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RESEARCH ARTICLE

KARYOMORPHOLOGICAL ANALYSIS OF SOME EDIBLE AROIDS OF UPPER BRAHMAPUTRA VALLEY OF ASSAM

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SUMMARY Aroids (Araceae) locally known as '*Kachu*' are among the most favoured edible plants throughout Assam. Karyomorphology of 16 collections belonging to 10 species of edible aroids of Upper Brahmaputra Valley of Assam has been studied. The species included here are, *Alocasia macrorrhizos* (L.) G. Don (2n = 42), *A. odora* (Roxburgh) K. Koch (2n = 28), *Amorphophallus bulbifer* (Roxb.) Blume (2n = 26), *Colocasia antiquorum* Schott (2n = 56), *C. esculenta* (L.) Schott (2n = 28, 42, 56), *Cyrtosperma merkusii* (Hassk.) (2n = 26), *Lasia spinosa* (L.) Thwaites (2n = 26, 28), *Steudnera assamica* Hook. f. (2n = 28), *Typhonium trilobatum* (L.) Schott (2n = 26) and *Xanthosoma sagittifolium* (L.) Schott (2n = 26). The lowest and highest diploid chromosome numbers in the taxa studied here are, 2n = 26 and 56 respectively and the intervening numbers being 2n = 28 and 42. Intraspecific variations in chromosome number and evolutionary significance of karyotypes are discussed. Satellite markers were not observed in the accessions.

Keywords: Edible aroids, karyomorphology, aneuploidy, polyploidy, Assam.

INTRODUCTION

Aroids (Araceae) colloquially known as *Kachu*, are one of the most important and favoured edible plants of not only the people of Upper Brahmaputra Valley of Assam but the entire Northeast India. This family has 8 subfamilies, 119 genera and 6450 species distributed mostly in tropical and subtropical regions (Mabberley 2017).

Chromosome data are known to be of taxonomic value and found to be essential in studies focusing on diversification (Stebbins 1971). Karyomorphological features also play an important role in determining the taxonomic status of the species as they help in the study of plant systematics and evolution (Clark & Wall 1996). When different taxa showed the same chromosome number and karyotypic features, then it is very problematic to distinguish between them by conventional cytological analysis (Sultana et al. 2011). Hence, there is a need to generate more cytological and morphological information which will be helpful in examining relationships within the species as well as in the genera (Sheffer & Croat 1983).

Various works have been done on cytological and karyomorphological features of Aroids both in edible and as well as in wild varieties by many workers from India and aboard viz., Alam & Deen (2002), Bhattacharyya (1957), Begum et al. (2009), Chen et al. (2007), Coastes et al. (1988), Cotias-de-Oliveira et al. (1999), Cusimano et al. (2012), D'Emerico et al.(1993), Das et al. (2015), Delay (1951), Fu-Hua et al. (2001), Ghimire et al. (2012), Hore & Tanti (2014), Ito (1942), Kawahara (1978), Kurakubo (1940), Kuruvilla et al.(1981), Lakshmanan et al. (2015), Lukhtanov et al. (2011), Mookerjea (1955), Okada & Hambali (1989), Parvin et al.(2008), Petersen (1989), Pfitzer (1957), Rao (1947), Sharma & Das (1954), Sharma & Datta (1961), Sreekumari & Mathew (1991a, b), Yang et al. (2003), Yen & Wheeler (1968).

Different species of edible aroids were collected from the study area and identified based on their morphological features. Due to their phenotypic plasticity (Sultana et al. 2011) it is very difficult to reach authentic identification as they show morphological variations in different environmental conditions. The present study deals with chromosome number and morphology of 10 species of edible aroids viz., *Alocasia macrorrhizos* (L.) G. Don, *A. odora* (Roxburgh) K. Koch, *Amorphophallus bulbifer* (Roxb.) Blume, *Colocasia antiquorum* Schott, *C. esculenta* (L.) Schott, *Cyrtosperma merkusii* (Hassk.), *Lasia spinosa* (L.) Thwaites, *Steudnera assamica* Hook. f., *Typhonium trilobatum* (L.) Schott and *Xanthosoma sagittifolium* (L.) Schott.

MATERIALS AND METHODS

The materials for cytological analysis were collected from different places of Upper Brahmaputra Valley of Assam (Jorhat, Golgahat, Sivasagar, Charaideo, Dibrugarh and Tinsukia) and were cultivated in home gardens. Karyo-morphological investigations were carried out using the root tips of the accessions. For the study of somatic chromosomes, methods used by Sharma & Sharma (1980), Sreekumari & Mathew (1991a), Yang et al. (2003) and Zhang et al. (2010) were followed. The root tips were collected from the plants between 5:00 and 8:30 A.M. and washed them thoroughly with running water and then pretreated in paradichlorobenzene at room temperature for two and a half h or an ice water mixture solution for 24 h at 4° C. The root tips were fixed in freshly prepared Carnoy's solution (60% ethanol, 30% chloroform and 10% glacial acetic acid) for 24 h. After fixation, the root tips were washed with 70% alcohol and finally stored in 70% alcohol. Root tips were also directly fixed in Carnoy's solution without pretreatment in para-dichlorobenzene which had an advantage as they produce a clear picture in photographs of metaphase chromosomes instead of hazy appearance in pretreated materials. Moreover, the chromosome condensation was better and centromeres were easily recognized (Zhang et al. 2010). Therefore, root tips without pretreatment of paradichlorobenzene were used during the investigation.

