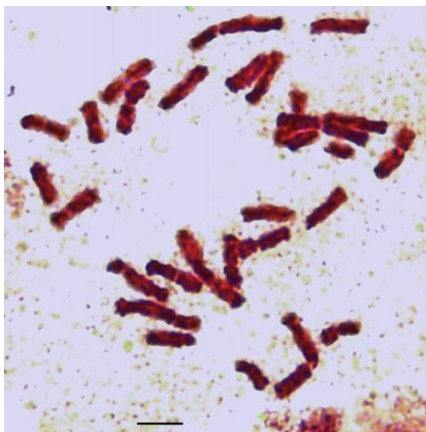


Figure 5.17: Scattered metaphase plate of CLPU. (Bar is 10 μ m)

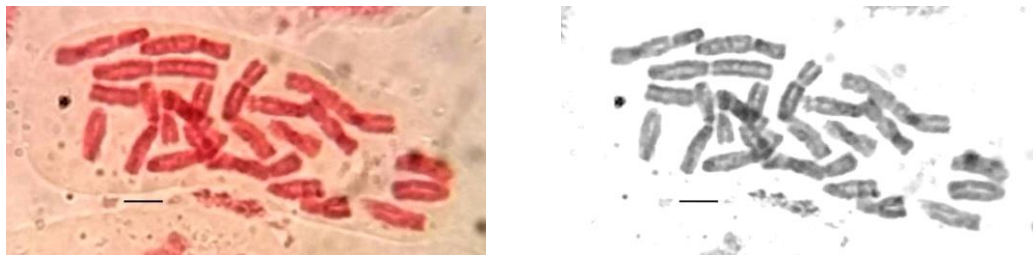


Figure 5.18: Scattered metaphase plate of CLSH. (Bar is 10µm)

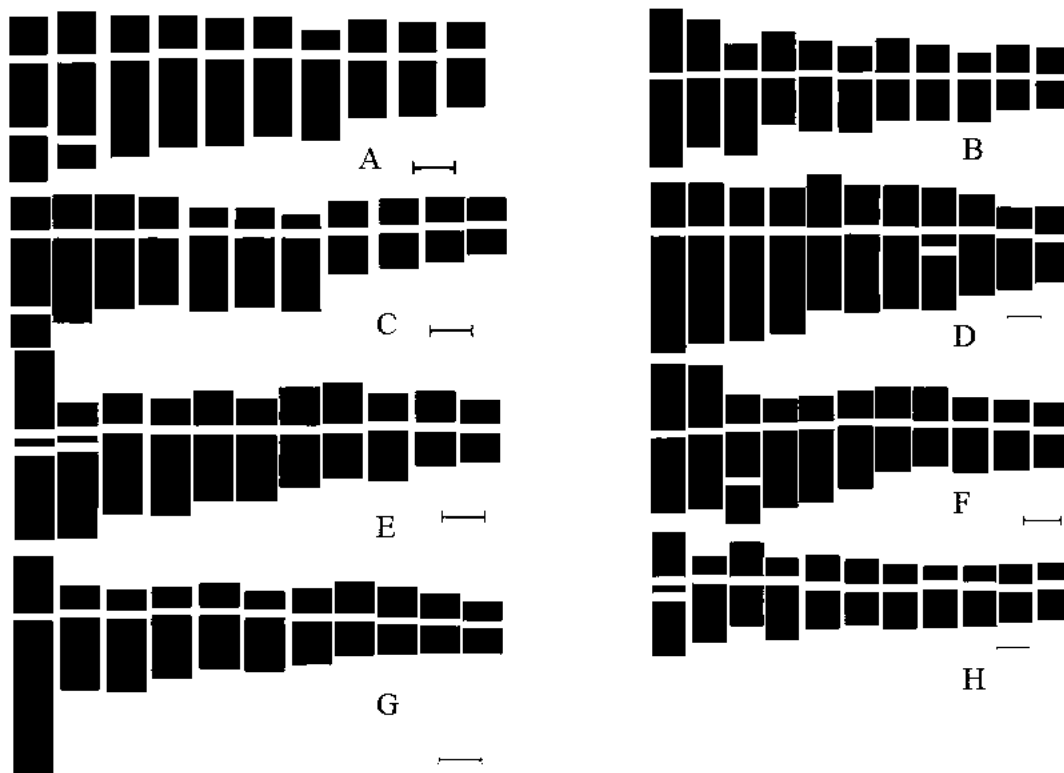


Figure 5.19: Ideogram of all the eight provenance of *C. asiaticum* L.