The hydrolysis of the cells of root tips was done with a mixture of 1N HCl for 30 min at room temperature (25^0 C) and washed it with distilled water for four times. The materials were then stained in 1.5% aceto-orcein for 20 min. The deeply stained meristematic parts of the root tips were excised out and placed in a drop of 45 % acetic acid on a clean slide and squashed. For uniform dissociation of cells, gentle pressure with the thumb finger was applied on the coverslip and

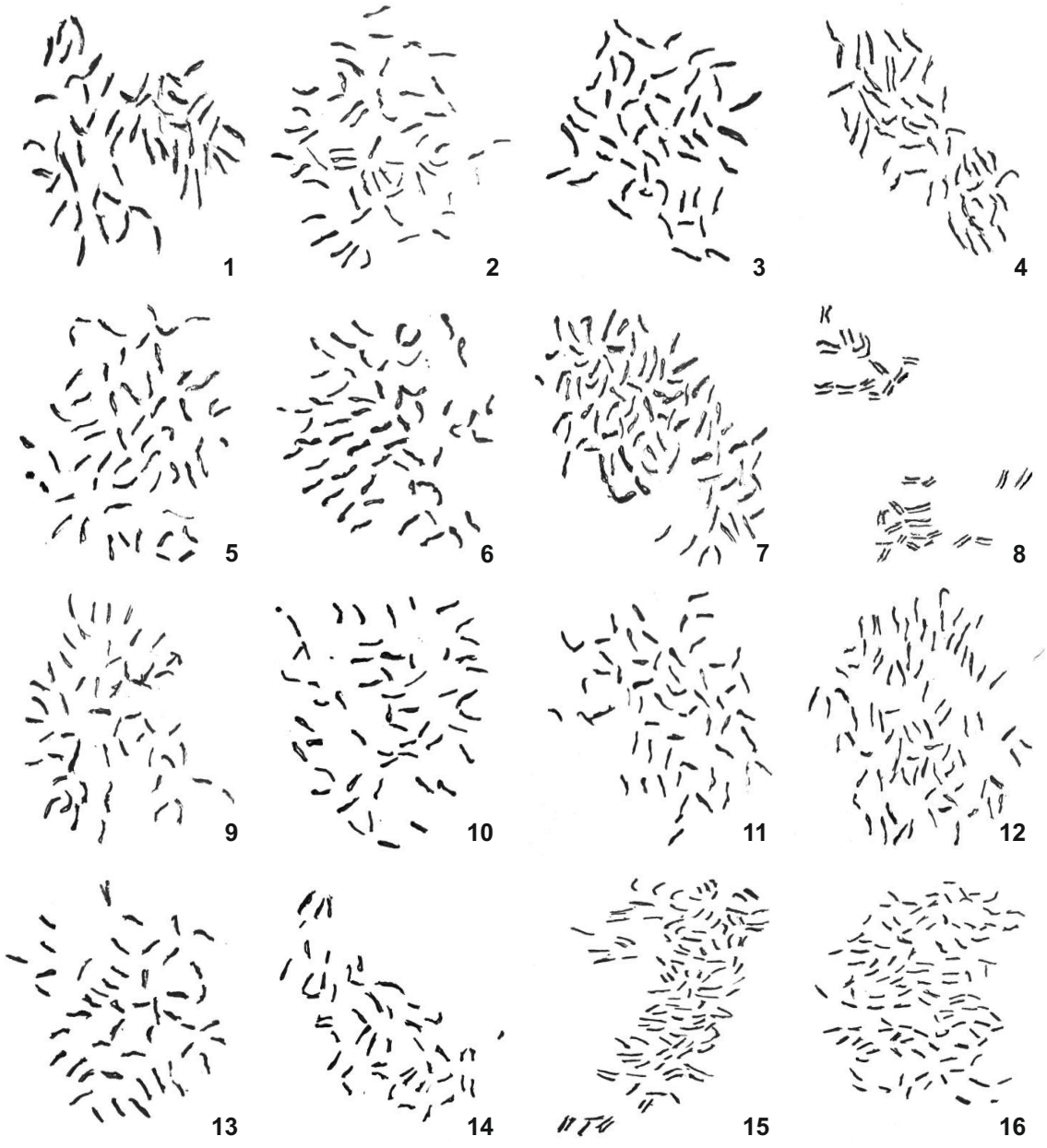
finally sealed with paraffin wax. The temporary preparations were observed under a compound microscope (Olympus CH20i). Well spread metaphase plates were selected for karyomorphological analysis of chromosomes. The measurements of the chromosome lengths were taken with the help of stage and ocular measurements (Govindarajan & Subramanian 1983, 1985). The mean length was calculated for each chromosome pair. Measurements of chromosome arms were based on three metaphase plates. In the present investigation the total complement length (TCL), arm ratio, gradient index, chromosome volume, TF%, relative length of chromosomes, asymmetry index, mitotic index and phase index were calculated following established standard procedure (Arano 1963, Arano & Saito 1980, Battaglia 1957a 1957b, Bora 1998, Deogade & Nasare 2016, Khosla & Sobti 1985, Levan et al. 1964, Li & Chen 1985, Pritchard 1967).

The chromosomes were classified according to the classifications followed by Tanaka (1971, 1977, 1980). Karyotype formulae were derived on measurements of metaphase chromosomes from photomicrographs. On the basis of length, chromosomes were categorized into Type A (>4.00 μm), Type B (3.00–4.00 μm), Type C (2.00–2.99 μm), Type D (1.00–1.99 μm) and Type E (< 0.99 μm). Based on the centromeric position, the chromosomes were classified into median (M), metacentric (m), sub-metacentric (sm), subtelocentric (st) and telocentric (t). Karyotype analysis and symbols for the description of chromosomes were done by following the system proposed by Levan et al. (1964). Karyotype symmetry was determined by the method proposed by Stebbins (1971). Idiograms of each accession was prepared by arranging the haploid set of chromosomes in order of decreasing length (Battaglia 1955, Stebbins 1971).

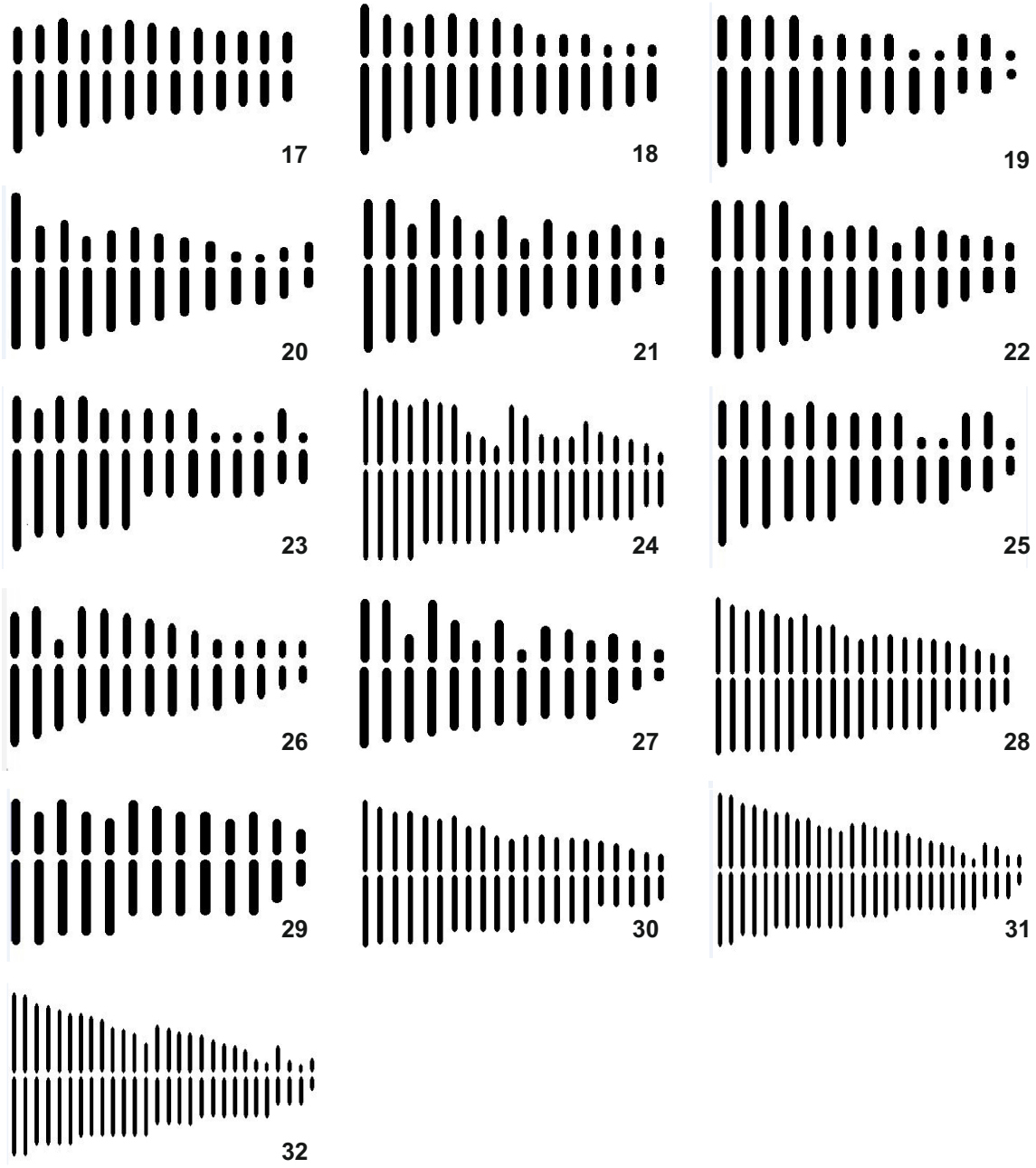
OBSERVATIONS

The chromosomes at mitotic metaphase of 10 species were examined (Figs 1–16). The karyomorphological characteristics of the accessions are summarized in Tables 1 and 2. Idiograms are given in Figs 17–32. Four different diploid chromosome numbers of 26, 28, 42 and 56 have been observed and in two species intraspecific variation in chromosome number has been noticed.

In *Amorphophallus bulbifer*, *Cyrtosperma merkusii*, *L. spinosa* (A1), *T. trilobatum*. and *X. sagittifolium* the diploid number was found to be 26. In *Alocasia odora* (A9), *Colocasia esculenta* (A5–7), *L. spinosa* (A2), and *S. assamica* the diploid number was found to be 28. In *Alocasia macrorrhizos* (A8) and *Colocasia esculenta* (A12) the diploid number was found to be 42 while in *Colocasia antiquorum* (A15) and *C. esculenta* (A16) the highest number of chromosomes 2n = 56 has been observed. The total complement length of 539.7 μm is highest in accession A12 of *C. esculenta* and lowest in *L. spinosa* (A1) with 78.65 μm. The chromosome length varies from 24.6 to 6.00 μm in *C. esculenta* (A12) and *L. spinosa* (A1), respectively. The mitotic index was highest in A7 of *C. esculenta* with 61.65% and lowest of 45.27% in A5 of *C. esculenta*. The phase index is highest in A5 of *C. esculenta* with 220.91% and lowest of 162.20% in A7 of *C. esculenta* whereas the karyotypic asymmetry index is highest in A16 of *C. esculenta* with 64.43% and lowest in A12 of *C. esculenta* with 52.97%. The size gradient within the genome i.e., gradient index is lowest (14.49%) in accession A11 of *S. assamica* and highest (49.02%) in A1 of *L. spinosa*.



Figs 1–16: Somatic chromosomes of edible aroids. 1. *L. spinosa* (A1). 2. *L. spinosa* (A2). 3. *Cyrtosperma merkusii* (A3). 4. *T. trilobatum* (A4). 5. *Colocasia esculenta* (A5). 6. *C. esculenta* (A6). 7. *C. esculenta* (A7). 8. *Alocasia macrorrhizos* (A8). 9. *A. aodora* (A9). 10. *C. esculenta* (A10). 11. *Steudnera assamica* (A11). 12. *C. esculenta* (A12). 13. *Amorphophallus bulbifer* (A13). 14. *Xanthosoma sagittifolium* (A14). 15. *C. antiquorum* (A15). 16. *C. esculenta* (A16).



Figs. 17–32: Idiograms. 17. *L. spinosa* (A1). 18. *L. spinosa* (A2). 19. *Cyrtosperma merkusii* (A3). 20. *T. trilobatum* (A4). 21. *Colocasia esculenta* (A5). 22. *C . esculenta* (A6). 23. *C. esculenta* (A7). 24. *Alocasia macrorrhizos* (A8). 25. *A. odora* (A9). 26. *C. esculenta* (A10). 27. *Steudnera assamica* ((A11). 28. *C. esculenta* (A12). 29. *Amorphophallus bulbifer* (A13). 30. *Xanthosoma sagittifolium* (A14). 31.*C. antiquorum* (A15). 32. *C. esculenta* (A16).