[A)- CAKO, B)CAMO, C) CANA, D) CANO, E) CAPA, F) CAPU, G) CASH and
H) CASU. Bar is 10µm]

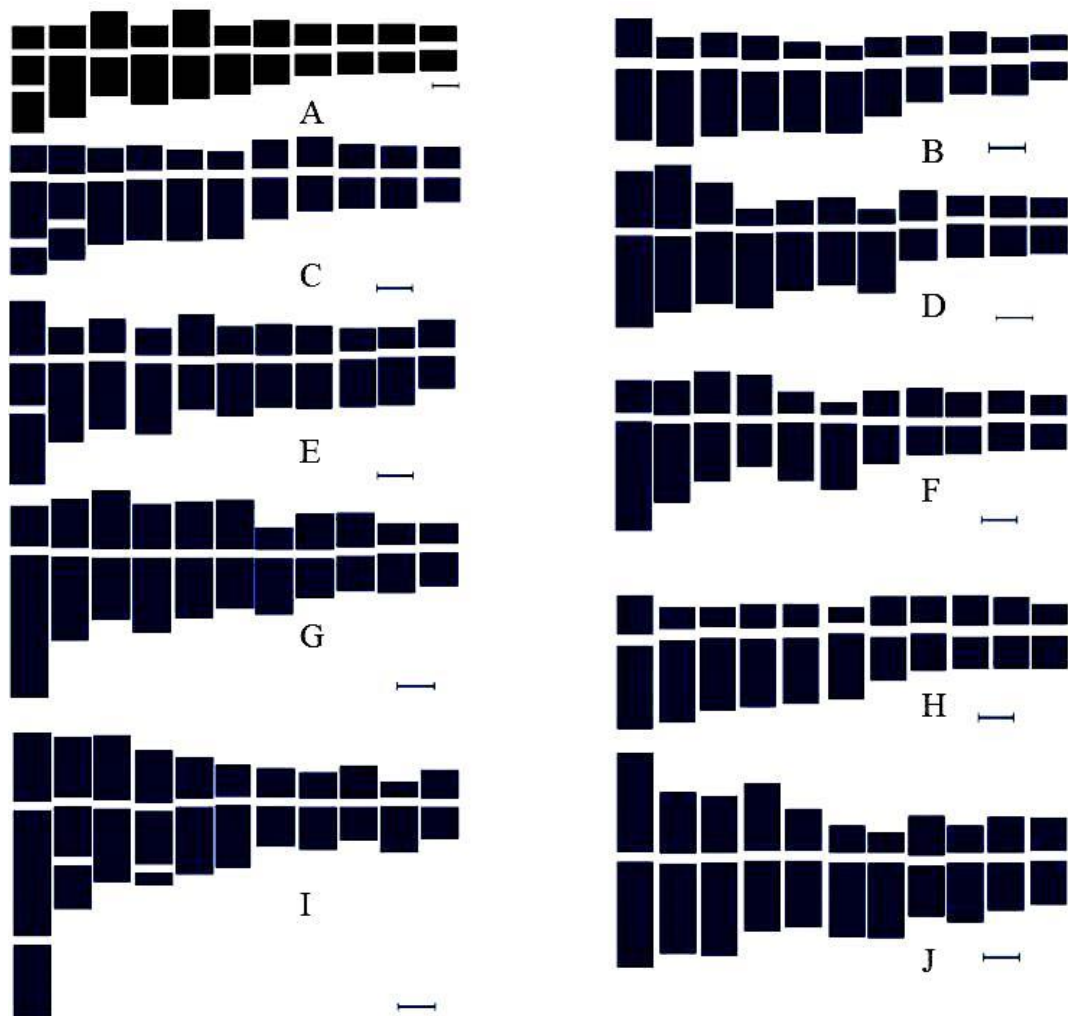


Figure 5.20: Ideogram of all the eight provenance of *C. latifolium*. [A)- CLAS, B)CLBA, C) CLGA, D) CLKA, E) CLKO, F) CLNA, G) CLOD, H) CLPA, I) CLPU and J) CLSH. Bar is 10 μ m]