TABLE 1: Karyotypic data of 16 accessions of edible aroids.

Sl. No.	Species	Local name	Place of collection	Accessions	2n	Chromosome length (µm)		TCL (µm)	TF %	Asymmetry index (%)	Mitotic index (%)	Phase index (%)	Gradient index (%)
						LA	SA						
1	*Alocasia macrorrhizos*	Maan Kachu	C, D, G, J, S , T	A8	42	18.0	4.5	466.5	42.12	57.92	55.05	181.66	24.17
2	*A. odora*	Dahi/Shillong Kachu	C, D, G, J, S , T	A9	28	13.5	3.0	231.0	37.66	62.34	58.75	170.21	22.22
3	*Amorphophallus bulbifer*	Ol Kachu	C, D, G, J, S , T	A13	26	12.0	3.0	205.5	39.42	60.58	53.47	187.02	33.33
4	*Colocasia antiquorum*	Mukhia Kachu	C, D, G, J, S , T	A15	56	9.0	3.0	316.0	38.86	61.14	58.10	172.10	33.33
5	*C. esculenta*	Ahinia Kochu	C, D, G, J, S , T	A7	28	15.0	6.0	234.0	35.9	64.10	61.65	162.20	30.00
6	*C esculenta* (with Light Brown Petiole)	Teli Kachu	C, D, G, J, S , T	A10	28	10.0	3.0	181.1	38.16	61.84	61.08	163.71	25.00
7	*C. esculenta* (with Light Green Petiole)	Pani Kachu	C, D, G, J, S , T	A5	28	10.5	3.0	194.2	39.44	60.56	45.27	220.91	28.57
8	*C. esculenta* (with Purple Petiole)	Nil Kochu	C, D, G, J, S , T	A6	28	12.0	2.5	209.6	40.55	59.45	54.73	182.73	23.53
9	*C. esculenta* (with Green Petiole)	Kachu	C, D, G, J, S , T	A12	42	18.9	5.7	539.7	47.03	52.97	50.43	198.29	30.16
10	*C. esculenta* (with Black Petiole)	Kolia/Kola Kachu	C, D, G, J, S , T	A16	56	8.7	3.0	317.1	35.57	64.43	51.99	192.33	34.48
11	*Cyrtosperma merkusii*	Aiti/Nol Kachu	C, S	A3	26	13.5	3.0	216.0	37.5	62.5	53.09	188.36	37.50
12	*Lasia spinosa*	Chengmora	C, D, G, J, S , T	A1	26	4.0	2.0	78.65	43.65	56.45	47.74	209.46	49.02
13	*L. spinosa*	Chengmora	C, D, G, J, S , T	A2	28	6.0	2.5	103.4	37.72	62.86	50.53	197.9	48.54
14	*Steudnera assamica*	Edalia Kachu	C, D, G, J, S , T	A11	28	14.25	3.0	246.0	40.24	59.76	49.84	200.63	21.05
15	*Typhonium trilobatum*	Chamakachu	C, D , S	A4	26	13.5	3.0	182.36	35.8	64.20	52.61	190.08	22.22
16	*Xanthosoma sagittifolium*	Bao Kachu	C, D, G, J, S , T	A14	26	12.0	4.5	207.6	35.93	60.58	49.96	200.17	25.00

C, Charaideo; D, Dibrugarh;G, Golaghat; J, Jorhat; S, Sivasagar; T, Tinsukia.

TABLE 2: Karyotype analysis in 16 accessions of edible aroids.

Sl. No.	Species	Accn No.	Karyotypic formula	Chromosome formula
1	*Alocasia macrorrhizos*	A8	$M_8 + m_{18} + sm_{14} + st_2$	$A_{42} + B_2$
2	*A. odora*	A9	$M_6 + m_{10} + sm_8 + st_4$	$A_{26} + B_2$
3	*Amorphophallus bulbifer*	A13	$M_8 + m_6 + sm_{12}$	$A_{26} + B_2$
4	*Colocasia antiquorum*	A15	$M_8 + m_{12} + sm_{16} + st_{20}$	$A_{54} + B_2$
5	*C. esculenta* (with Black Petiole)	A16	$M_2 + m_{12} + sm_{14} + st_{30}$	$A_{54} + B_2$
6	*C. esculenta* (with Green Petiole)	A12	$M_{10} + m_{32}$	A_{42}
7	*C. esculenta* (with Light Brown Petiole)	A10	$M_2 + m_{16} + sm_8 + st_2$	$A_{20} + B_8$
8	*C. esculenta* (with Light Green Petiole)	A5	$M_6 + m_{11} + sm_{10} + st_2$	$A_{26} + B_2 + C_2$
9	*C. esculenta* (with Purple Petiole)	A6	$M_2 + m_{16} + sm_{10}$	$A_{22} + B_4 + C_2$
10	*C. esculenta*	A7	$M_2 + m_{10} + sm_{16}$	A_{28}
11	*Cyrtosperma merkusii*	A3	$M_6 + m_8 + sm_8 + st_4$	$A_{24} + B_2$
12	*Lasia spinosa* Type I (Non –pinnatifid)	A1	$M_7 + m_{13} + sm_6$	$A_6 + B_8 + C_{12}$
13	*L. spinosa* Type II (Pinnatifid)	A2	$M_0 + m_{12} + sm_{16}$	$A_9 + B_{13} + C_6$
14	*Steudnera assamica*	A11	$M_4 + m_{12} + sm_6 + st_2$	$A_{26} + B_2$
15	*Typhonium trilobatum*	A4	$M_2 + sm_{16} + m_4 + st_4$	$A_{22} + B_4$
16	*Xanthosoma sagittifolium*	A14	$M_8 + m_6 + sm_{12}$	$A_{24} + B_2$

M, Median; m, metacentric; sm, submetacentric; st, subtelocentric.

TABLE 3: Chromosome numbers of edible aroids from Upper Brahmaputra Valley of Assam.

Sl. No.	Species and Accn No.	Present study		Previous reports	
		2n	x	2n	Authors
1	*Alocasia macrorrhizos* (A8)	42	14	28	Das (2018)
2	*A. odora* (A9)	28	14	56	Sultana et al. (2011)
3	*Amorphophallus bulbifer* (A13)	26	13	26	Chandler (1943)
				26	Hotta (1971)
				39	Marchant (1971b)
				39	Ramachandran (1977)
				39	Chauhan & Brandhan (1985)
				26	Kuruvilla et al. (1989)
				39	Shete et al. (2015)
4	*Colocasia antiquorum* (A15)	56	14	28	Kurakubo (1940)
				28	Ito (1942)
				28	Sharma & Das (1954)
				28, 42	Fedorov (1969)
5	*C. esculenta* (A7)	28	14	42	Nakajima (1936)
				42	Janaki Ammal (1945)
				36	Rao (1947)
				42	Mookerjea (1955)
				42	Rattenbury (1957)

(Contd)

TABLE 3: (Concluded)

Sl. No.	Species and Accn No.	Present study		Previous reports	
		2n	x	2n	Authors
				42	Pfitzer (1957)
				28, 42	Mace & Godwin (2002)
				14, 28, 36, 42, 48	Dastidar (2009)
				28	Wahidi & Nursyahra (2018)
6	*C. esculenta* (A16)	56	14	-	-
7	*C. esculenta* (A10)	28	14	-	-
8	*C. esculenta* (A12)	42	14	28	Alam & Deen (2002)
9	*C. esculenta* (A5)	28	14	28	Alam & Deen (2002)
10	*C. esculenta* (A6)	28	14	28	Alam & Deen (2002)
11	*Cyrtosperma merkusii* (A3)	26	13	-	-
12	*Lasia spinosa* (A1)	26	13	26	Sultana et al. (2006)
				24	Hore & Tanti (2014)
13	*L. spinosa* (A2)	28	14	28	Sultana et al. (2006)
				26	Hore & Tanti (2014)
14	*Steudnera assamica* (A11)	28	14	-	-
15	*Typhonium trilobatum* (A4)	26	13	18	Banerji (1947)
				26	Simmonds (1954)
				18	Sharma & Mukhopadhyay (1965)
				18	Subramanian & Munian (1988)
16	*Xanthosoma sagittifolium* (A14)	26	13	26	Janaki Ammal (1945)

DISCUSSION

Chromosomes are the carriers of genetic material in the nucleus and any changes in chromosome structure provide the basis of speciation (Landry & Aubin-Horth 2014, Muratovicc et al. 2010). The karyotype is the highest level of the structural and functional organization of chromosomes (Weiss-Schneeweiss & Schneeweiss, 2013). Karyotypic properties are conferred by evolutionary changes (Leitch et al. 2013) that result from natural selection (Petrov 2001) and may substantially influence plant performance (Cronk 2004). For many years, karyotypes have received much attention as an important cytological trait in modern-day research. Cytological data are widely used to explain the relationships of the species, whether they are intraspecific or interspecific and are used to validate the identification of a specimen (Hong & Zhang 1990, Raven 1975, Stebbins 1971). Cytological studies, especially the karyotypic data are very useful in plant systematics. Work done by Barua (1995), Khosla & Sobti (1985), Lombello & Fomi-Martins (2002), Madhusoodan & Nazeer (1983), Mathew & Mathew (1982), Muramoto et al. (2008) Raven & Kyhos (1965) and Subramanyam & Chowdary (1992) are very important in taxonomic delimitation of the plant species.

The present investigation reveals 2n = 28 in *A. odora* which is contrary to the previous reports of 2n = 56 by Sultana et al. (2011) suggesting the occurrence of diploid and tetraploid conditions in

one and the same species. Similarly, contrary to earlier report of 2n = 28 by Das (2018), in the present study, *Alocasia macrorrhizos* shows 2n = 42 indicating a triploid state on basic number of 14.

Amorphophallus bulbifer studied here revealed 2n = 26 as reported by Kuruvilla et al. (1989) on basic number 13. However, previous workers reported different chromosome numbers for *A. bulbifer*. Whereas Chandler (1943) and Hotta (1971) recorded 2n = 36, Chauhan & Brandhan (1983), Merchant (1971), Ramachandran (1977) and Shete et al. (2015) recorded 2n = 39 for this species.

Colocasia esculenta exhibits chromosomal instability. While studying 7 varieties of this species Parvin et al. (2008) reported 2n = 21 to 42 and Dastidar (2009) reported 2n=14, 28, 36, 42, and 48. However, in the present study, in 4 out of 6 accessions studied, the diploid number of 28 has been found as reported by Alam & Deen (2002) and Wahidi & Nursyahra (2018); the other two accessions showed 2n = 42 and 56. While the former is in the conformity with previous reports by Dastidar (2009), Mace & Godwin (2002) and Parvin et al. (2008), 2n = 56 reported here is a new record for this species. In *C. antiquorum*, present study revealed 2n = 56 for the first time deviating from the earlier reports of 2n = 14, 28 and 42 (Ito 1942, Kurakubu 1940, Sharma 1956, Sharma & Das 1954). These variations in chromosome number of *Colocasia* species show that they are polymorphic, allogamous and protogynous species (Quero-Garcia et al. 2006).

In *L. spinosa* Hore & Tanti (2014) reported 2n = 24 and 26 and Sultana et al. (2006) reported 2n = 24 and 27. But our studies show 2n = 26 in the accession A1 and 28 in the accession A2 indicating intraspecific variation of chromosome number.

Typhonium trilobatum studied here revealed 2n = 26 as reported by Simmonds (1954) which differs from earlier reports of 2n = 18 by Banerji (1947) and Sharma & Mukhopadhyay (1965).