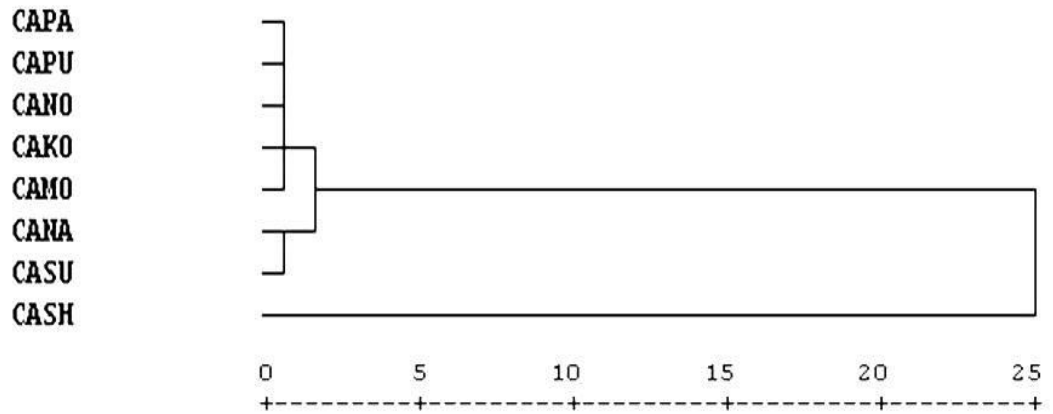


Figure 5.21: Dendrogram of eight provenances of *Crinum asiaticum* L.

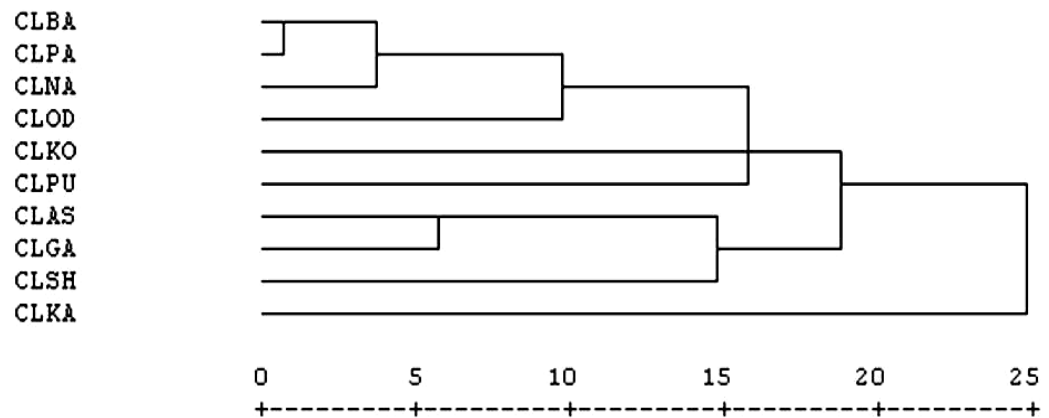


Figure 5.22: Dendrogram of ten provenances of *Crinum latifolium* L.