The total complement length (TCL) of all 16 accessions ranged from 78.65 µm to 539.70 µm. According to Stebbins (1950), a decrease in TCL is one of the factors indicating the trend for evolution. Thus, *L. spinosa* (A1) may be considered as the most advanced and *Colocasia esculenta* (A16) as primitive among all the accessions studied. Based on TF% *T. trilobatum* may be considered as most advanced and *Colocasia esculenta* (A12) as most primitive. Metacentric chromosomes are predominant in the karyotypes of all the accessions. According to Stebbins (1971) the abundance of metacentric chromosomes is characteristic of symmetrical karyotype which is primitive in nature. On the other hand, the species having asymmetrical karyotype is supposed to be more advanced than symmetrical ones (Stebbins 1950). Generally, karyotype shows a shift from symmetry to asymmetry in higher plants (Stebbins 1971). Primitive species mostly have a symmetrical type of karyotypes, whereas the advanced plant species show the asymmetrical type of karyotypes. If the karyotype asymmetry index is close to or equal to 50%, the karyotype symmetry is considerably higher, and the karyotype is considered as most primitive. The karyotype analysis of 16 accessions of edible aroids show

karyotype asymmetry index (As.K %) which ranges from 52.97% to 64.43%. Therefore, the karyotype symmetry is high. More cytological analysis in a larger number of edible aroids is important for establishing the basic number of chromosomes and for understanding trends in chromosome evolution within the species (Cotias-de-Oliveira et al. 1999).

In *Colocasia esculenta* with variable chromosome numbers, 2n = 26, 28, 42 and 56, are well supported by their colour of the petioles, while the difference in leaf morphology of *L. spinosa* are well supported by their chromosomal counts of 2n = 26 and 28. Hence, they may be called *C. esculenta* with light green petiole Type I, *C. esculenta* with purple petiole Type II, *C. esculenta* with light brown petiole Type III, *C. esculenta* with green petiole Type IV and *C. esculenta* with black petiole Type V while *L. spinosa* non–pinnatifid Type I and *L. spinosa* pinnatifid Type II, respectively. Further studies relating to chemotaxonomy, molecular taxonomy, palynology, etc. are needed in these taxa to decide the taxonomic status of these morphotypes.

Variation of chromosome numbers among the genera (Table 3), suggests that there is an increase in chromosome number in some phyletic lines to a higher level of ploidy in *C. esculenta* and *L. spinosa* while in some it has reduced which may be due to the spontaneous mutation occurring in the accessions (Mayo et al. 1997). According to Petersen (1989) the basic chromosome numbers of 14 or 12 may be the starting points for all the chromosome numbers known in Araceae due to aneuploid changes at the diploid as well as polyploid levels.

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REFERENCES

ALAM SK S & DEEN S S 2002 Karyotype and isozyme analysis in three forms of *Colocasia esculenta* (Araceae) *Bangladesh J Bot* **31** 95–98

ARANO H 1963 Cytological studies in subfamily Carduoideae (Compositae) of Japan IX The karyotype analysis and phylogenic considerations on *Pertya* and *Ainsliaea Bot Mag* (Tokyo) **76** 32–39

ARANO H & SAITO H 1980 Cytological studies in family Umbelliferae 5 Karyotypes of seven species in the subtribe Seselinae *Kromosomo* **2** 471–480

BANERJI I 1947 Life history of *Typhonium trilobatum* Schott *Proc Nat Inst Sci Ind* **13** 207–230

BARUA P K 1995 Karyomorphological studies of seven *Albizzia* species used in tea plantations of North-East India *Indian Soc Genet Pl Br* **3** 1441–1448

BATTAGLIA E 1955 Chromosome morphology and terminology *Caryologia* **8** 179–187

BATTAGLIA E 1957a A new<<5 minutes-fixation» in chromosome analysis *Caryologia* **9** 368–370

BATTAGLIA E 1957b A simplified Feulgen method using cold hydrolysis *Caryologia* **9** 372– 373

BEGUM K N & ALAM S K S 2009 Karyotype analysis in three morphological forms of *Colocasia fallax* Schott *Cytologia* **74** 209–214

BHATTACHARYYA U C 1957 Karyotypic variation in *Scindapsus officinalis* Schott (Aroideae) *Caryologia* **9** 286–292

BORA J 1998 *Cytogenetics of the genus Clerodendrum L Studies on karyomorphology and nuclear DNA in certain species* Ph D Thesis Gauhati University

CHANDLER C 1943 The number of chromosomes in two species of *Amorphophallus Bull Torrey Bot Cl* **70** 612–614

CHAUHAN K P S & BRANDHAN P E 1985 Chromosome and DNA variation in *Amorphophallus* (Araceae) *Kew Bull* **40** 745–758

CHEN A ZHUANG M & HUANG M 2007 Karyotype of the two species of genus *Dieffenbachia* (Araceae) *Acta Botanica Yunnanica* **29** 441–443 http//europepmcorg/abstract/cba/641938

CLARK M S & WALL W J 1996 *Chromosomes the complex code* Chapman & Hall London

COATES D J, YEN D E & GAFFE P M 1988 Chromosome variation in Taro *Colocasia esculenta* Implications for origin I the pacific *Cytologia* **53** 551–560

COTIAS-DE-OLIVEIRA A L P, GUEDES L S M & BARRETO C E 1999 Chromosome numbers for *Anthurium* and *Philodendron* spp (Araceae) occuring in Bahia Brazil *Genet Mol Bio* **22** 237–242

CRONK Q C 2004 *Plant adaptation molecular genetics and ecology* NRC Research Press Ottawa

CUSIMANO N, SOUSA A & RENNER S S 2012 Maximum likelihood inference implies a high not a low ancestral haploid chromosome number in Araceae with a critique of the bias introduced by 'x' *Ann Bot* **109** 681–692 doi 101093/aob/mcr302

DAS A B, DAS A, PRADHAN C & NASKAR S K 2015 Genotypic variations of ten Indian cultivars of *Colocasia esculenta* var *antiquorom* Schott evident by chromosomal and RAPD markers *Caryologia* **68** 44–54

DAS B N 2018 Karyomorphological studies in three species of *Alocasia* (Schott) G Don An ethno-medicinally and economically important genus *Int J Life Sci Scienti Res* **4** 2116–2121

DASTIDAR S G 2009 *Colocasia esculenta An account of its ethnobotany and potentials* M Sc Thesis University of Texas

DELAY J 1951 Nombreschromosomiques chez les phanéorgames *Rev Cytol Biol Végét* **12** 1–368

D'EMERICO S, BIANCO P & MEDAGLI P 1993 Chromosome numbers and karyotypes in *Arum* (Araceae) *Caryologia* 161–170

DEOGADE S D & NASARE P N 2016 Mitotic index and phase index in Agrifound White and Yamuna Safed varieties of *Allium sativum* Linn *J Cytol Genet* **17** (NS) 1–6

FEDOROV A 1969 *Chromosome numbers of flowering plants* V L Komarov Botanical Institute Leningrad

FU-HUA B, ZHONG-LANG W, HENG L & KAI-YUN G 2001 Karyotypic studies on two species in the genus *Sauromatum* (Araceae) [J] *Acta Botanica Yunnanica* **4** 011 http//encnkicom cn/Article_en/CJFDTOTAL-YOKE200104011htm

GHIMIRE B K, YU C Y, KIM H J & CHUNG I M 2012 Karyotype and nucleic acid content in *Zantedeschia aethiopica* Spr and *Zantedeschia elliottiana* Engl *Afr J Biotech* **11** 11604–11609

GOVINDARAJAN T & SUBRAMANIAN D 1983 Karyomorphological studies in South Indian Acanthaceae *Cytologia* **48** 491–504

GOVINDARAJAN T & SUBRAMANIAN D 1985 Karyomorphological studies in South Indian Acanthaceae *Cytologia* **50** 473–482

HONG D Y & ZHANG S Z 1990 Observations on chromosomes of some plants from western Sichuan *Cathaya* **2** 191–197

HORE P & TANTI B 2014 Karyomorphological studies of two morphotypes of *Lasia spinosa* (Lour) Thwaites avaiable in Assam India *Ann Pl Sci* **3** 792–796

HOTTA M 1971 Study of the family Araceae general remarks *Jap J Bot* **20** 269–310

ITO T 1942 Chromosomen und sexualität von der Araceae I Somatische Chromosomenzahleneiniger Arten *Cytologia* **12** 313–325

JANAKI AMMAL E K 1945 *Chromosome atlas of cultivated plants* George Allen & Unwin London

JQ Y E, JIA Y Y, FAN K, SUN X J & WANG X M 2014 Karyotype analysis of *Rheum palmatum Genet Mol Res* **13** 9056–9061

KAWAHARA T 1978 Chromosome number of Taros in Nepal and India *Chrom Inf Serv* **24** 4–5

KHOSLA M K & SOBTI S N 1985 Karyomorphological studies in genus *Ocimum* II Sanctum group *Cytologia* **50** 253–263

KURAKUBO Y 1940 Über die chromosomenzahlen von Araceae-Arten *Bot Zool* (Tokyo) **8** 1492

KURUVILLA K M & SINGH A 1981 Karyotypic and electrophoretic studies on taro and its origin *Euphytica* **30** 405–413

KURUVILLA K M, DUTT B & ROY R P 1989 Karyomorphological investigations on aroids of north-eastern hills *J Cytol Genet* **24** 13–22

LAKSHMANAN P S, VAN L K, EECKHAUT T, HUYLENBROECK J V, BOCKSTAELE E V & KHRUSTALEVA L 2015 Karyotype analysis and visualization of 45S rRNA genes using fluorescence *in situ* hybridization in aroids (Araceae) *Comp Cytogen* **9** 145–160

LANDRY C R & AUBIN-HORTH N 2014 *Advances in experimental medicine and biology* Springer Dordrecht

LEITCH I J, GREILHUBER J, DOLEZEL J & WENDEL J F 2013 *Plant Genome Diversity* Volume **2** Springer-Verlag Wien

LEVAN A, FREDGA K & SANDBERG A A 1964 Nomenclature for centromeric position on chromosomes *Hereditas* **52** 201–220

LI M X & CHEN R Y 1985 A suggestion on the standardization of karyotype analysis in plants *J Wuhan Bot Res* **3** 297–302

LOMBELLO R A & FORNI- MARTINS E R 2002 Cytogenetics and evolutionary analysis of *Lophanthera* an Amazonian Arboreal Malpighiaceae *Cytologia* **67** 41–45

LUKHTANOV V A, DINCĂ V, TALAVERA G & VILA R 2011 Unprecedented within-species chromosome number cline in the Wood White butterfly Leptideasinapis and its significance for karyotype evolution and speciation Bmc *Evol Biol* **11** 109

MACE E S & GODWIN I D 2002 Development and characterization of polymorphic microsatellite markers in taro (*Colocasia esculenta*) NRC *Res Press* **45** 823–832

MABBERLEY D J 2017 *Mabberley's Plant-Book* Cambridge University Press Cambridge

MADHUSOODAN K J & NAZEER M A 1983 Comparative morphology of somatic karyotypes of vegetable *Amaranthus* and its phylogenetic significance *Cytologia* **48** 237–244

MARCHANT C J 1971 Chromosome variation in Araceae 3 Philodendreae to Pythonieae *Kew Bull* **25** 323–329

MAYO S J, BOGNER J & BOYCE P C 1997 *The genera of Araceae* Royal Botanic Gardens Kew **12** 370 http//wwwjstororg/stable/4114530

MATHEW A & MATHEW P M 1982 Studies on South Indian Compositae III Karyomorphology of nine species of *Blumea* DC *Cytologia* **47** 153–162

MOOKERJEA A 1955 Cytology of different species of Aroids with a view to trace the basis of their evolution *Caryologia* **8** 221–291

MURAMOTO K, KATO S, HARA Y & NOZAKI H 2008 Morphological and genetic variation in the cosmolitan snow alga *Chloronas nivalis* (Volvocales Chlorophyta) from Japanese mountain area *Cytologia* **73** 91–96