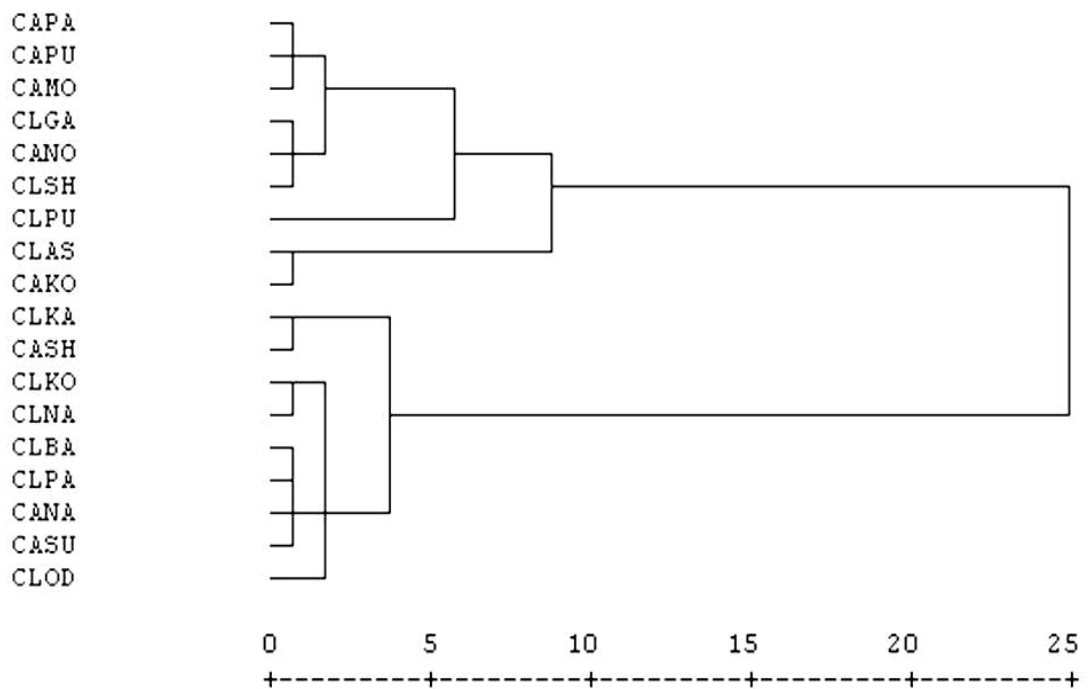


Figure 5.23: Dendrogram of eight provenances of *Crinum asiaticum* L. and ten provenances of *Crinum latifolium* L.

Discussion

Karyo-morphological study of both species has revealed that the studied provenances equally have $2n=22$ with basic chromosome number $x=11$. These numbers comply with earlier reports (Sharma and Ghosh 1954, Raina and Khosol 1971, Patwar and Zaman 1975), however, contrasting reports claiming the diploid somatic chromosome as 33 (VizayaValli and Mathew 1992, Ahamed et al. 2014). Presence of such variation indicates the occurrence of different ploidy to play in course of evolution of the species under this genus. Some earlier workers had also reported the existence of polyploidy in the species of the genus (Bose 1965, Sharma and Bhattacharya 1956, Raintakhos 1971). However, such variation does not seem to violate the base number. Karyotype studies have revealed all the provenances of both of the species to have asymmetric type of karyotype but with considerable difference in chromosomal lengths of related individuals of same species, which is also supported by earlier records (Johnes and Smith 1967, Raina and Khosu 1971, Laksmi 1980, Lekhak and Jadav 1911, Meerow et al. 2003, Ahamed et al. 2004, Dolai and Nandi 2020). Many earlier reports have registers series of polyploidy numbers for the different species and genus (Bose 1965, Walstrom and Lani 1979, Sharma and Bhattacarya 1956). In the present study have found that among the eight provenances of *Crinum asiaticum* L. total form percentage (TF %) range between 31.39 to 38.04 and relative length percentage (RL %) varies from 03.85 to 04.55. Provenances of same species have shown different karyotypes in respect of total chromosome length of haploid complement, centromeric index, short and long arm ratio of the chromosome, degree of karyotype asymmetry symmetry index etc. (Table 5.2, 5.4, 5.16). The detail

karyotype analysis of different provenances of *C. latifolium* L. also showed the diversity in respect to different chromosomal parameters like form percent (F %), length of chromosome symmetry and asymmetry index and class symmetry index followed by Stebins (Table 5.2, 5.4 - 5.16). The same species collected from different bio-geographical provenances have shown different chromosomal features and karyotype formulae of both of the species have expressed their diversity in chromosome morphology, as it was also apparent in showing ideograms (Figures 19 and 20). On the basis of the position of centromere, the chromosomes were classified into different name (Table 5.1).

In both the species, karyotypes were moderately symmetrical and both fell into the 2B and 2C category of Stebbins (1971). Most of the karyotypes in the genus *Crinum* L. fall in 2B and only a few in 3B category (Raina and Khoshoo 1971) which depicted that karyotypes are moderately or reasonably symmetrical. The similarity in the chromosome number of two species, but with certain morphological variations indicates that certain nominal changes in chromosome morphology might have played role in speciation within the genus. Dendrograms prepared for both of species with the help of different parameters of chromosome have shown plausible relationship among them. It is noted that provenance of CAPA, CAPU, CANO, CAKO and CAMO of *C. asiaticum* have been found in same clade, whereas, CANA and CASU differ from the rest and *C. asiaticum* of Shillong is totally different from rest seven provenances (Figure 21). Whereas, ten provenances of *C. latifolium* are separated in five different clades, among them only *C. latifolium*, collected from Kashmir, is totally different from others (Figure 22).

Conclusion:

The detail chromosomal study concludes that subtle variations in respect of detail chromosome morphology in both of the species *C. asiaticum* L. and *C. latifolium* L. Different chromosomal morphologies revealed for different provenances of the same species may indicate towards different cytotypes, under progress, in these two species in future. Such variation being recorded for the provenances from different regions of the country may highlight the role of different eco-physiological conditions on chromosomal morphology. Presence of such variation at infraspecific level may prove to be quite worthy, too, in having its manifestation in different levels of useful traits, and such variations may be effective in practicing selection amongst the provenances of same species, in search of the provenance with best or better attributes.