MURATOVICĆ E, ROBIN O, BOGUNIĆ F, SOLJAN D & SILJAK-YAKOVLEV S 2010 Karyotype evolution and speciation of European lilies from *Lilium* sect Liriotypus *Taxon* **59** 165–75

NAKAJIMA G 1936 Chromosome numbers in some crops and wild angiosperms *Jap J Genet* **12** 211–218

OKADA H & HAMBALI G G 1989 Chromosome behaviors in meiosis of the inter-specific hybrids between *Colocasia esculenta* (L) Schott and *C gigantean* Hook f *Cytologia* **54** 389–393

PARVIN S, KABIR G, UD-DEEN M M & SARKER J K 2008 Karyotype analysis of seven varieties of taro *Colocasia esculenta* (L) Schott from Bangladesh *J Bio-Sci* **16** 15-18

PETERSON G 1989 Cytology and systematics of Araceae *Nord J Bot* **9** 119-166

PETROV DA 2001 Evolution of genome size new approaches to an old problem *Trends in Genetics* **17** 23 – 28 PMID 11163918

PFITZER P 1957 Cromosomenzahlen von Araceen *Chromosoma* 8 436–446

PRITCHARD A J 1967 The somatic shromosomes of *Trifolium cherleri* L *T hirtum* All *T ligusticum* Balb and *T scabrum* L *Caryologia* **204** 323–331

QUERO-GARCIA J, COURTOIS B, IVANCIC A, LETOURMY P & RISTERUCCI A M 2006 First genetic maps and QTL studies of yield traits of taro (*Colocasia esculenta* (L) Schott *Euphytica* **151** 187–199

RAMACHANDRAN K 1977 Karyological studies on 4 South Indian species of *Amorphophallus Cytologia* **42** 645–652

RAO N S 1947 A note on the chromosome number of *Colocasia antiquorum* Schott *Curr Sci* **16** 229

RATTENBURY J A 1957 Chromosome numbers in New Zealand angiosperms *Trans Roy Soc NZ* **84** 936–938

RAVEN P H & KYHOS D W 1965 New evidence concerning the original basic chromosome number of angiosperms *Evolution* **19** 244–248

RAVEN P H 1975 The bases of angiosperm phylogeny cytology *Ann Missouri Bot Gard* **62** 724–764

SHARMA A K 1956 A new concept of a means of speciation in plants *Caryologia* **9** 93–130

SHARMA A K & DAS N K 1954 Study of karyotypes and their alteration in Aroids *Agronomial Lusitania* **16** 23–48

SHARMA A K & DATTA K B 1961 A Cytological study to work out the trend of evolution in *Aglaonema* and *Richardia Caryologia* **143** 439–454

SHARMA A K & SHARMA A 1980 *Chromosome Techniques Theory and Practice* Aditya Books Butterworth-Heinemann Oxford

SHARMA A K & MUKHOPADHYAY S 1965 Cytological study on two genera of Araceae and correct assessment of their taxonomic status *Genet Agrar* **18** 603–616

SHEFFER R D & CROAT T B 1983 Chromosome numbers in the genus *Anthurium* (Araceae) II *Amer J Bot* **70** 858–871

SHETE C C, WADKAR S S, GAIKWAD N B & PATIL K S 2015 Cytological studies in some members of *Amorphophallus* from western ghats of Maharashtra *J Cytol Genet* **16** (NS) 17–24

SIMMONDS N W 1954 Chromosome behaviour in some tropical plants *Heredity* **8** 139–146

SREEKUMARI M T & MATHEW P M 1991a Karyomorphology of five morphotypes of Taro (*Colocasia esculenta* (L) Schott) *Cytologia* **56** 215–218

SREEKUMARI M T & MATHEW P M 1991b Karyotypically distinct morphotypes in Taro (*Colocasia esculenta* (L) Schott) *Cytologia* **56** 399–402

STEBBINS G L 1950 *Variation and evolution in plants* Columbia University Press New York

STEBBINS G L 1971 *Chromosomal evolution in higher plants* Edward Arnold London

SUBRAMANIAN D & MUNIAN M 1988 Cytotaxonomical studies in South Indian Araceae *Cytologia* **53** 59–66

SUBRAHMANYAM B V S & CHOWDARY Y B K 1992 Karyomorphogical studies on some Indian Charophyta *Cytologia* **57** 409–415

SULTANA S S, ARA H & ALAM S S 2011 Karyotype analysis with orcein and CMA in two species of *Alocasia* (Schott) G Don (Araceae) *Bangladesh J Bot* **40** 53–56

SULTANA S , RAHMAN H & ALAM S S 2006 Karyotype analysis in three morphological forms of *Lasia spinosa* (L) Thwaites (Araceae) *Cytologia* **71** 359–364

TANAKA R 1971 Types of resting nuclei in Orchidaceae *Bot Mag* (Tokyo) **84** 118–132

TANAKA R 1977 Recent karyotype studies *In* Ogawa K Kurozumi K Koike S & Sato S (eds) *Plant cytology* Asakura Book Tokyo pp 293–326

TANAKA R 1980 The karyotype *In* Yamashita K (ed) *Plant Genetics* Shokabo Tokyo pp 335–358

WAHIDI I & NURSYAHRA 2018 Starch and karyotype study of Taro (*Colocasia esculenta* L) from West Sumatra Indonesia *Int J Sci and Res Pub* **8** 256–260

WEISS-SCHNEEWEISS H & SCHNEEWEISS G M 2013 Karyotype diversity and evolutionary trends in angiosperms *In* Leitch I J, Greilhuber J, Doležel J & Wendel J F(eds) *Physical structure behavior and evolution of plant genomes* Springer-Verlag Wien pp 209–230

YANG Z, YI T, LI H & GONG X 2003 A cytological study on three species of *Colocasia* (Araceae) from Yunnan *Caryologia* **56** 323–327

YEN D E & WHEELER J M 1968 Introduction of taro into the pacific the indications of chromosome numbers *Ethnology* **7** 259–267

ZHANG X H, JAIME A, SILVA T D & MA G H 2010 Karyotype analysis of *Santalum album* L *Caryologia* **63** 142–148